PERFORMANCE OF WEST AFRICAN DWARF GOATS FED MICROBIAL-TREATED BAMBARA NUTSHELL

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ABSTRACT

A study was conducted using twenty-one (21) West African Dwarf (WAD) goats with an average weight of 10.50 ± 0.36 kg to evaluate the nutrient intake, weight gain, and nitrogen balance of WAD goats fed microbial-treated Bambara nutshell diets. The chemical and mineral compositions of the diets were also determined. The goats were allotted to seven dietary treatments, replicated three times in a completely randomized design. The Bambara nutshells were sterilized for 15 minutes, inoculated with 25, 50, and 75 ml of each Pleurotus pulmonaris and Aspergillus niger, incubated for 7 days and air dried. The treated Bambara nutshell was incorporated into the diets at the rate of 0ml (Diet A), 25 ml P. pulmonaris (Diet B), 50 ml P. pulmonaris (Diet C), (Diet D), 75 ml P. pulmonaris (Diet E), 25 ml A. niger (Diet F) 50 ml A. niger and (Diet G) 75 ml A. niger respectively. The experimental period lasted for 56 days excluding 2 weeks of adaptation. Results showed that the proximate compositions were significantly influenced (p<0.05) by the treatment except for crude protein (CP). Diet F had the highest dry matter (DM) values (94.77%) and CP (20.33%) while Diet C had the least (92.33%) DM and Diet G (19.16%) had the least CP. Goats fed Diet D had the highest daily weight gain (107.14 g/day), and best feed/gain ratio of 6.20. Conclusively, microbial treatment of Bambara nutshell will help in the conversion of these wastes to better quality ruminant feed for better performance.

Keywords: West African Dwarf (WAD) goat, *Pleurotus pulmonaris*, *Aspergillus niger*, Bambara nutshell

INTRODUCTION

Livestock production depends on the availability, quantity, and quality of feed provided to the animal (Kim *et al.,* 2012). One of the limiting factors for ruminant production is the inadequate and low quality of feedstuff during the dry season in the semi-arid zone of Nigeria (Abdurrahaman, 2017). For ruminant animals, forages such as grasses and legumes are the main source of feeds to satisfy their nutritional requirements, either for maintenance, production, or reproduction (Kim *et al.,* 2012).

Bambara nutshell is one of the by-products of the Bambara nut - *Vigna subterranea* L. (Fabales: Fabaceae) is a legume indigenous to Africa and is cultivated across the semi-arid sub-Saharan Africa region (Hillocks *et al.,* 2012). It is a hardy crop and has been recognized as an important nutritious food source when food is scarce (Mbosso *et al.,* 2020). This could be attributed to its climate-smart features, including its ability to fix nitrogen, and to grow under adverse environmental conditions such as poor soils and drought (Mayes *et al.,* 2019, Paliwal *et al.,* 2020).

Bambara nutshell is a by-product of Bambara nutshell and it contains 6.7% crude protein (CP), 3.9% ash, 47.6% neutral detergent fibre, and 29.8% acid detergent fibre (Ibrahim *et al.*, 2022). Furthermore, it has essential and non-essential amino acids at 32.72 and 67.28%, respectively, per 100 g of grain (Gonné *et al.*, 2013). Bambara nutshell despite the limitations could be recycled and used as a source of valuable lignocellulose biomass for animals if treated with fungi. Ogunjemite and Ibhaze (2020) reported that microbial-treated maize cob and husk diets in complete diets of WAD goats showed better performance in terms of weight gain which is the interest of every farmer. Hence, treating maize husks using microorganisms (*Neurospora crassa* and *Lactobacillus delbrueckii*) helped in the conversion of this agricultural waste to higher-quality ruminant feed.

Pleurotus pulmonaris (Fr.) Quél. (Agaricales: Pleurotaceae), commonly known as the Indian oyster, Italian oyster, Phoenix mushroom, or lung oyster, is a mushroom very similar to *Pleurotus ostreatus*, the pearl oyster, but with a few noticeable differences (Otunla, 2015). *P. pulmonaris* extracts may decrease cancer cell proliferation and act as an adjuvant to cancer therapy, as well as slow the progression of diabetes. It is also effective in the treatment of hay fever, reduces sneezing and nasal rubbing by inhibiting histamine release (Lavi *et al.*, 2010), and also displays antimicrobial properties (Ramesh and Pattar, 2010).

Aspergillus niger Van Tieghem (Eurotiales: Aspergillaceae) is a mould classified within the *Nigri* section of the *Aspergillus* genus. The *Aspergillus* genus consists of common moulds found throughout the environment within soil and water, on vegetation, in faecal matter, on decomposing matter, and suspended in the air (Rodrigues *et al.*, 2022).

Thus, this study was carried out to evaluate the effect of using *A. niger* and *P. pulmonaris* in improving the nutritive value of Bambara nutshell as feed resources for West African Dwarf (WAD) goat.

MATERIALS AND METHODS

Experiment Site: The experiment was carried out at the Sheep and Goat Unit of the Teaching and Research Farm of the Federal University of Technology, Akure, Ondo State, Nigeria. Akure is located at longitude 4.944055°E and 5.82864°E, and latitude 7.491780°N with annual rainfall ranging between 1300 and 1650 mm and annual daily temperature ranging between 27 and 38°C (Daniel, 2015).

Collection and Preparation of Experimental Diets: Bambara nutshell was collected from farmers in Okene in Kogi State. 1000 grams of sun-dried Bambara nutshell was moistened with one litre of water and was sterilized in the autoclave at a temperature of 121°C for 15 minutes to eliminate microbial contamination of the Bambara nutshell. The Bambara nutshell was allowed to cool at room temperature (25°C) and was inoculated with 0, 25, 50, and 75 ml of *P. pulmonaris* and *A. Niger* respectively. Thereafter, they were sun-dried for some days based on the intensity of the sun. The concentrate was formulated with crushed cassava peel, wheat offal, urea, palm kernel cake (PKC), microbial-treated Bambara nutshell, bone meal, premix, and salt mixed manually. Seven experimental diets with varying levels of microbial-treated Bambara nutshell were formulated as shown in Table 1. All dietary ingredients and resultant diets were proximately assayed for their compositions (Thangaraj, 2019).

Experimental Layout and Animal Management: Twenty-one WAD goats (does) of about one to one and a half years were bought at an open market in Akure and Itaogbolu with an average weight of 10.50 ± 0.36 kg, and were randomly assigned to seven dietary treatments of three replicate per treatment in a completely randomized design (CRD). Animals were housed in individual pens and offered fresh clean water. Before the commencement of the experiment, the WAD goats were vaccinated against PPR disease and treated against ectoparasites (Jones *et al.,* 1993).

Table 1: Gross composition of the experimental diet fed to West African dwarf goats

Ingredient	A	B	C	D	E	F	G
Cassava peel	50	50	50	50	50	50	50
UBNS	6	-	-	-	-	-	-
TBNS	-	6	6	6	6	6	6
Wheat offal	24	24	24	24	24	24	24
PKC	15	15	15	15	15	15	15
Bone meal	1	1	1	1	1	1	1
Urea	1	1	1	1	1	1	1
Salt	2	2	2	2	2	2	2
Premixes	1	1	1	1	1	1	1
Total	100	100	100	100	100	100	100
Calculated Analysis							
Crude Protein (%)	19.70	19.10	19.53	19.78	19.20	20.33	19.12
Metabolizable Energy (MJ/Kg)	3061.82	2596.07	2628.59	2843.19	2738.03	2505.40	2858.84
Ether Extract (%)	14.14	6.74	10.60	10.25	8.77	5.69	8.52
Crude Fibre (%)	16.76	17.93	21.29	16.00	16.43	19.58	11.86
Phosphorus (%)	0.22	0.18	0.18	0.24	0.19	0.17	0.20
Calcium (%)	0.40	0.31	0.41	0.45	0.45	0.32	0.41

A= Untreated Bambara nut shell; B = 25 ml Pleutorus pulmonaris; C= 50 ml Pleutorus pulmonaris; D = 75 ml Pleutorus pulmonaris; E = 25 ml Aspergillus niger; F = 50 ml Aspergillus niger; G = 75 ml Aspergillus niger; UBNS = untreated Bambara nut shell TBNS = treated Bambara nut shell; PKC = palm kernel cake

The goats were given a daily ration of 5% of their body weight. The feeding trial lasted for 56 days excluding the 2 weeks of adaptation. All animals were cared for and managed according to the ethical approval and guidelines of NENT (2016).

Data and Sample Collection: The animal's growth response to the experimental diets was monitored by taking their initial body weights and weighing them every week before feeding. Feed offered to animals was recorded and leftover was weighed daily to compute feed intake by the animals. Dry matter, crude protein, dry matter intake, nitrogen intake (g/day), faecal nitrogen (g), nitrogen balance (g/day), nitrogen retention (%), initial weight (kg), final weight (kg), dry matter intake (g), daily weight gain (g/day), and feed conversion gain were collected using standard analytical methods described in AOAC (2012). The nitrogen intake and balance were determined through feed and faecal analysis, and nitrogen retention was calculated as the difference between intake and excretion (NRC, 1989), while initial and final weights were recorded at the beginning and end of the trial, respectively

Data Analysis: Data collected were subjected to a one-way analysis of variance (ANOVA) procedure of SPSS (2017) version 21.0. Significant means were separated using Duncan's multiple-range tests of the same software. A simple correlation analysis between milk yield and kid weights was computed using the Pearson correlation procedure of SPSS (2017).

RESULTS AND DISCUSSION

Chemical Composition of Microbial-Treated Bambara Nutshell: The parameters assessed were significantly influenced ($p<0.05$ by the treatment except for the CP (Table 2). Diet F had the highest dry matter (DM) values (94.77 ± 0.13%), while Diet C had the least (92.33 ± 0.21%). The high DM content observed in the diets can be attributed to the inherent dryness of the feedstuffs and the values reported in this study align with the findings of 94.55% reported by Olagunju *et al.* (2013) for fungus (*Lachnocladium* spp.) fermented corncobs and Mohammed and Mhya (2021) for Bambara groundnut varieties grown in Northeastern Nigeria, but higher than the values (87.38%) reported by Fajemisin *et al.* (2018) who investigated the effect of *P. pulmonaris* on cocoa bean shell meal.

Table 2: Chemical and mineral composition of microbial-treated Bambara nutshell diets fed to West African dwarf goats

Parameters	A	B	C	D	E	F	G
Dry matter	94.13 ± 0.09^{b}	94.07 ± 0.14^{b}	92.33 ± 0.21^{a}	93.47 ± 1.11^{ab}	92.56 ± 0.23^{a}	94.77 ± 0.13^{b}	93.41 ± 0.21^{ab}
Crude protein	19.65 ± 0.66	19.19 ± 0.54	19.53 ± 0.16	19.78 ± 0.36	19.20 ± 0.03	20.33 ± 0.10	19.16 ± 0.00
Crude fibre	16.76 ± 0.27^{bc}	17.93 ± 0.45^{c}	21.29 ± 0.08^{e}	16.00 ± 0.33^{b}	16.43 ± 0.58^{b}	19.58 ± 0.74^{d}	11.86 ± 0.08^{a}
Ether extract	14.14 ± 0.26^{e}	6.74 ± 0.23^{a}	10.60 ± 0.23^{d}	10.25 ± 1.30^{cd}	8.77 ± 0.04^{bc}	5.690.18^{a}	8.520.18^{b}
Ash	9.29 ± 0.30^{a}	11.53 ± 0.08^{c}	10.55 ± 0.25^{b}	10.47 ± 0.21^{b}	10.17 ± 0.12^{b}	11.75 ± 0.02^{c}	11.86 ± 0.06^{c}
NFE	34.31 ± 0.07^{b}	38.69 ± 0.36^{c}	30.37 ± 0.19^{a}	36.98 ± 0.71^{c}	37.99 ± 0.68^{c}	37.43 ± 0.93^{c}	42.03 ± 0.37^{d}
NDF	43.00 ± 1.73^{b}	41.00 ± 4.04^{b}	51.00 ± 0.58^{c}	38.00 ± 1.15^{ab}	40.00 ± 1.15^{ab}	45.00 ± 4.04^{bc}	33.00 ± 0.58^{a}
ADF	34.00 ± 1.15^{ab}	38.00 ± 4.62^{bc}	44.00 ± 0.00^{c}	30.00 ± 3.46^{ab}	32.00 ± 1.15^{ab}	37.00 ± 2.89^{bc}	27.00 ± 1.73^{a}
ADL	18.50 ± 0.87^{b}	18.25 ± 0.72^{b}	15.00 ± 0.58^{a}	18.50 ± 0.87^{b}	20.75 ± 0.14^{c}	19.75 ± 0.72^{bc}	14.00 ± 0.00^{a}
Hemicellulose	9.00 ± 0.58^{b}	3.00 ± 0.58^{a}	7.00 ± 0.58^{b}	8.00 ± 0.23^{b}	8.00 ± 0.00^{b}	8.00 ± 0.12^{b}	6.00 ± 0.12^{ab}
Cellulose	15.50 ± 2.02^{a}	19.75 ± 3.90^{a}	29.00 ± 0.58^{b}	11.50 ± 4.33^{a}	11.25 ± 1.01^{a}	17.25 ± 2.17^{a}	13.00 ± 1.73^{a}
ME(Kcal/kg)	3061.82 ± 122.74^{d}	2596.07 ± 12.73^{cd}	2628.59 ± 6.21^{bc}	2843.19 ± 118.02^{b}	2738.03 ± 10.56^{bc}	2505.40 ± 120.54^{a}	2858.84 ± 17.12^{b}

^{abc} = means within the same row with different superscripts are significantly different (P<0.05), ADF= Acid detergent fibre, NDF= Neutral detergent fibre, ADL= Acid detergent lignin, NFE= Nitrogen free extract, ME = Metabolisable energy, A = untreated Bambara shell, B = 25 ml Pluerotus pulmonaris, C = 50 ml Pluerotus pulmonaris, D = 75 ml Pluerotus pulmonaris, E = 25 ml Aspergillus niger, F = 50 ml Aspergillus niger, and G = 75 ml Aspergillus niger

The CP content of the microbial-treated maize cob and husk diets was more than the critical 7% CP recommended for ruminant animals by McDonald *et al.* (2002). However, Diet F (20.33 ± 0.10%) had the highest level of CP although similar to those recorded (19.73 - 28.88%) by Fajemisin *et al*. (2018). Diet F exhibited higher CP content (20.33 ± 0.10%) than other diet. This variation can be attributed to the increased fungal biomass, as suggested by de Vries *et al*. (2007). Although no significant differences (p>0.05) were observed between the diets, contradicting Fajemisin *et al*. (2018) findings, which recorded higher CP values in treated cocoa bean shell meal (23.63%) compared to untreated (18.98%).

The trend in crude fibre content increased from Diet A (16.76 ± 0.27%) to Diet C (21.29±0.08%), attributed to the fungi's secretion of hydrolysing and oxidizing enzymes, facilitating the decomposition of recalcitrant compounds into utilizable compounds (Akinyele *et al*., 2017). The ash content values (9.29 ± 0.30 – 11.86 ± 0.06%) compared favourably with those reported (11.29 – 19.84%) by Omotoso *et al*. (2019). Neutral detergent fibre ranged between 51.00 ± 0.58% (Diet C) and 33.00 ± 0.58% (Diet G), potentially linked to the lignocellulose content of the diets. These values were compared favourably with the report of Belewu *et al*. (2003). In our study, the acid detergent fibre and lignin values were lower than those reported by Belewu and Fagbcmi (2007), who studied *Aspergillus*-treated cassava (*Manihot esculutus*) waste-based diets. This also agreed with the report of Belewu *et al.* (2003) that fermentation generally degrades or breaks cellulose bonds of crude fibre content in crop residue especially when fermented with fungi, because they possess the ability to produce cellulase that can degrade lignocellulose fibre. Nitrogen-free extract values (30.37 ± 0.19 – 42.03 ± 0.37%) were consistent with values reported by Omotoso *et al*. (2019), who fed West African dwarf goats' molasses-treated rice husk. The values of ash were higher in the diets that contained *A. niger*-treated Bambara nutshell and this may be attributed to the enzymatic activities of *A. niger* may have led to the release of minerals bound within the plant material., thereby increasing the ash content in the treated diets.

Nutrient Intake of West African Dwarf Goats Fed Microbial-Treated Bambara Nutshell Diets: The dry matter intake (DMI) recorded in this study (Table 3) was significantly influenced (p<0.05) by microbial-treated Bambara nutshell. This observation may be attributed to the protein quality, palatability and acceptability of the experimental diets. This observation was in agreement with the report of Ahamefule *et al.* (2006) that a higher level of CP stimulates DMI. This observation was also in agreement with the report of Ventura *et al.* (1975) that nutrient intake increases as DMI and CP concentration quality increases. However, the average voluntary DMI values of the goats were above 3.5% of the body weight recommended for small ruminants by McDonald *et al.* (2002). Interestingly, this finding diverged from the outcomes of a study by Fajemisin *et al*. (2018), which found no significant effect of *P. pulmonaris*-treated cocoa bean shell meal on DMI in WAD goats. It is worthy of note that the CP intake varied across diets, with some diets meeting or exceeding the recommended minimum of 41.50 g/day for goats (NRC, 1981). The CP intake ranged from 109.24 ± 6.57 to 130.44 ± 4.94 g/day; these values obtained were higher than 76.26 – 83.2 g/day reported by Ahamefule *et al.* (2006) for WAD bucks fed pigeon pea-cassava peel-based diet. Moreover, the observed values for CP intake were elevated compared to select prior investigations, including those conducted by Fajemisin *et al*. (2018). Nevertheless, these values aligned closely with the findings of Belewu *et al*. (2003), who evaluated West African dwarf goats fed graded levels of *Aspergillus*-treated rice husk. The discernible increase in both CP and DMI can be attributed to the pronounced degradation of the Bambara nutshell facilitated by the fungal treatment, thereby enhancing nutrient availability. The ether extract (EE) intake was highest in goats fed Diet D (93.79 ± 1.32 g/day). This may be connected to the higher concentration of fat/oil in the diet. Maia *et al.* (2012) reported an increase in ether extract intake in sheep-fed oils. Ether extract represents the fat portion of the diet, and this can be used as a source of energy by the goats.

Table 3: Nutrient intake of West African dwarf goats fed microbial-treated Bambara nutshell diets (g/day)

Parameters	A	B	C	D	E	F	G
Dry matter	619.88 ± 2.71^{b}	597.29 ± 7.10^{b}	642.03 ± 7.07^{b}	663.64 ± 4.71^{b}	579.00 ± 7.39^{a}	613.56 ± 8.45^{a}	570.27 ± 10.23^{ab}
Crude protein	122.53 ± 0.78^{b}	114.27 ± 0.34^{b}	125.37 ± 2.91^{b}	130.44 ± 4.94^{b}	112.00 ± 6.56^{a}	124.72 ± 3.21^{b}	109.24 ± 6.57^{ab}
Crude fibre	99.13 ± 0.86^{b}	107.36 ± 8.44^{b}	136.67 ± 2.04^{c}	111.18 ± 1.33^{b}	108.45 ± 2.23^{b}	120.00 ± 4.08^{bc}	67.56 ± 3.63^{a}
Ether extract	63.73 ± 8.80^{b}	40.38 ± 3.55^{a}	68.09 ± 2.23^{b}	93.79 ± 1.32^{c}	51.76 ± 6.26^{b}	34.89 ± 1.01^{a}	48.66 ± 3.89^{a}
Ash	64.87 ± 0.52^{a}	68.92 ± 4.17^{a}	67.74 ± 2.32^{a}	61.60 ± 1.72^{a}	60.58 ± 2.97^{a}	72.10 ± 1.71^{b}	67.67 ± 4.36^{a}
NFE	229.31 ± 7.11^{bc}	230.86 ± 10.21^{bc}	194.93 ± 0.94^{ab}	227.67 ± 1.37^{bc}	212.21 ± 9.58^{bc}	229.75 ± 8.67^{bc}	239.44 ± 9.42^{c}
NDF	235.39 ± 4.36^{bc}	247.47 ± 37.24^{ab}	327.36 ± 0.11^{c}	285.27 ± 10.33^{ab}	220.29 ± 24.49^{ab}	276.64 ± 28.93^{bc}	187.85 ± 8.48^{a}
ADF	185.45 ± 19.25^{bc}	229.92 ± 39.73^{bc}	282.50 ± 3.11^{c}	225.58 ± 6.74^{ab}	213.82 ± 18.69^{bc}	227.41 ± 21.11^{bc}	152.96 ± 4.97^{a}
ADL	114.80 ± 6.73^{b}	109.47 ± 10.14^{b}	96.22 ± 2.65^{ab}	122.82 ± 6.25^{b}	107.52 ± 14.53^{b}	121.28 ± 6.36^{b}	79.84 ± 4.79^{a}
Hemicellulose	49.93 ± 14.89^{b}	17.55 ± 2.49^{a}	44.86 ± 3.21^{b}	59.70 ± 3.59^{b}	48.52 ± 5.86^{b}	49.24 ± 7.84^{b}	34.89 ± 8.65^{ab}
Cellulose	70.65 ± 5.67^{a}	120.46 ± 29.97^{b}	186.27 ± 5.78^{c}	102.76 ± 12.89^{sb}	117.84 ± 4.78^{ab}	106.13 ± 14.89^{ab}	73.13 ± 6.67^{ab}

^{abc} = means within the same row with different superscripts are significantly different (p<0.05), ADF= Acid detergent fibre, NDF= Neutral detergent fibre, ADL= Acid detergent lignin, NFE= Nitrogen free extract, ME = Metabolisable energy, A = untreated Bambara shell B = 25 ml Pluerotus pulmonaris C = 50 ml Pluerotus pulmonaris, D = 75 ml Pluerotus pulmonaris, E = 25 ml Aspergillus niger, F = 50 ml Aspergillus niger, and G = 75 ml Aspergillus niger

This therefore suggests that more energy would be available to the animals for metabolic processes. Moreover, this higher ether intake did not show any deleterious effect on the animals. Additionally, goats exhibited heightened consumption of crude fibre and ether extract, a trend that could be attributed to the specific nutritional composition of the diets. Furthermore, intake values for acid detergent fibre, lignin, cellulose, and hemicellulose surpassed those reported by Belewu and Yahaya (2008), potentially due to the improved CP quality resulting from the fungal treatment.

Performance and Nitrogen Balance of West African Dwarf Goats Fed Microbial-Treated Bambara Nutshell Diets: In this study, goats fed Diets A and C exhibited significantly ($p<0.05$) higher nitrogen intake compared to those on other diets (Table 4). This was in agreement with Olorunnisomo *et al.* (2008) findings, indicating enhanced nitrogen utilization with improved intake. The increased nitrogen availability in the rumen likely contributed to microbial activity and protein synthesis in ruminants. Notably, Diet B resulted in the highest nitrogen balance (0.89±0.06 g/day), signifying ample nitrogen supply to the rumen. The faecal nitrogen was highest in goats fed diet G (3.98±0.09) and this can be attributed to the crude protein quality of the diet. The positive nitrogen retention obtained, however, signifies that the diets were adequate in their supply of nitrogen to the rumen, and the more nitrogen consumed and digested, the more the nitrogen retained and vice versa, as observed and reported by (Okeniyi *et al*., 2010), and this also buttressed the fact that the diet was well balanced in energy and protein which reduced nitrogen excretion in urine (Noblet and Van Milgen, 2004). All the treatments gave positive N balance and N retention values, an indication that the protein requirement for maintenance in the experimental animals was adequately met by the dietary treatments. The initial weight reported in this study ranges from 10.27 ± 1.05 (diet G) to 10.73 ± 0.08 (Diet E), also the final ranges from 13.67 ± 0.14 (Diet E) to 16.50 ± 0.12 (Diet D) and this highest weight final weight in goat fed diet can be attributed to the quality of the diet and the effective utilization of the nutrient by the goats. The goats fed D had the best weight gain (6.00g/day) compared to does fed other diets. This observation might be attributed to feed intake and protein quality of the diet which could be attributed to the inclusion of microbial-treated Bambara nutshell in the diets. Goats on Diet D (75 ml *P.* pulmonaris) demonstrated the highest weight gain (107.14 ± 8.92 g/day), surpassing results reported by Ibhaze (2015). The favourable outcomes in this study may be attributed to the feed's palatability, protein quality, and microbial protein availability, stimulating increased intake and effective diet utilization. This was in agreement with Davis *et al.* (2014) assertion that weight gain depends on DM, protein intake, and nutrient digestibility. Furthermore, goats on Diet D exhibited the best feed/gain ratio (6.20 ± 0.63) among all experimental diets, highlighting its superior performance in promoting weight gain. The superior feed-to-gain ratio (6.20 ± 0.63) of Diet D over the other diets is a reflection of the observed higher growth rates and higher feed utilization of the goats fed the respective diet. This is because the higher the value of the feed conversion ratio (FCR), the less desirable the diet, as the animal consumes more feed to produce a unit weight gain (Tona *et al*., 2014).

Conclusion: The inclusion of 75 ml *P. pulmonaris* treated Bambara nutshell in Diet D resulted in superior daily weight gain (107.14 8.92 g/day), surpassing other diet. This positive outcome can be attributed to the feed's palatability, high protein quality, and enhanced microbial protein availability, promoting increased intake and effective diet utilization. Consistent with the assertion that weight gain is influenced by DM, protein intake, and nutrient digestibility, goats on Diet D demonstrated the best feed/gain ratio (6.20) among all experimental diets, emphasizing its superior performance in fostering weight gain and efficient feed utilization showcasing the potential benefits of this dietary supplementation.

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Table 4: Performance and nitrogen balance of West African dwarf goats fed microbial-treated Bambara nutshell

Parameter	A	B	C	D	E	F	G
Nitrogen intake (g/day)	20.87 ± 0.79^{b}	18.28 ± 2.28^{b}	20.06 ± 0.51^{b}	19.60 ± 1.05^{aa}	14.72 ± 0.47^{b}	19.96 ± 0.05^{b}	17.48 ± 0.13^{b}
Faecal nitrogen(g)	2.80 ± 0.03^{a}	3.00 ± 0.02^{cd}	2.69 ± 0.10^{a}	2.73 ± 0.03^{a}	3.17 ± 0.05^{b}	3.60 ± 0.12^{b}	3.98 ± 0.09^{b}
Urine nitrogen (g)	14.21 ± 0.14^{c}	14.40 ± 0.08^{c}	13.60 ± 0.12^{bc}	12.20 ± 1.03^{ab}	10.77 ± 0.23^{a}	12.59 ± 0.78^{ab}	12.80 ± 1.32^{bc}
Nitrogen balance (g/day)	0.74 ± 0.04^{ab}	0.89 ± 0.06^{b}	0.76 ± 0.06^{ab}	0.58 ± 0.11^{a}	0.78 ± 0.05^{ab}	0.77 ± 0.06^{ab}	0.70 ± 0.30^{ab}
Nitrogen retention (%)	73.84 ± 4.09^{ab}	88.59 ± 6.04^{b}	76.39 ± 5.70^{ab}	57.77 ± 10.88^{a}	77.86 ± 5.02^{ab}	76.53 ± 5.83^{ab}	69.78 ± 3.00^{ab}
Initial weight (kg)	10.67 ± 1.07	10.65 ± 0.72	10.35 ± 0.38	10.50 ± 0.06	10.73 ± 0.08	10.43 ± 0.23	10.27 ± 1.05
Final weight (kg)	15.43 ± 1.09	15.75 ± 1.59	15.05 ± 0.09	16.50 ± 0.12	13.67 ± 0.14	15.30 ± 0.06	13.93 ± 0.12
Dry matter intake (g)	619.88 ± 2.71^{b}	597.29 ± 7.10^{b}	642.04 ± 7.07^{b}	663.64 ± 4.71^{b}	579.10 ± 7.39^{a}	613.56 ± 8.45^{a}	570.27 ± 10.23^{ab}
Daily weight gain (g/day)	85.12 ± 2.75^{bc}	91.07 ± 4.56^{bc}	83.93 ± 4.79^{bc}	107.14 ± 8.92^{c}	52.38 ± 2.35^{a}	86.90 ± 1.10^{bc}	65.48 ± 4.56^{b}
Feed conversion gain	7.31 ± 0.36^{ab}	6.84 ± 0.45^{a}	7.71 ± 0.65^{ab}	6.20 ± 0.63^{a}	9.30 ± 0.95^{c}	7.16 ± 0.36^{ab}	8.72 ± 0.17^{b}

^{abc} = means within the same row with different superscripts are significantly different (p<0.05), A = untreated Bambara shell, B = 25 ml Pluerotus pulmonaris, C = 50 ml Pluerotus pulmonaris, D = 75 ml Pluerotus pulmonaris, E = 25 ml Aspergillus niger, F = 50 ml Aspergillus niger, and G = 75 ml Aspergillus niger

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