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Nutritional evaluation of spent and uninoculated mushroom substrate of *Pleurotus ostreatus* grown on cassava peels and sawdust

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ABSTRACT

This study aims to evaluate the role of edible fungi in the biodegradation of mushroom substrate by comparing the mineral and proximate composition of a pasteurized substrate before inoculation (BI) with the spent mushroom substrate (SMS) of *Pleurotus ostreatus* cultivated on cassava peels and sawdust. The experiment was conducted at the Federal University of Technology, Owerri, Imo State Nigeria. The treatment for this investigation comprised different levels of wheat bran namely: T1 (C/N 17:0 in the control), T2 (C/N ratio 17:1), and T3 (C/N ratio 17:3). 2% lime was added to the substrate to stabilize the pH. The experiment was laid out in a completely randomized design (CRD) which was replicated three times. The mineral and proximate compositions were determined using standard procedures. The data generated were subjected to analysis of variance (ANOVA) at ($p = 0.05$). The result obtained from this investigation reviewed that the mineral composition before substrate inoculation was significantly higher than those obtained from the SMS which were in the range: of Na (0.10-0.17 mg/kg), Mg (0.25-0.40 mg/kg), Ash (1.56-2.65%), Ca (0.62-1.40 mg/kg), K (0.25-0.42 mg/kg), and P (0.11-0.44 mg/kg) while the proximate composition is in the range: dry matter (81.6-93.3%), N (0.18-0.31%), crude protein (CP) (1.13-1.94%), crude fiber (2.84-4.82%). This result revealed that significant quantities of the nutrients unlocked by *Pleurotus ostreatus* were assimilated into the mushroom fruit bodies. Therefore, *Pleurotus ostreatus* could be used to enrich cassava peels and sawdust substrates which can further be utilized in the formulation of livestock feeds. However, further studies are recommended especially in evaluating more nutritional indices of the substrate.

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1. INTRODUCTION

Food materials needed for growth by man include those that are rich in animal protein such as meat, milk, and egg. The diet of an average Nigerian is majorly cereal and carbohydrates as a result of poverty. These animal products are less available in developing countries like Nigeria. Food and agricultural organization (FAO) [1] reported the daily consumption of animal protein in many developed countries as

54 g while the value for developing countries is very low (11 g). The low level of protein intake does not meet the minimum requirement of 34 g indispensable for normal growth and healthy mental development. This is a result of the high cost of animal feed due to escalating prices of feed ingredients. The increase in animal products has resulted in the inability of many households to purchase them. Hence the need to investigate other sources of low-cost inputs in the formulation of animal feeds. This research will evaluate the nutritional composition of a spent mushroom substrate (SMS) and compare it with the pasteurized, but not inoculated substrate from cassava peels and sawdust to determine the role of edible fungi in unlocking the nutritional components of the lignocellulose materials through microbial degradation and its further utilization in the formulation of livestock feed.

Despite the evident benefits of mushrooms, the exponential increase in their consumption worldwide is also generating a high volume of SMS. Consequently, one of the main problems faced by mushroom production companies is finding a way to properly dispose of the SMS without contaminating water and soil. The production of edible mushrooms globally is about 6 million tonnes per annum [2] while about 30 million tons of SMS are produced in return. Elenwo and Okere [3] have advocated the need to dispose of these huge SMS generated annually in an environmentally friendly manner especially its reintegration into the agricultural value chain because of the escalating environmental concern arising from its generation.

One of the numerous methods of recycling SMS is its use as animal feed which appears to be promising and reasonable due to the ingredients contained in it. SMS which is a by-product of mushroom cultivation is a nutrient-rich organic compound. Many scholars have reported on its successful use as animal feed [4]–[7].

The nutritional composition of sawdust-based SMS is as follows: neutral detergent fiber (NDF) 78.2%, acid detergent fiber (ADF) 60.4%, hemicellulose 17.8%, cellulose 40.4%, lignin 20.0%, non-fibrous carbohydrate 7.8%, crude protein (CP) 7.2%, total protein/CP 69.4%, NPN/CP 30.6%, ADF-CP/CP 36.4%, crude ash 4.7%, and dry matter 40.8% [7]. Based on these findings, sawdust–based SMS needs to be enriched nutritionally and processed before being used as animal feed [2], [8], [9]. Mushroom substrates are far from being spent and can be put to various other uses [10].

In the cultivation of edible mushrooms various agricultural and industrial wastes are utilized as substrates which act as sources of nutrients for their growth [11]. These wastes include cereals, wheat straw, sawdust, and soybean meal which require varying levels of supplementation to improve yield [12], [13]. Cassava (*Manihot esculenta*) is a staple food for about 800 million people [14], [15] and the sixth globally most important food crop [16]. This important root crop is mainly cultivated in Africa, Asia, the Pacific islands, Central America, and South America [17]–[19]. Africa accounts for most of the cassava harvest worldwide with more than half of the world's total production [20]. Others are Asia and Latin America in order of reducing production capacity. Apart from its importance as animal feed and industrial raw material, cassava has emerged as an important biofuel resource [21]. It is therefore a cash source for resource-poor farmers.

Cassava peels are lingo-cellulosic materials that consist basically of three major components namely cellulose, hemicellulose, and lignin [22], [23]. However, Tewe and Lutaladio [23] reported that cassava peels may contain higher levels of cyanogenic glycosides and higher protein content than other parts of the tuber. The peel is a by-product of cassava flour and garri are made from cassava roots. About 400,000 MT (dry matter basis) of cassava are produced annually [24]. They are used to feed livestock in Nigeria and other parts of Africa, hence there is a need to investigate the ability of edible fungi to enrich it for the formulation of livestock feeds. This paper will therefore evaluate the role of edible fungi in the biodegradation of sawdust and cassava peels mixed as the substrate for mushroom cultivation by comparing the nutritional composition of the substrate before inoculation (BI) and after fruit body production SMS to further utilize it in the formulation of livestock feeds.

2. RESEARCH METHOD

2.1. Study site and source of spawn

This research was conducted at the school of agriculture teaching and research farm. Cassava peels and sawdust were collected around the Eziobodo community. While mushroom spawns established on guinea corn seed were obtained from dilomat mushroom farms and services in Port Harcourt, Rivers State, Nigeria.

2.2. Preparation of substrate

Samples were prepared according to the modified method of Stamets [25]. Shredded and moistened cassava peels (50%) and sawdust (50%) were mixed with different levels of wheat bran in the following carbon/nitrogen rations: 17:0 (T1 control), 17:1 (T2), 17:3 (T3), which represent the treatments for this

investigation and were replicated three times and composted for two weeks. 2% lime (CaCO3) was added to the treatments to correct the pH of the substrate. 1 kg of the composted substrate was measured into high-density polypropylene bags. The bags were packed inside a drum steamer and pasteurized for three hours and allowed to cool overnight before being inoculated with a spawn of *Pleurotus ostreatus*. The inoculated substrates were incubated at ambient temperature in a specially constructed growth chamber where temperature and relative humidity were monitored. After incubation, the bags were opened and induced for fruit body production after 43 days of spawning.

2.3. Laboratory analysis

The minerals evaluated in this study include Na (mg/kg), Mg (mg/kg), ash (%), Ca (mg/kg), K (mg/kg), and P (mg/kg) using atomic absorption spectrometry while the proximate composition evaluated include dry matter (%), N (%), CP (%), crude fiber (%) using the procedure outlined by Khalil and Manan [26] at the soil science laboratory, Federal College Land Resource Technology (FECOLAT) Owerri Imo State, Nigeria.

2.4. Experimental design and data analysis

The experiment was laid out in a completely randomized design (CRD). The data generated were subjected to analysis of variance (ANOVA). According to the procedure outlined by Steel and Torrie [27], means were separated using fishers' least significant difference at $p = 0.05$.

3. RESULTS AND DISCUSSION

3.1. Evaluation of the mineral and proximate composition of the substrate before inoculation

The result obtained from the evaluation of the mineral and proximate composition of the composted and pasteurized substrate BI is presented in Tables 1 and 2 respectively. The result revealed that T1 contained 0.17 mg/kg Na higher than T3 (0.16 mg/kg) while the lowest value of 0.15 mg/kg was obtained from T2. T3 had 0.4 mg/kg higher Mg than T2 (0.37 mg/kg) while the lowest value of 0.35 mg/kg was obtained from T1 (0.35 mg/kg). The result of the ash content showed that T1 had 2.65% higher than T2 (1.64%) while T3 had the lowest value of 1.56%. The result further revealed that T1 had the highest values of Ca, K, and P with the values 1.23, 0.42, and 0.23 mg/kg respectively while the lowest values were obtained from T2 with the values 0.69, 0.30, and 0.11 mg/kg for Ca, K, and P respectively. The result further revealed that T1 (control) contained 93.3% higher dry matter than T2 (92.4%) while the lowest value of 84.3% was obtained from T3. T2 had 0.21% N higher than T3 (0.20%) while the lowest value of 0.18% was obtained from T1. The result obtained from the evaluation of the CP equally revealed that T2 had 1.31% higher than T3 (1.25%) while T1 (control) had the lowest value of 1.13%. Again T1 had the highest value of 4.82% crude fiber than T3 (3.34%) while T2 had the lowest value of 3.23%. These results were highly significantly different. The result presented showed that treatments T1 (control) with zero wheat bran contained the highest values of dry matter, crude fiber, ash, Na, Ca, K, and P but it contained less nitrogen and CP. The result further revealed that the addition of wheat bran improved/increased the nitrogen and CP content of the substrate but did not enhance the level of the other minerals in the substrate. These findings are in agreement with the findings of Kwak *et al.* [28] though they reported lower levels of dry matter but higher levels of CP and percent ash on the only sawdust-based substrate. Furthermore, this result is in agreement with the findings of Tewe and Lutaladio [23] who reported that cassava peels contain higher protein content than other parts of the tuber.

3.2. Evaluation of the mineral and proximate composition of the spent mushroom substrate

The result obtained from the evaluation of the mineral and proximate composition of the SMS is presented in Tables 3 and 4. T2 and T3 had equal values of Na (0.12 mg/kg) higher than T1 which had 0.10 mg/kg. The result further revealed that the highest value of Mg (0.35 mg/kg) was obtained from T2 while the lowest (0.25 mg/kg) was obtained from T3. T2 had 2.53% ash higher than T1 (1.65%) and T3 (1.57%). Furthermore, T3 contained higher Ca, K, and P with the values 1.40, 0.40, and 0.44 mg/kg respectively while the lowest was obtained from T2 with the values 0.62, 0.25, and 0.21 mg/kg for Ca, K, and P respectively. The result obtained from the evaluation of the proximate composition revealed that T3 had the highest dry matter of 93.2%, followed by T1 (92.4%) while the lowest was obtained from T2 with a value of 81.6%. However, the highest value of N and CP values of 0.31 and 1.94% were obtained from T1 while the lowest values of 0.22 and 1.38% were obtained from T3. Again the result showed that T3 had 4.07% crude fiber higher than T1 and T2 which had 3.66 and 2.84% respectively. These results were highly significantly different. This result showed that T1 had the highest nitrogen and CP than the other treatments, this could be attributed to the poor mushroom colonization resulting in low assimilation of these nutrients by the fruit bodies. The result further revealed significant improvements in the mineral content of the SMS when it was compared with the substrate BI. This result suggests that SMS are enriched nutritionally because of the

bioconversion of the lignocelluloses by edible fungi and as a result could be utilized in the formulation of livestock feeds which is in agreement with the findings of Foluke *et al*. [29] who reported the use of SMS as a replacement of wheat bran in broiler diets. They reported significantly higher values of CP, crude fiber, ash, and nitrogen than our findings which could be attributed to low yield resulting in poor assimilation by the fruit bodies when compared with our investigation.

Table 1. Evaluation of the mineral composition of the substrates BI

Treatments	Na (mg/kg)	Mg (mg/kg)	Ash (%)	Ca (mg/kg)	K (mg/kg)	P (mg/kg)
T1	0.17^{a}	0.35^{c}	2.65^{a}	1.23^{a}	0.42^{a}	0.23^{a}
T2	0.15^{c}	0.37^{b}	1.64^{b}	0.69^{b}	0.30^{a}	0.11^{b}
T3	0.16^{b}	0.40^{a}	1.56^{b}	1.21^{a}	0.26^{a}	0.19^{a}
F LSD (p = 0.05)	0.008	0.008	0.08	0.194	0.194	0.047

Key**:**
T1-C/N 17:0 (control)
T2-C/N 17:1
T3-C/N 17:3
BI-Before inoculation
Figures on the same column with the same superscript are not statistically significant

Table 2. Evaluation of the proximate composition of the substrate BI

Treatments	Dry matter (%)	N (%)	CP (%)	Crude fiber (%)
T1	93.3^{a}	0.18^{c}	1.13^{c}	4.82^{a}
T2	92.4^{b}	0.21^{a}	1.31^{a}	3.23^{b}
T3	84.3^{c}	0.20^{b}	1.25^{b}	3.34^{c}
F LSD (p = 0.05)	0.067	0.008	0.008	0.08

Key:
T1-C/N 17:0 (control)
T2-C/N 17:1
T3-C/N 17:3
BI-Before inoculation
Figures on the same column with the same superscript are not statistically significant.

Table 3. Evaluation of the mineral composition of the SMS

Treatments	Na (mg/kg)	Mg (mg/kg)	Ash (%)	Ca (mg/kg)	K (mg/kg)	P (mg/kg)
T1	0.10^{b}	0.34^{b}	1.65^{b}	1.32^{a}	$0.32^{a, b}$	0.30^{a}
T2	0.12^{a}	0.35^{a}	2.53^{a}	0.62^{b}	0.25^{b}	0.21^{b}
T3	0.12^{a}	0.25^{c}	1.57^{b}	1.40^{a}	0.40^{a}	0.44^{a}
FLSD(p = 0.05)	0.008	0.008	0.107	0.302	0.149	0.170

Key:
T1-C/N 17:0 (control)
T2-C/N 17:1
T3-C/N 17:3
Figures on the same column with the same superscript are not statistically significant

Table 4. Evaluation of the proximate composition of the SMS

Treatments	Dry matter (%)	N (%)	CP (%)	Crude fiber (%)
T1	92.4^{b}	0.31^{a}	1.94^{a}	3.66^{b}
T2	81.6^{c}	0.24^{b}	1.50^{b}	2.84^{c}
T3	93.2^{a}	0.22^{c}	1.38^{c}	4.07^{a}
FLSD(p = 0.05)	0.667	0.008	0.047	0.066

Key:
T1-C/N 17:0 (control)
T2-C/N 17:1
T3-C/N 17:3
Figures on the same column with the same superscript are not statistically significant

3.3. Comparative analysis of the mineral and proximate composition of the substrate before inoculation and after fruit body production (spent mushroom substrate)

The comparative analysis of the mineral compositions and proximate analysis of the substrate after fruit body production SMS and BI are presented in Figures 1 and 2 respectively. The result showed that T1 (SMS) had 0.17 mg/kg higher Sodium than T1 (BI) with 0.10 mg/kg. T2 (SMS) equally had 0.15 mg/kg higher than T2 (BI) (0.12 mg/kg), while T3 (SMS) had 0.16 mg/kg Na than T3 (BI) which had 0.12 mg/kg. However, T1 (SMS) had 0.35 mg/kg higher Mg when compared with T1 (BI) which had 0.34 mg/kg, T2

(SMS) had 0.37 mg/kg less than T2 (BI) which had 0.45 mg/kg. T3 (SMS) had 0.40 mg/kg higher Mg than T3 (BI) which contained 0.25 mg/kg. T1 (SMS) had a higher ash content of 2.65% than T1 (BI) with 1.65%, T2 (SMS) contained 1.64% less ash than T2 (BI) which contained 2.53%, T3 (SMS) had 1.56% less than T3 (BI) which had 1.57%. T1 (SMS) had 1.23 mg/kg less Ca when compared with T1 (BI) with 1.32 mg/kg, T2 (SMS) also had 0.69 mg/kg less than T2 (BI) which had 0.62 mg/kg. T3 (SMS) had less Ca by 1.21 mg/kg while T3 (BI) had 1.40 mg/kg. The result further revealed that T1 (SMS) contained 0.42 mg/kg higher K when compared with T1 (BI) which had 0.32 mg/kg, T2 (SMS) had 0.30 mg/kg Ca while T2 (BI) had 0.25 mg/kg, T3 (SMS) had 0.26 mg/kg less K when compared with T3 (BI) with 0.40 mg/kg K. However, T1 (SMS) had 0.23 mg/kg less P when compared with T1 (BI) which had 0.50 mg/kg, T2 (SMS) also had 0.11 mg/kg less P than T2 (BI) which had 0.21 mg/kg, T3 (SMS) had 0.19 mg/kg less P than T3 (B1) with 0.44 mg/kg P. The result of proximate analysis further revealed that T1 (SMS) had 93.3% dry matter content higher when it was compared with T1 (BI) (92.4%). T2 (SMS) had 92.4% higher than T2 (BI) with 81.6% dry matter. However, T3 (SMS) had 84.3% less dry matter than T3 (BI) which had 93.2%. The result further revealed that T1 (SMS) had 0.18% less Nitrogen than T1 (BI) which had 0.31%. T2 (SMS) had 0.21% N less than T2 (BI) which had 0.24% N. T3 (SMS) had 0.20% less N than T3 (BI) with 0.22% N. The result obtained from the evaluation of CP further revealed that T1 (SMS) contained 1.13% less CP when it was compared with T1 (BI) (1.94%) CP. T2 (SMS) had 1.31% less than T2 (B1) had 1.50% CP. T3 (SMS) had 1.25% less CP than T3 (BI) which had 1.38%. The result of the crude fiber further revealed that T1 (SMS) contained 4.82% higher crude fiber than those obtained from T1 (BI) (3.66%). T2 (SMS) had 3.23% while T2 (BI) had 2.84%, T3 (SMS) had 3.34% less crude fiber than T3 (BI) which had 4.07%. These results were highly significantly different which clearly revealed that edible fungi *Pleurotus ostreatus* nutritionally enriched the sawdust and cassava peels-based substrate which could be attributed to the microbial degradation of the cellulose, hemicelluloses, and lignin present in the substrate suitable for mushroom cultivation This result is in agreement with the findings of Sidana and Farooq [30]. However, the result further revealed that SMS recorded slightly lower values in the nutrients evaluated. This observation could be attributed to the assimilation of nutrients into the mushroom fruit bodies which is in agreement with the findings of Zhang *et al.* [31].

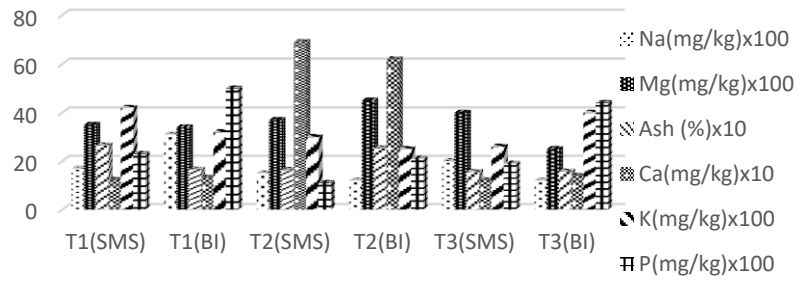

Figure 1. Comparative analysis of the mineral composition of the substrate BI and the SMS

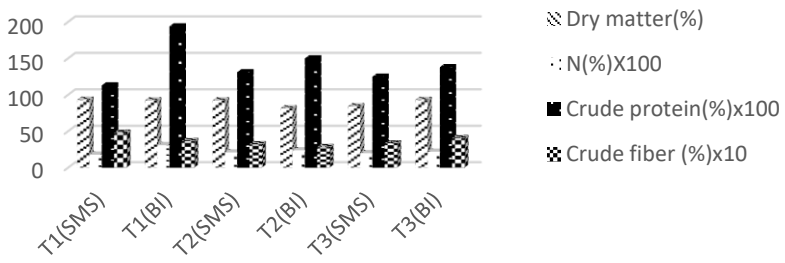

Figure 2. Comparative analysis of the proximate composition of the substrate BI and the SMS

4. CONCLUSION

The major findings from this investigation are as follows: cultivation of *Pleurotus ostreatus* on a 1:1 ratio of cassava peels and sawdust-based substrate nutritionally enriched the substrate through microbial

degradation though significant quantities of these nutrients were assimilated into the fruit bodies. Therefore it is recommended that a fully colonized substrate yet to produce fruit bodies should be utilized in the formulation of livestock feeds in order to utilize all the unlocked nutrients in the substrate. However, further studies are recommended especially in the evaluation of more nutritional indices of the substrate.

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