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FERMENTATION OF HIGHLY LIGNIFIED SUBSTRATE-SUGARCANE BAGASSE USING FUNGI *PLEUROTUS OSTREATUS:* ASSESSMENT OF NUTRITIONAL UPLIFTMENT AT DIFFERENT INCUBATION PERIODS

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ABSTRACT

Sugarcane bagasse which is abundant in lignocellulose, are increasingly being considered as substitute feed options for ruminants. Despite this, their nutritional worth is somewhat diminished because of their high fibre but low protein content, along with limited digestibility and palatability. Therefore, the nutritional value of this by-product was attempted to improve with fungal treatment. The objective of this study was to evaluate the chemical changes of fungi fermented feed. This research was carried out to improve the nutritive values of low-quality roughages using white-rot fungus (*Pleurotus ostreatus*) to fungi fermented feed (FFF). The chemical composition of upliftment fungi treated sugarcane bagasse was targeted. The chemical composition was performed according to AOAC, (2011). The results found that in the case of concentrate, *P. ostreatus* fermented wheat improved crude protein (CP), ether extract (EE) and total ash (TA) levels by 119.17%, 332%, and 6.56%, and decreased crude fiber (CF) and nitrogen free extract (NFE) by 18.42% and 12.69% at 2 weeks, respectively. The results found that *P. ostreatus* fermentation increased the crude protein and total ash of fermented sugarcane bagasse was increased crude protein (CP) levels by 21.25–109.66% and reduced dry matter (DM), total tannin (TT) and total phenolic (TP) contents by 28.76–72.24%, 20.61-21.75%, 50–71.42%, and 21.27–27.65%, respectively. Crude fiber (CF), nitrogen free extract (NFE), *in vitro* organic matter digestibility (IVOMD), metabolizable energy (ME), total gas production (TGP), methane (CH_4) gas production, and pH content of fungi-fermented sugarcane bagasse were almost similar to those of non-fermented sugarcane bagasse. In

conclusion, *P. ostreatus* fungus increased the protein level and declined the fiber content of poor-quality roughages as well as energy-rich concentrates, which improved the palatability of feed resulted better utilization of feed.

Keywords: Fermentation, Sugarcane Bagasse, Fungi (*Pleurotus ostreatus*), Nutritional Upliftments, Different Incubation Periods

1 INTRODUCTION

The agricultural sector of Bangladesh is a key aspect of its high-density, developing economy, encompassing crops, livestock, fisheries, and forestry. Livestock, including cattle and goats, play a crucial role in this landscape, contributing significantly to the agricultural economy and meeting the growing demand for animal protein [23]. Sugarcane bagasse, a by-produce of the sugar manufacturing, is known for its low nutritional value, characterized by low CP content, high CF, and low-slung lusciousness [8,24]. Predominantly found in developing nations, this highly lignified material contributes to environmental concerns due to its abundance. [4] point out that its poor digestibility and low nitrogen content pose significant nutritional challenges when used as bodily feedstuff. Studies by [9,5] reveal that sugarcane bagasse typically contains less than 3% protein, over 40% cellulose, more than 35% hemicellulose, and over 15% lignin, leading to a low digestibility rate of 20–30%. [33] highlighted the main constraint of bagasse as feedstuff: its low-slung digestibility, resulting from the complex association of lignin with cellulose and hemicelluloses and its resistance to degradation by ruminal microorganisms. Despite its poor nutritional quality, sugarcane bagasse could be a potential liveliness basis, due to its in elevation lignin contented and cell-wall polysaccharides [5,31]. White rot fungi like *P. ostreatus* may breakdown lignin and lignocellulose complexes, improving rumen microbial fermentation by increasing nutrition availability [26]. These fungi colonize and change the substrate to provide hemicellulose for fruit bodies. Fungi treatment efficiency depends on substrate biochemistry, fungus strain, and treatment duration [34]. Fungi (*Pleurotus ostreatus*) are preferentially breakdown lignin in low-quality cereal crop residual cell walls [35]. The best scenario is that fungus mushrooms are appetizing and agree to farmers to employ the knowledge to improve sugarcane bagasse qualities and foodstuff assembly [26]. Edible fungus *P. ostreatus* degrades lignin also and improves tropical cereal crop residue chemical composition and rumen degradability. Fungi supplements for ruminants enhance fiber digestibility, microbiological protein and amino acid levels in the enormous intestine, microbial population numbers and species. Fungi supplements for ruminants also improve gut bacteria balance, digestive problems, acidosis risk, and bedding humidity, decreasing stress [27]. Their hyphae can after all develop on particle surfaces, pierce other particle gaps, and colonize solid substrates. However, little of this work has yet to be completed in Bangladesh. As fungi have been thought to be the most suited to solid state fermentation (SSF), this study focuses on fungus (*P. ostreatus*) as a solid-state fermenter for the nutritional enhancement of agricultural wastes of ruminants.

2 MATERIALS AND METHODS

The study was accompanied to assess chemical composition, nutritive values, *in vitro* digestibility, ammonia and pH of fed with or without fungi fermented substrates sugarcane bagasse (SB) feed samples.

2.1 Ethic statement

The study was accompanied and the specific experiment was performed with close monitoring of the 'Ethic Committee' approved protocol #AUP2021007 of the Sylhet Agricultural University, Sylhet, Bangladesh.

2.2 Location of study

The study was conceded obtainable in the Laboratory of the Department of Animal Nutrition, Microbiology and Immunology, Faculty of Veterinary, Animal and Biomedical Sciences, Biochemistry and Chemistry, Faculty of Biotechnology and Genetic Engineering, Sylhet Agricultural University, Sylhet.

2.3 Substrates preparation, pretreatment and chemical analysis

Sugarcane bagasse was collected commencing native feed market of Sylhet. The collected lignified sugarcane bagasse was chopped using a chopper, processed for experimental fermentation and chemical analysis [2]. The analyses focused on determining the levels of DM, CP, CF, EE, NFE and TA, following the procedures specified in [3].

2.4 Collection and preparation of fungal samples

Spawning of fungus *P. ostreatus* remained obtained from the Mushroom Development Institute in Savar, Dhaka. High-quality Oyster mushroom spawns were also procured from the same institute and maintained at the Animal Nutrition Analytical Laboratory at Sylhet Agricultural University, Sylhet.

2.5 Production of fungal seed and preparation of Potato Dextrose Agar media for fungi

Production of fungal (*P. ostreatus*) seed, preparation of PDA media with tissue culture was followed for growth of fungi. The cultivation medium utilized was potato dextrose agar (PDA). Tissue culture techniques, as detailed by [13], were employed to produce fungal mycelia. The following protocols were maintained for PDA preparation. At first conical flask was washed and dried then 50 milliliter of purified water existed taken using 2 g of commercial PDA media and was heated slowly on the fire flame of a spirit lamp to dissolve. Then the tip of the conical flask and test tube were wrapped with aluminum foil and was autoclaved (121ºC, 1.25 kgcm^2, 15-20 minutes). Then 0.25 ml of gentamycin, was added in conical flask to prevent microbial contamination and thereafter 8-10 ml of PDA media with gentamycin solution was taken into every test tube and was slant every test tube at 45° for coagulation. And finally, fungal PDA media was prepared. Fungi *P. ostreatus* were collected and incubated for growth in the laboratory on solid growth media or in liquid broths [28,29].

2.6 Preparation of fungal tissue and mother culture

Wheat is rich in carbohydrates, and also contains protein, vitamins, minerals and dietary fibre [25]. We choose wheat as a mother culture because wheat increased highest amount of CP compare to CM, RP and WB at 2 weeks. At the eve of the work, laminar airflow (BIOBASE, BBS-DDC, China) was heated with UV light before starting pure tissue culture for preventing and microbial contamination. This was achieved through autoclaving, where they were exposed to a temperature of 121ºC and a pressure of 1.25 kg/cm^2 for a duration ranging between one to two hours. To develop tissue culture (*P. ostreatus*), a piece of healthy and juvenile fruit body (V-shaped) was cut with the help of scissors from the stipe with the help of inoculating loop with PDA media taken coagulated test tube. The test tube was incubated at normal temperature (20-25°C) in the dark for 7-12 days. Within 7-12 days mycelium run in that test tube and finally fungal tissue culture was prepared [28,29]. Same procedures were followed for mother culture [28,29].

2.7 Preparations of fungal spawning with sugarcane bagasse

Sugarcane bagasse was initially cut into pieces of 1.5 to 2 inches using a chopper machine. The development of fruiting bodies was closely monitored, and it was noted that the bags were completely enveloped by white mycelium, as discussed in studies by [28,29].

2.8 Determination of chemical composition with and without fungi fermented sugarcane bagasse

The feedstuff samples of were evaluated for DM, TA, CP, CF, EE and NFE according to [3] technique.

2.9 Collection of rumen fluid, preparation of inoculums, *in vitro* incubation, buffer, dilution of rumen-buffer solution, estimation of total gas and methane gas production

Rumen fluid, pH of 6.5, was attained as of goats at the Sylhet City Corporation slaughterhouse. The collection took place in the morning right after the animals were slaughtered. The measurement of gas produced was then making a note at set intervals to monitor the fermentation process [18]. The buffer solution remained ready following the procedures established by [17], using the [21]. Following this, rumen fluid remained combined by means of the buffer solution in equal proportions, ensuring 1:1 mix ratio. This combination of rumen fluid and buffer solution then subjected to incubate in a hot liquid bath, maintaining a consistent heat of 39°C. The standard planning was as defined by [17,18]. Additionally, the pH of the buffered rumen fluid was closely resolute by means of pH meter (HI 2211 pH/ORP Meter and a HI 98107, HANNA Instruments). Following the incubation periods of 24, 36, 48, and 72 hours, the gas produced [18] in each syringe was carefully transferred to a different syringe, which contained clear lime water, as per the technique defined by [7].

2.10 Determination of *in vitro* organic matter degradability (IVOMD) and metabolizable energy (ME)

Gas assembly measurements remained taken at intervals of 24, 36, and 48 hours, with a final recording at the 72-hour mark to capture the total gas production. The calculations for IVOMD and ME in roughage feeds were established taking place their biochemical composition and net gas production. Net gas production adjusted for blanks and reference standards at the 72-hour incubation mark. [22] formulas were used for these calculations:

For roughage feed:

- IVOMD (%) = 16.49 + 0.9042 GP+ 0.0492 CP+ 0.0387 TA
- ME (MJ/kg) = 2.20 + 0.1357 GP+ 0.0057 CP+ 0.000286 EE
- Here, IVOMD (%)-*in vitro* organic matter degradability, expressed in percentage terms. ME (MJ/kg DM)-metabolizable energy, GP - volume of gas produced (ml) per 200 mg of DM, CP (g/kg DM) - crude protein, TA (g/kg DM) - total ash content, and EE (g/kg DM) - ether extract content.

2.11 Determination of P^H and ammonia (NH_3)

At first, checked the P^H with calibration of different buffers (4.0, 7.0, and 10.0) in the P^H meter reader (HI 2211 P^H, ORP Meter, HI 98107 P^H, HANNA instruments) [18]. Kept the ammonia duo tube in the ammonia (100 NS) duo reader (Ammonia Duo, Palintest, UK) and waited for ammonia reading and multiply by 4 (1:4 dilutions) and then the result was expressed as mg/litre by [18].

2.12 Determination of Total Phenolics (TP) and Total Tannins (TT)

To assess the total phenolic (TP) content, Folin-Ciocalteu method, as outlined using [32] and further described by [19], was employed. Tannic acid served as the reference standard, and the results were stated in milligrams of tannic acid equivalent/g of the sample, calculated on a dry matter (DM) basis, following [19] methodology. To measure tannins, a modified version of [19] method was used.

2.13 Statistical analysis

The data were arranged according to Completely Randomized Design (CRD) to compute Analysis of Variance (ANOVA) and were analyzed by the statistical computer program [30].

3 RESULTS AND DISCUSSION

3.1 Nutrient composition of fungi fermented wheat

This study was accompanied to carry out the effect of fermenting sugarcane bagasse with the fungus *Pleurotus ostreatus* on their nutritional content. Table 1 displays the nutritional composition of wheat, both with and without the application of fungi fermentation, after a 2-week period. Significant variations were observed in CP content, with values of 8.50% and 18.63% when treated with fungi-fermented wheat. Between the two treatments (W_0 and W_2), the DM, CF, NFE, pH, and NH3 levels were notably higher in W_0 compared to W_2, and these differences were statistically significant ($p<0.05$), except for NFE content. Conversely, CP, EE, TA, tannin, total phenolic, IVOMD, ME, and TGP showed significant improvements ($p<0.05$) in the W_2 treatment compared to W_0.

Table 1: DM and nutrient composition of fungi fermented wheat at 2 weeks incubation

Parameters	Treatment		SEM	*P* value
	W_0	W_2		
DM (%)	95.02^a±0.004	18.69^b±0.005	17.1	0.001
CP (%)	8.50^b±0.21	18.63^a±0.22	2.27	0.001
CF (%)	11.07^a±0.012	9.03^b±0.013	3.38	0.001
EE (%)	0.25^b±0.18	1.08^a±0.19	0.220	0.034
TA (%)	6.55^b±0.005	6.98^a±0.006	0.767	0.001
NFE (%)	73.63^a±0.29	64.28^b±0.30	0.246	0.171
Tannin (mg/g DM)	0.36^b±0.011	1.07^a±0.011	0.159	0.001
TP (mg/g DM)	0.46^b±0.009	1.42^a±0.010	0.216	0.001
IVOMD (%)	39.59^b±1.03	47.92^a±1.04	1.97	0.005
ME (MJ/kg DM)	8.92^b±0.16	10.11^a±0.17	0.285	0.007
TGP (ml/200mg DM)	40.91^b±0.33	50.33^a±0.34	2.12	0.001
Methane (ml/200mg DM)	30.00^b±1.02	37.66^a±1.03	1.83	0.006
pH	6.93^a±0.006	6.73^b±0.007	0.043	0.001
NH_3 (mg/L)	156.33^a±7.24	35.33^b±7.25	27.4	0.001

W_0-wheat at 0 weeks (without fungi fermented), W_2-wheat at 2 weeks (fungi fermented), DM-dry matter, CP-crude protein, EE-ether extract, TA-total ash, NFE- nitrogen free extract, TP- total phenolic, IVOMD-in vitro organic matter digestibility, ME-metabolizable energy, TGP-total gas production, NH3-ammonia, SEM-standard error of mean.

Table 1 represented the nutrient composition of non-fermented wheat and fungi compare to fermented wheat at 2 weeks indicated that the DM, CF, NFE, pH and NH_3 contents were higher in non-fermented wheat then fungi fermented wheat. However, the CP, EE, TA, tannin, T phenolic, IVOMD, ME and TGP were higher in fungi fermented wheat. [14] observed that the fermentation of wheat leads to a marginal rise in its CP and EE content similar to the present study. This change is attributed to a reduction in non-starch polysaccharides (NSP), which decreased 120 g/kg DM in non-fermented wheat 104 g/kg DM in fermented variant. They attributed the enhanced energy digestibility to the fermentation process's ability to increase the digestibility of the fibrous components in feedstuff constituents. [25] reported that fungi (CPL-1 *Colletotrichum* spp) fermented wheat increased the CP, EE, total carbohydrate, and nitrogen levels while the CF and tannin levels decreased. Wheat is one of the most important cereal crops in the world. Wheat is rich in carbohydrates, and also contains protein, vitamins, minerals and dietary fibre. Therefore, wheat plays a vital role in human nutrition, livestock feeding, agriculture and the economy [25].

3.2 Nutrient composition of fungi fermented sugarcane bagasse

The nutrient composition of fungi (*P. ostreatus*) fermented and non-fermented sugarcane bagasse is shown in Table 2. There was a substantial variation of CP (2.07, 2.51, 4.34%) while treated with fungi fermented sugarcane bagasse than that of non-fermented sugarcane bagasse. Except for EE, the DM, TA, tannin and Total phenolic contents of fungi fermented sugarcane bagasse SB_3 and SB_4 were significantly ($p<0.05$) lower than non-fermented sugarcane bagasse (SB_0). The CP and NH_3 content of fungi fermented sugarcane bagasse SB_3 and SB_4 were significantly ($p<0.05$) lower than non-fermented sugarcane bagasse (SB_0). CF, NFE, IVOMD, ME, TGP, methane gas production and pH content of fungi fermented sugarcane bagasse were almost similar ($p<0.05$) to those of non-fermented sugarcane bagasse, except for ME, TGP and methane which were similar ($p>0.05$).

Table 2: DM and nutrient composition of fungi fermented sugarcane bagasse at 3-4 weeks of incubation

Parameters	Treatment			SEM	*P* value
	SB_0	SB_3	SB_4		
DM (%)	88.95^{a} ±0.005	24.69^{c} ±0.006	63.36^{b} ±0.006	9.34	0.001
CP (%)	2.07^{b} ±0.008	2.51^{b} ±0.008	4.34^{a} ±0.008	0.741	0.001
CF (%)	41.02^{a} ±0.19	41.50^{a} ±0.19	40.16^{b} ±0.20	0.218	0.008
EE (%)	0.91^{a} ±0.10	0.75^{ab} ±0.11	0.41^{b} ±0.11	0.091	0.042
TA (%)	2.62^{a} ±0.005	2.08^{b} ±0.006	2.05^{c} ±0.006	0.093	0.001
NFE (%)	53.38^{a} ±0.19	53.16^{a} ±0.20	53.10^{a} ±0.20	0.638	0.001
Tannin (mg/g DM)	0.28^{a} ±0.032	0.08^{b} ±0.033	0.14^{ab} ±0.033	0.033	0.015
TP (mg/g DM)	0.47^{a} ±0.006	0.37^{b} ±0.007	0.34^{b} ±0.007	0.020	0.001
IVOMD (%)	31.46^{b} ±0.69	30.25^{c} ±0.70	33.05^{a}±0.70	0.676	0.02
ME (MJ/kg DM)	4.78^{b} ±0.12	4.58^{c} ±0.12	5.03^{a} ±0.12	0.086	0.113
TGP (ml/200mg DM)	20.33±0.15	20.33±0.16	20.75±0.16	0.106	0.184
Methane (ml/200mg DM)	16.33±0.83	15.00±0.84	18.00±0.84	0.603	0.113
pH	6.93^{a} ±0.005	6.87^{b} ±0.006	6.89^{b} ±0.006	0.009	0.001
NH_3 (mg/L)	89.00^{b} ±0.69	71.33^{c} ±0.69	95.00^{a} ±0.69	3.57	0.001

SB_0-sugarcane bagasse at 0 weeks (without fungi fermented), SB_3-sugarcane bagasse at 3 weeks (fungi fermented), SB_4-sugarcane bagasse at 4 weeks (fungi fermented), DM-dry matter, CP-crude protein, EE-ether extract, TA-total ash, NFE-nitrogen free extract, TP- total phenolic, IVOMD-in vitro organic matter digestibility, ME-metabolizable energy, TGP-total gas production, NH3-ammonia, SEM-standard error of mean.

Table 2 showed like the straw, the DM, EE, CF, TA, tannin and T phenolic contents of fungi fermented sugarcane bagasse on 3rd and 4th weeks were lower when compared to non-fermented sugarcane bagasse. The DM, EE and CF contents of fungi fermented sugarcane bagasse on 3rd weeks were also found lower reported by [1]. The sugarcane bagasse was treated with *Pleurotus* fungus that decreases 11.5% to 13.3% DM described by [15]. Whereas, the CP contented of fungi fermented sugarcane bagasse on 3rd and 4th weeks was greater than those of non-fermented sugarcane bagasse. The research conducted by [11,12], along with a studied by [16], demonstrated that SB, rice straw, and dried maize cobs, when fermented with fungi over a period ranging from 28 to 30 days, exhibited a significant increase in CP content. The amount of gas production from different roughages during incubation varied significantly ($p<0.001$), with rice straw producing the least gas at 74 ml per gram of DM. This lower gas production in rice straw is attributed to its reduced digestibility, a result of lignification and silicification [16]. [10] Observed an upturn in CP content tends to boost gas production in feeds. Methane emissions from these roughages were also significant, with rice straw emitting 21.07 ml of methane per gram of DM after 72 hours of incubation. This result is in line with [20], recorded 12.1 ml of methane per gram of DM from rice straw after 24 hours, suggesting that variations could be due to differences in animal species. Broken rice, in comparison, produces more methane than bran, likely owing to its upper content of certainly fermentable Non-Fiber Carbohydrates (NFC), which provides rumen microbes with ample starch, sugar, or hemicellulose for fermentation [20].

4 CONCLUSION

Sugarcane bagasse treated with fungus (*P. ostreatus*) needs more one week to get more CP. The wheat treated with fungus (*P. ostreatus*) improved CP levels by 2.19 times in 2nd weeks. Fungi (*P. ostreatus*) fermented feed increased CP, TA and reduced CF. Farmers can be used low quality roughages fermented by white-rot fungus at 4th weeks to get best performance.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare that no conflicts of interest regarding this manuscript.

REFERENCES

[1] Akinfemi A and Ogunwole OA (2012). Chemical composition and in vitro digestibility of rice straw treated with *Pleurotus ostreatus, Pleurotus pulmonarius* and *Pleurotus tuber-regium*. Slovak Journal Animal Sciences 45 14-20.

[2] AOAC (Association of Official Analytical Chemists) (2006). Official Methods of Analysis. 18th ed., Association of Official Analytical Chemists, AOAC International, Gaithersburg, Maryland, USA, AOAC International. Washington DC, USA. Item no. 49.2.02, P 3 (Chapter 49).

[3] AOAC (Association of Official Analytical Chemists) (2011). Official Methods of Analysis. 18th ed., Association of Official Analytical Chemists, Washington DC, USA.

[4] Chaji M, Naserian AA, Valizadeh R, Shahroodi FE and Hasaami O (2007). The effects of steam treated sugarcane pith as a feed ingredient on performance of lactating dairy goats. Annual Conference, British Society of Animal Science, Southport, UK, p. 144.

[5] da Costa DA, de Souza CL, Saliba EDOS and Carneiro JD (2015). By-products of sugar cane industry in ruminant nutrition. International Journal Advance Agriculture Research 3 1–9.

[6] Datta C and Singh G (1995). Effect of protein supplementation on *in vitro* digestibility and gas production of wheat straw. Indian Journal of Dairy Sciences 48(2) 357-361.

[7] Fievez V, Babayemi OJ and Demeyer D (2005). Estimation of direct and indirect gas production in syringes: A tool to estimate short chain fatty acid production requiring minimal laboratory facilities. Animal Feed Science and Technology 123 197-210.

[8] Gado HM, Sohair A, Nasr BKM and Mahrous AA (2007). Effect of biological treatments on the nutritive value of rice straw. Egyptian Journal of Nutrition & Feeds 9 207-219.

[9] Gunun N, Wanapat M, Gunun P, Cherdthong A, Khejornsart P and Kang S (2016). Effect of treating sugarcane bagasse with urea and calcium hydroxide on feed intake, digestibility, and rumen fermentation in beef cattle. Tropical Animal Health and Production 48 1123–1128.

[10] Hamid P, Akbar T, Hossein J and Ali MG (2007). Nutrient digestibility and gas production of some tropical feeds used in ruminant diets estimated by the in vivo and in vitro gas production techniques. American Journal of Animal and Veterinary Sciences 2(76) 108-113.

[11] Huyen NT, Tuan BQ, Ngo XN, Nguyen TB and Le NT (2019). Effect of using fungal treated rice straw in sheep diet on nutrients digestibility and microbial protein synthesis. Asian Journal of Animal Sciences 13 1-7.

[12] Huyen NT, Le NT and Tuan BQ (2021). Fermented sugarcane bagasse with the fungus *Pleurotus eryngii* reduced in vitro methane production. Livestock Research for Rural Development 33 **(6)** 156-7.

[13] Jonathan SG and Fasidi IO (2012). Effect of carbon, nitrogen and mineral sources on growth *Psathyrella atroumbonata* (Pegler), a Nigerian edition mushroom. Food chemistry 72 479-483.

[14] Jørgensen H, Sholly D, Pedersen AØ, Canibe N and Knudsen KE (2010). Fermentation of cereals—Influence on digestibility of nutrients in growing pigs. Livestock Science 134 56-8.

[15] Kamra DN, Kandeepan G, Anjaneyulu ASR, Rao VK, Pal UK, Mondal P and Das CK (1993). Rumen microbial ecosystem. Current Science 89 124-135.

[16] Kermani M, Bahrololoum S and Koohzadi F (2019). Investigating the possibility of producing animal feed from sugarcane bagasse using oyster mushrooms: a case in rural entrepreneurship. Journal of Global Entrepreneurship Research 9 1-8.

[17] Khan MMH and Chaudhry AS (2010). Chemical composition of selected forages and spices and the effect of these spices on *in vitro* rumen degradability of some forages. Asian-Australasian Journal of Animal Sciences 23 (7) 889-900.

[18] Khan MMH and Chaudhry AS (2012). Spice supplementation of forage based ruminant diets (*in vitro* study). LAP Lambert Academic Publishing Gmblt & Co, KG Saarbrucken, Germany.

[19] Khan MMH (2012). Novel supplements to improve utilization of low quality forages in ruminants. Muktodesh Prokashon, Islami Tower, 11/1 Bangabazar, Dhaka-1100, Bangladesh, 2012, First Edition: Dhaka. pp 3-163/1-215. ISBN: 978-984-8690-00-0.

[20] Lee H, Lee S, Kim J, Oh Y, Kim B, Kim C and Kim K (2003). Methane production potential of feed ingredients as measured by *in vitro* gas test. Asian Australasian Journal of Animal Sciences 16(8) 1143-1150.

[21] McDougall EI (1948). Studies on ruminant saliva: The composition and output of Sheep's saliva. Institute of Animal Pathology, University of Cambridge, Biochemistry Journal 43 99-100.

[22] Menke HH and Steingass (1988). Estimation of the energetic feed value obtained from chemical analysis and in vitro gas production using rumen fluid. Animal Research and Development 28 7-55.

[23] MOFL (2022). Annual Report 2021-22. Ministry of Fisheries and Livestock.

[24] Pandey A, Soccol CR, Nigam P and Soccol VT (2000). Biotechnological potential of agro-industrial residues. I: sugarcane bagasse. Bioresource Technology 74 69-80.

[25] Patil RH, Patil MP and Maheshwari VL (2020). Microbial transformation of crop residues into a nutritionally enriched substrate and its potential application in livestock feed. SN Applied Sciences 2 1140-1149.

[26] Sarnklong C, Cone JW, Pellikaan W and Hendriks WH (2010). Utilization of Rice Straw and Different Treatments to Improve Its Feed Value for Ruminants: A Review. Asian-Australasian Journal of Animal Sciences 23(5) 680 – 692.

[27] Sharma RK and Arora DS (2015). Fungal degradation of lignocellulosic residues: an aspect of improved nutritive quality. Critical Reviews in Microbiology 41 52-60.

[28] Sarker NC, Chowdhury BK, Khan AS, Munmun M, Kakon AJ and Haque M (2013). Mushroom training manual (National mushroom development and extension centre). pp 21-27.

[29] Sánchez C (2004). Modern aspects of mushrooms culture technology. Appl Microbiol Biotechnol 64 756–762.

[30] SAS (2007). Statistical Analysis System Institute Inc., SAS/STAT. User's guide. Version 6.3rd edition Carry. North Carolina, USA. 943.

[31] Shelke SK, Chhabra A, Puniya AK and Sehgal JP (2009). *In vitro* degradation of sugarcane bagasse based ruminant rations using anaerobic fungi. Annals of Microbiology 59 415-418.

[32] Singleton VL and Rossi JA (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. American Journal of Enology and Viticulture 16 144-158.

[33] Suksombat W (2004). Comparison of different alkali treatment of bagasse and rice straw. Asian-australasian Journal of Animal Sciences 17 1430-1433.

[34] Tuyen VA, Cone JW, Baars JJP, Sonnenberg ASM and Hendriks WH (2012). Fungal strain and incubation period affect chemical composition and nutrient availability of wheat straw for rumen fermentation. Biological Resources Technology 111 336–342.

[35] Tirsit TB (2020). Biotechnological applications of white rot fungi: a review. GSC Advanced Research and Reviews 5 97-103.