PHYSICOCHEMICAL CHARACTERISTICS OF BANANA PSEUDO-STEM FERMENTED WITH *PLEUROTUS TUBER-REGIUM*

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ABSTRACT
The study was aimed at investigating the physicochemical changes in banana pseudo-stem (BPS) during a 20-day solid-state fermentation with Pleurotus tuber-regium . The experiment which was carried out in a completely randomized design (CRD), comprised of two treatments (T1 and T2) replicated thrice. One of the portions of the dried and ground BPS was composted and inoculated with P. tuber-regium as T2 while the untreated portion referred to as T1 (control). The physicochemical characteristics were analyzed for both fermented and unfermented BPS. Data generated were analyzed using the student t-test to determine the statistical effects of the treatment. The mushroom failed to colonize the composted BPS due to the production of high levels of ammonia gas in acidic pH (5.9–6.7) of the substrate. The results revealed significant reductions ($p<0.05$) in Water holding capacity (WHC), oil absorption capacity (OAC), swelling capacity (SWC), crude protein (CP), Gross Energy (GE) and metabolizable energy (ME) values due to the degradation process. Similarly, the fiber fraction results showed significant reductions ($p<0.05$) in the neutral detergent fiber (NDF), acid detergent fiber (ADF), and hemicellulose contents of the fermented BPS. It was concluded that banana pseudo-stem may not be suited for king tuber mushroom mycelia colonization using the method described in this study. It is recommended that the composting method adopted for the banana pseudo-stem be reviewed either by extending composting period or blending with other substrates.
Keynote: Banana pseudo-stem (BPS), physicochemical, Pleurotus tuber-regium, solid-state fermentation, mycelia colonization.

INTRODUCTION

The banana trunk or pseudo-stem (BPS) is one of the wastes generated from banana production. The utilization of BPS as raw feedstock in biomass conversion has been considered as a promising approach to exploiting the large volumes produced annually by banana farmers (Taib *et al*., 2021). The banana pseudo-stem contains high levels of moisture, lignin, minerals and starch, which could be fermented with the aid of the *P.tuber-regium* to enhance the nutrient value and therefore used as feedstuffs for livestock such as ruminants and pigs (Ray *et al*., 2013). The livestock industry has grown significantly in the last seven decades and has led to increased demand for the feed raw materials needed to meet the industry nutritional demands (Wendinu, 2021). The conversion of biomass waste materials into feedstuff has been shown to be a cheap and affordable approach. Their high fibre content which is usually difficult to digest by livestock is however a major constraint to their utilization in animal nutrition (Amata, 2014). White rot fungi such as mushrooms can breakdown the high fibre content in biomass waste thereby improving their nutritive value (Souza *et al*., 2018). One of such white rot fungi, the king tuber mushroom (*Pleurotus tuber-regium*) that has attracted growing interest recently because of its sensory attributes, high nutritional values, and important medicinal properties (Lin *et al*., 2020). It has been reported to be a good degrader of different types of biomass wastes and rich in bioactive polysaccharides, proteins, essential amino acids, essential fatty acids, dietary fibre, minerals, and vitamins (Lin *et al*., 2020). It is therefore possible to exploit the biomass waste degradation ability of *P.tuber-regium* to improve the feeding value of local biomass wastes as well as its production as food for human consumption (Ekute *et al*., 2021).

The main objective of this study is to determine the physicochemical characteristics of banana pseudo-stem fermented with *Pleurotus tuber-regium* as a potential feed raw material.

MATERIALS AND METHODS

Experimental site

The study was carried out in the Federal University of Technology (FUTO) in Imo State, in Southeastern Nigeria. The state is divided into 27 Local Government Areas (LGA), which are further grouped into three agricultural zones namely, Owerri, Orlu and Okigwe. Imo state is situated in the rainforest vegetational belt of Nigeria, and longitude $6^{0}15^{1}$ and $7^{0}34^{1}$ E, at an altitude of about 90m above sea level, except elevations of about 200m at the Okigwe highlands (Amangabara, 2015). The statistical analysis was carried out at Precision food and feed analysis laboratory, Iyana Agbala, Ejikeyi, Ibadan.

The banana pseudo-stem was collected from households and banana plantations within Owerri and its environs. The BPS was washed with potable water, weighed, and cut into smaller pieces and sun dried. The dried material was ground into coarse powder using a food grinder to produce dried banana pseudo-stem meal (BPM) and thereafter stored in polythene sacks until needed.

The tubers of *P. tuber-regium* sourced locally were washed to eliminate any potential dirt. Then, they were immersed in water for an hour and transferred to a transparent plastic bucket and properly covered for three (3) days to allow for spore formation (spawn production). Following this, the *P. tuber-regium* tubers were removed and sliced into smaller pieces carrying the spores, according to the method reported by Wuanor and Carew (2018). A wooden tray constructed with 5.08 x 5.08 cm wood (forming the sides) and wire mesh (covering the bottom) were used to load the composted BPM. The trays' bottoms were covered with white polyethylene sheet disinfected with methylated spirit and the composted BPM was placed on top of the polythene sheet.

Spores from the *P. tuber-regium* were inoculated into the composted BPM at a ratio of 100 g of spores to 500 g of BPM. The polyethylene sheet was closed after spawning to create an airtight environment. The samples were placed in triplicates in the fermentation room for 20 days to ensure complete colonization of the composted BPM by the fungus which was indicated by whitish growth. At the end of the fermentation period, the samples were taken out of the fermentation room and sun-dried to stop mycelia growth. The dried materials were stored at room temperature until needed for laboratory analysis.

The Physical and proximate composition of the BPS were determined in triplicates for each of the parameters in accordance with the methods described by AOAC International (2016). Metabolizable energy composition of the test materials were also determined through calculation using the values generated from the proximate analysis according to the modified Atwater equation (AAFCO, 1997).

The formula is ME (Kcal/100g) = 10 × (3.5 x %CP) + 8.5 x %EE) + (3.5 x %NFE)

Data Analysis

The data generated from the study was subjected to student T-test analysis to determine the effects of the solid-state fermentation on the different parameters using the Statistical Package for Starts Tester (2020). Ver.4.0.1

RESULTS AND DISCUSSION

Table 1 highlighted the result of the physical characteristics of fermented and unfermented banana pseudo-stem. The results showed that there were no significant differences (P>0.05) between the bulk density and specific gravity values of UBPS and FBPS indicating that there was no treatment effect on the material. The values of the bulk density and specific gravity of both the UBPS and FBPS were however higher than the values (0.21g/ml and 0.19 g/ml respectively) reported by Etuk (2023).

Table 1: Physical characteristics of unfermented and fermented banana pseudo-stem

Parameters	UBPS	FBPS	SEM	P<0.05
BD (g/mL)	0.473 ± 0.001	0.489 ± 0.001	0.006	0.114
WHC	561.31 ± 4.22	515.51 ± 1.26	3.194	0.005
Specific Gravity (g/mL)	0.473 ± 0.001	0.489 ± 0.001	0.006	0.114
OAC (%)	384.81 ± 4.21	335.99 ± 3.33	4.139	0.007
SWC (%)	765.36 ± 2.25	702.30 ± 1.17	0.768	0.0001

BD = bulk density, WHC = water holding capacity, OAC = oil absorption capacity, SWC = swelling capacity, UBPS = unfermented banana pseudo-stem, FBPS = fermented banana pseudo-stem, SEM = sum of error mean

Meanwhile, the results for WHC, OAC and SWC values of unfermented BPS were significantly higher (P<0.05) than that of fermented BPS. These results indicate that there was treatment effect for the parameters mentioned above. The values of WHC for both the UBPS and FBPS were lower than the values (744.02%) reported by Etuk (2023), meanwhile, she reported lower values (365.56%) of OAC than that of UBPS but higher than the value of FBPS. Physiologically, the WHC of any material makes it capable to retain water when subjected to an external centrifugal gravity force or compression Ramu *et al*. (2017). The result of this study implies great water holding capacity of the test materials.

Table 2 highlighted the results of proximate composition of both unfermented and fermented banana pseudo-stem and their energy values. For the proximate composition of the UBPS and FBPS only the Crude protein (CP) of the unfermented BPS was significantly higher (P<0.05) than that of fermented BPS. The UBPS values generated falls within the range of values (3.74% - 10.94%) reported by Ramu *et al*. (2017) but disagrees with the finding of Etuk (2023) who reported crude protein values of 7.07%. Meanwhile, the FBPS agreed with their findings.

Whereas the results of Ether extract (EE), Crude fibre (CF) Total ash (TA) and nitrogen free extract (NFE) showed no significant differences (P>0.05) between the treatment means. The results therefore indicate that there was no treatment effect between the unfermented and the fermented BPS. The EE obtained from this study was within the range reported by Ramu *et al*. (2017), he reported -2.29 – 4.25% but the result varied with the finding of Etuk (2017) who reported 3. 97% EE. The crude fibre value gotten from this study disagreed with Etuk (2023) who reported lower value (8.84%) than the results of this studies. For total ash, the result for both treatments were found to be higher than the result (11.26%) of Etuk (2023). The result of NFE for this study deviated from the findings of Ramu *et al*. (2017) and Etuk (2023) who reported higher values; 44.25 – 48.91% and 59.77% respectively than the values obtained from this study for both treatments. Generally, the proximate values of FBPS where lower than that of UBPS which indicate that most of the nutrients were utilized by the microbes during composting, however, the lower value of CF gives better value to the FBPS and makes it potential feedstuff for ruminants. Meanwhile, the differences recorded by other authors could be related to the different botanical origins, geographical conditions such as soil, climate, and collection time of the sample material (Ramu *et al.,* 2017).

The results of UBPS for both the gross and metabolizable energy were significantly higher (P<0.05) than that of FBPS thus confirming the fact that there was treatment effect between the means. This decline in energy values may illustrate that the microbes produced during the process utilized some of the energy contents of the material although the values obtained were still high enough to be considered an energy feedstuff.

Table 2: Proximate value of unfermented and fermented BPS standardized to dry matter content of 88% and energy values.

Parameters	UBPS	DBPS	SEM	P<0.05
Crude Protein (CP) %	9.54 ± 0.31	8.10 ± 0.56	0.20	0.02
Ether Extract (EE)%	1.06 ± 0.05	0.94 ± 0.06	0.06	0.23
Crude Fibre (CF)%	35.11 ± 0.80	33.10 ± 0.54	0.70	0.10
Total Ash (TA)%	15.47 ± 0.13	14.68 ± 0.27	0.30	0.10
NFE%	23.22 ± 1.52	22.16 ± 1.37	1.20	0.50
Gross Energy (kcal/kg)	269.73 ± 2.82	249.55 ± 2.62	2.664	0.02
ME (kcal/kg)	4240.35 ± 130.13	3690.75 ± 153.71	68.13	0.02

NFE = nitrogen free extract, ME = metabolizable energy, UBPS = unfermented banana pseudo-stem, FBPS = fermented banana pseudo-stem, SEM = sum of error mean

The study also compared the fiber composition of UBPS and FBPS as shown in table 3. NDF in UBPS was significantly higher than in FBPS, with UBPS exceeding values (66.25±0.67% and 56.84%) reported by Ramu *et al*. (2017) and Etuk (2023) respectively. ADF and Hemicelluloses in UBPS were also significantly higher, differing from the studies of Ramu *et al*. (2017) and Etuk (2023) who reported ADF values of Banana pseudo-stem; 51.88±2.35% and 38.79%. Their result revealed higher values than the UBPS, whereas the FBPS values were slightly higher than the report

of Etuk (2023) but lower than the values revealed by Ramu et al. (2017). The ADL and Cellulose of from the study showed no significant differences (P>0.05) between the treatment means. The ADL values gotten from this study were at variance with the finding of Etuk (2023), who reported lower values (14.49%) than both the UBPS and the FBPS. Some authors have reported higher values of cellulose than the values from this study; Ramu *et al.* (2017) reported 44.02±0.91% and Etuk (2023) reported 24.29%. The fibre fraction result showed that NDF and hemicelluloses reduced with degradation whereas, the ADL, ADF and cellulose increased with degradation, this could be because of microbial action in the utilization of the soluble fibre of the material.

Table 3: Fibre fractions in undegraded and degraded BPS

Parameters	UBPS	FBPS	SEM	P<0.05
NDF	69.10 ± 0.41	59.94 ± 0.96	0.966	0.010
ADF	34.03 ± 0.20	39.00 ± 0.73	0.661	0.017
ADL	21.35 ± 0.46	24.12 ± 1.43	1.2770	0.162
Cellulose	12.68 ± 0.39	14.88 ± 0.77	0.7600	0.101
Hemicelluloses	35.07 ± 0.31	20.94 ± 0.81	0.7752	0.003

NDF = neutral detergent fiber, ADF = acid detergent fiber, ADL = acid detergent lignin, UBPS = unfermented banana pseudo-stem, FBPS = fermented banana pseudo-stem, SEM = sum of error mean

CONCLUSION

Throughout the fermentation period, the mycelia of P. tuber-regium couldn't colonise the substrate and was attributed to presence of excess ammonia. At the end of the fermentation, reductions were observed for most of the physicochemical components except in ADF, ADL and cellulose that showed increase values. Banana pseudo-stem may not be suited for king tuber mushroom mycelia colonization using the method described in this study.

Recommendation

Since ammonia production in the composted substrate was a hindrance to the mycelia production by the king tuber mushroom during fermentation, it is recommended that the composting method adopted for the banana pseudo-stem be reviewed ether by extending composting period or blending with other substrates.

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