Evaluation of Growth and Nutritional Value of *Pleurotus sajor-caju* (F.) Singer Cultivated on Sawdust of Different Wood Species

***Dania, V.O.[1], and Ekpo, E.N.[2]**
[1]Department of Crop Protection and Environmental Biology,
University of Ibadan, Nigeria.
[2]Department of Forest Conservation and Protection,
Forestry Research Institute of Nigeria, Ibadan, Nigeria
*Corresponding Author E-mail: *victorohileobo@gmail.com*

Abstract

The potential of sawdust substrate of selected tree species in the cultivation of the oyster mushroom, *Pleurotus sajor-caju*, was evaluated. Sawdust was collected from wood processors in various sawmills at Ibadan, southwest Nigeria and composted for mushroom cultivation. Biological efficiency (BE) and Production rate (TP) of *P. sajor-caju* on the various wood substrates and proximate analysis were carried out to determine rate of substrate utilization and nutritional value of harvested mushrooms using standard procedures. Spawn run period of the composted substrate bags ranged between 21 and 29 days. Mushroom cultivated on *Brachystegia eurycoma* and *Gmelina arborea* substrates had the highest total fruit body yield of 172.8 g and 168.2 g, respectively at harvest. BE varied considerably between 17.3% and 37.7%. *B. eurycoma* gave the highest BE of 37.7%. TP was also highest in mushrooms cultivated on *B. eurycoma* and *G. arborea* sawdust with 64.0% and 62.5%, respectively. Analyzed samples showed significant amounts of crude fibre, protein, and carbohydrate that varied from 9.3-15.1, 18.2-30.2 and 37.7 - 51.5%, respectively. Calcium, magnesium and phosphorus content (mg $100g^{-1}$) varied from 27.3 - 30.1, 27.6 - 44.2 and 37.6 - 60.04, respectively. Lipid constituent was generally $\leq 1.5\%$. Therefore, the utilization of these agro forestry wastes for the production of the oyster mushrooms, *Pleurotus sajor-caju,* is economically viable and ecologically practicable.

Keywords: Biological efficiency, Fruiting body, *Pleurotus sajor-caju*, Proximate analysis, Sawdust.

Introduction

Mushrooms are fleshy saprophytic fungi found growing on damp rotten log of wood trunk of trees, decaying organic matter and damp soil rich in organic substances. The importance of edible mushrooms has increased in recent years because of their gastronomic value, nutritional potential, medicinal properties and ability to degrade and recycle agro-industrial residues (Bonatti *et al.,* 2004; Cheung and Cheung, 2005; Pedra *et al.,* 2009). The cultivation and consumption of mushroom can solve the malnutrition problem of developing countries; their waste can be recycled into food and the environment may be less endangered by pollution (Eswaran and Ramabadran, 2010; Stanley, 2011). The major problem associated with the transfer of technology for mushroom cultivation is the inadequate technical know-how for its cultivation (Khaund and Joshi, 2013).

Many fungi that form mushroom are often associated with trees, and this is one of the reasons why the forest is often the target of mushroom hunters (Das, 2010). *Pleurotus* spp. are commonly known as "oyster mushroom". These are the second most popular mushroom after button mushroom all over the world (Adejoye *et al.,* 2006). Oyster mushrooms have a wide range of temperature tolerance (15-

30^0C) which is ideally suitable for cultivation under both temperate and tropical climatic conditions. Mushrooms hold a unique place in the world today. Human population expands by 2.1% representing a rise of 75 million people per year (FAO, 2009). Thus, food production has to keep pace with population increase. Mushroom along with yeast are referred to as alternative source of food (Ajankora, 2002). *Pleurotus* species are popular and widely cultivated throughout the world owing to their simple and low cost production technology and higher biological efficiency (Mane *et al.,* 2007).

Most mushrooms have exceptional medicinal potentials and properties, curative and prophylactic value especially in diseases such as high blood pressure, asthma, respiratory tract infection, anaemia, hepatitis, cancer and tumour (Johnsy *et al.,* 2011; Pokhrel *et al.,* 2013). *Pleurotus sajor-caju* inhibits hypertensive effects through its active ingredients, which affect the rennin-angio-tension system (Chang, 1996). They are rich in protein but less in unsaturated fatty acid and carbohydrate which makes it so ideal for diabetic and obesity patients (Pelczar *et al.,* 1986). However, nutritional composition is affected by many factors including differences among strains, composition of growth substrate, method of cultivation, stage of harvesting, specific portion of fruiting bodies, used analysis, time interval between harvest and measurement method (Benjamin, 1995; Ojo *et al*., 2010).

Cultivation of oyster mushroom has increased tremendously throughout the world because of their abilities to grow at a wide range of temperature and harvested all over the year (Amin *et al.,* 2007). Mushroom cultivation also serves as the most economically-viable biotechnology for the conversion of log cellulose materials into high quality protein food which will naturally open up new job opportunities, especially in the rural areas. Sawdust is one of the substrates used for mushroom cultivation. It is cheap, readily available and has short composting period. Timber processors are often faced with the challenge of how to ensure proper disposal of large quantities of sawdust from processed logs at sawmills. They either pay people to help dispose the wastes or resort to burning which results in environmental pollution. The use of these residues in bioprocesses may be one of the solutions to bioconversion of inedible biomass residues into nutritious protein rich food in the form of edible mushrooms (Mshandete and Cuff, 2008).

The suitability and use of sawdust for mushroom cultivation would also be a great relief to wood processors and ultimately ensure a cleaner environment. Currently, high biofuel prices have caused an increase in food prices and food scarcity in many countries. To alleviate hunger and malnutrition in a world of rising food prices, cultivation of mushrooms is a very reliable and profitable option. The different substrates used in cultivating mushrooms have an effect on the functional, organoleptic and chemical properties of mushrooms (Marcelo *et al.,* 2012; Manimozhi and Kaviyarasan, 2013).

There is, therefore, the need to evaluate the proximate composition of *P. sajor-caju* in order to know the effects of the different substrates on its nutritional quantity and quality. The objective of the study was to evaluate the growth yield and nutritional composition of *Pleurotus sajor-caju* using sawdust from eight different wood species from Nigeria as substrates.

Materials and Methods

Culture preparation

The pure culture of *Pleurotus sajor-caju* was obtained from the Forestry Research Institute of Nigeria, Jericho, Ibadan, Nigeria. The cultures

were maintained on Potato dextrose agar (PDA) slants at 4^0C. Sub culturing was done after 15 days.

Collection of sawdust of wood species

Sawdust of different wood species were collected from different wood processors at the Bodija, Apata and Sango sawmills at Ibadan, Southwest Nigeria. Sawdust of eight wood species: *Anogeissus leiocarpus* Gull and Merry, *Brachystegia eurycoma* Harms (De Wild) Merill, *Gmelina arborea* Roab, *Nauclea diderrichii* (De Wild and Durand) Merrill, *Funtumia elastica* (Preuss) Stapf, *Triplochiton scleroxylon* Schuman, *Ceiba pentandra* (L.) Gaertn and *Alstonia boonei* (De Wild) was evaluated in this study. Samples were collected in different sacks and clearly labelled. These were later transferred to the research laboratory at the Forestry Research Institute of Nigeria (FRIN) preparatory to composting.

Preparation of grain spawn

The wheat grain were thoroughly washed and soaked for 24 hrs in water and then sieved. The grains were then filled halfway into heat-resistant jam bottles and sterilized in the autoclave at 121°C about 2 hrs at 1.5 kg/cm^2. The sterilized grains were inoculated with mycelia of *P. sajor- caju* and incubated at room temperature (28±2^{0}C) for 2- 3 weeks depending on the rate of ramification (Oei, 2003).

Composting of substrate and pasteurization

Eight substrates were composted in bags for 7 days and were regularly turned every 3 days to ensure uniform temperature condition of the compost. Supplements such as 20% rice bran and 1% lime ($CaCO_3$) were added to each substrate which were sufficiently mixed with tap water to allow 1-2 drops of water when the moistened substrate was firmly pressed between fingers (Ekpo and Aluko, 2002). Then 500 g of mixture was packed tightly in 18×25 cm heat-resistant polypropylene bags. Each of the bags were filled with sawdust and the neck plugged with a ball of cotton and covered with brown paper and placing the rubber band to hold substrate bags tightly in place. The substrates were pasteurized in a drum with consistent heating for 4 hrs at a temperature of 100^{0}C. The pasteurized substrates were allowed to cool overnight preparatory to inoculation.

Inoculation, Incubation and Biological Efficiency

After cooling, 10g mother spawn were inoculated in to the bagged substrate in the laminar airflow cabinet and were kept at 26-28°C until the substrate became white with the mushroom mycelium. The inoculated substrate bags were transferred to a disinfected dark room and incubated at 28±2^{0}C for 2 to 3 weeks depending on rate of mycelial ramification (Oei, 2003). The dark environment maintained during incubation was to ensure rapid mycelial colonization of the substrate. The experiment was laid out in a completely randomized design (CRD), with eight treatments and 5 replicates. Weekly mycelial growth on the replicate treatments was recorded for four weeks. At full colonization, of the substrate bags, they were transferred to the cropping house made with wooden mats, maintained at room temperature and relative humidity of 75-85% ensuring adequate watering by spraying water twice a day. The bags were then opened and watered daily to increase the humidity and induce fruit body formation. The temperature of the culture house was maintained at 28±2°C. The density of mushroom mycelial growth on the different substrate bags observed visually and rated as follows: weak mycelial growth, light mycelial growth, dense mycelial growth.

Growth and Yield Parameters

Data were collected during the growth and fruiting phases of the mushrooms. Mycelial growth for *P. sajor-caju* was measured for the days required against all treatments. Yield in terms of percentage biological efficiency was calculated as fresh weight of harvested mushroom/weight of substrate 100 (Dias *et al.,* 2003; Oliveira *et al.,* 2007; Holtz *et al.,* 2007).

$$\text{Biological efficiency (BE)} = \frac{\text{mushroom mass (wet basis)}}{\text{Substrate mass (dry basis)}} \times 100$$

$$\text{Productivity (P)} = \frac{\text{mushroom mass (dry basis)}}{\text{Substrate mass (dry basis)}} \times 100$$

$$\text{Production rate (TP)} = \frac{\text{biological efficiency}}{\text{Total days of cultivation}} \times 100$$

Fruiting and Cropping

Mushrooms were harvested from the substrate when the caps got fully matured and before the fruiting bodies started to curl up. The clusters of the mushrooms were weighed, and several parameters were evaluated: the length of each phase of the fungus production cycle (first and second flush), earliness (the time lapse between the day of inoculation and the day of the first harvest), fruiting bodies number per flush and in total, the average weight of individual basidiomata per flush and in total, the average yield for each treatment per flush and in total, and biological efficiency (percentage yield of fresh mushroom over the dry weight of the substrate). Fruiting bags were watered on a daily basis. A clean scalpel was used to detach the mushroom at the base of the stipe from the bags. Weight of the fresh mushrooms was taken at each harvest and weighed before being packaged for consumption.

Proximal composition of *Pleurotus sajor-caju*

Moisture, fat, ash, protein, crude fiber and carbohydrate content were determined by the guideline given by Association of Official Analytical Chemists (AOAC, 1995).

Analysis for minerals in *Pleurotus sajor-caju*

Quantification of Calcium, Magnesium, and Phosphorus in the oyster mushroom were determined by employing the AOAC (1995) methodology by digestion of the sample with a mixture of 18 M tetraoxosulphate (VI) acid, 12 M perchloric acid and 16 M trioxonitrate V acid (0.5:1.0:0.5, v/v) using an atomic absorption spectrophotometer (GBC 904AA; Germany). The total phosphorus was determined as orthophosphate by the ascorbic acid method after acid digestion and neutralization using phenolphthalein indicator and combined reagent (APHA, 1995). The absorbance was read at 880 nm (Spectronic 21 D, Miltonroy, NY, USA) and KH_2PO_4 (Merck, India Limited, Mumbai, India) served as the standard.

Statistical analysis

Data obtained were analyzed by one way

analysis of variance and means were compared by Least Significant Difference (LSD) tests (SPSS 11.5 version). Differences were considered significant at $p<0.05$.

Results

Pleurotus sajor-caju showed dense white mycelial growth that was uniform throughout substrate bags of *B. eurycoma, G. arborea* and *T. scleroxylon* wood species with a spawn run period of 21 days (Table 1).

Complete ramification of substrate bags by *P. sajor- caju* mycelia was between 24 and 29 days on substrates of *A. leiocarpus*, *N. diderrichii*, *C. pantandra* and *A. boonei*. *Pleurotus sajor-caju* showed weak mycelial growth on *A. leiocarpus*, *F. elastica*, *C. pentandra* and *A. boonei* substrates. The fungal mycelia completely colonized the substrates within 29 days spawn run. Fruiting body of *P. sajor –caju* became apparent at 4-7 days after opening of the substrate bags (Table 2). With the exception of *A. leiocarpus* and *C. pentandra* that produced two and three flushes or harvest, respectively, all the test substrates produced four flushes within the study period. Mushrooms had produced highest fruit body yield on *B. eurycoma, G. arborea* and *T. scleroxylon* substrates. *A. leiocarpus* and *A. boonei* had the least yield of 56g and 54.4g, respectively at flush 1. Fruit body yield decreased progressively from flush 1 to 4.

Table 1: Comparison of Weekly Mycelial Growth of *Pleurotus sajor-caju* on different Substrates

Substrate	Mycelial growth	Time (Days	Mycelial growth diameter (cm)			
			WK 1	WK 2	WK 3	WK 4
A. leiocarpus	weak	*27ab	3.2ab	5.9b	8.2b	9.3ab
B. eurycoma	dense	21bc	4.8a	6.0b	12.3a	13.3a
G. arborea	dense	21bc	3.8ab	8.8ab	13.2a	13.2a
N. diderrichii	light	24b	5.0a	10.7a	11.6ab	11.6ab
F. elastica	weak	21bc	2.3b	8.8ab	12.4a	12.4a
T. scleroxylon	dense	21bc	1.5b	6.4b	10.6ab	10.6ab
C. pentandra	weak	29a	2.0b	7.3ab	7.6b	7.6b
A. boonei	weak	25b	2.6b	3.8bc	8.5b	8.5b

* = Means are average of three replicates. Means followed by the same letter along a column are not significantly different using Least Significant Difference ($P<0.05$).

Table 2: Yield and biological efficiency of *Pleurotus sajor-caju* on different sawdust species

Substrate	Days from bag opening to fruiting	Number of mushroom flush (g) 1	2	3	4	fresh weight (g) (g)	Biological Efficiency (%)	Productivity (P)	Production rate (TP)
A. leiocarpus	6	56.0	33.2	0.0	0.0	$89.2^{d}\pm1.4$	$29.73^{bc}\pm0.09$	$7.70^{bc}\pm0.1$	$33.03^{c}\pm0.4$
B. eurycoma	4	93.8	59.8	15.6	3.6	$172.8^{a}\pm0.8$	$57.6^{a}\pm0.1$	$11.16^{a}\pm0.02$	$64.0^{a}\pm0.05$
G. arborea	5	88.3	50.7	22.1	7.1	$168.2^{ab}\pm0.6$	$56.07^{a}\pm0.33$	$11.02^{a}\pm0.03$	$62.3^{a}\pm0.01$
N. diderrichii	6	72.9	19.2	4.9	2.8	$99.8^{cd}\pm0.3$	$33.27^{bc}\pm0.21$	$9.04^{b}\pm0.04$	$36.97^{bc}\pm0.07$
F. elastica	5	70.3	17.7	13.1	5.2	$106.3^{c}\pm0.5$	$35.43^{b}\pm0.07$	$9.06^{b}\pm0.01$	$39.37^{b}\pm0.02$
T. scleroxylon	4	82.9	48.0	17.7	5.5	$154.1^{b}\pm1.1$	$51.37^{ab}\pm0.13$	$9.40^{b}\pm0.02$	$50.08^{ab}\pm0.01$
C. pentandra	6	74.9	32.3	8.1	0.0	$113.3^{bc}\pm0.9$	$37.77^{b}\pm0.05$	$8.94^{bc}\pm0.01$	$41.97^{b}\pm0.23$
A. boonei	7	54.4	28.3	2.2	1.8	$86.7^{d}\pm0.1$	$28.91^{bc}\pm0.1$	$7.22^{bc}\pm0.03$	$32.12^{c}\pm0.11$

Values were expressed as mean ± SE Means followed by the same superscripts letter along a column are not significantly different using Least Significant Difference ($P<0.05$).

The first two flushes accounted for more than 70% of total fruit body yield. Biological efficiency (BE) varied considerably between 28.91 and 57.6%. *B. eurycoma* had the highest BE of 57.6% while *A. boonei* recorded the least BE of 28.91%. Mushroom yield was more dependent on mycelial density rather than length of mycelial growth. Hence, substrate from *B. eurycoma, G. arborea* and *T. scleroxylon* with uniformly white dense mycelia produced higher mushroom yield and BE than other treatments. Substrate from *B. eurycoma* and *G. arborea* had the highest productivity rate of 11.16% and 11.02%, respectively while *A. boonei* had the lowest productivity of 7.22%. Similarly, *B. eurycoma* and *G. arborea* had the highest production rates of62.3% and 64.0%, respectively. Nutrient composition varied among the mushrooms that were grown and harvested from sawdust substrate of the different wood species (Table 3). Mushroom cultivated on *N. diderrichii* had the highest crude fibre content of 17.7% while *C. pentandra* substrate produced mushroom with the lowest amount of 5.8%. *Gmelina arborea* substrate produced mushroom with the highest crude protein content of 30.2% which was closely followed by those cultivated on *A. boonei* substrate (28%), while harvested mushrooms from *A. leiocarpus* sawdust had the least yield of 18.2%.

Table 3: Effect of Sawdust of different species on proximate and minerals composition of *P. sajor-caju*

	Nutrient concentration on dry basis								
Sawdust species	Crude fibre (%)	Crude Protein (%)	Ash (%)	Lipids (%)	Moisture (%)	CHO (%)	Ca*	Mg*	P*
A. leiocarpus	12.9^{b}±0.2	18.2^{b}±0.77	3.1^{b}±0.03	0.4^{a}±0.01	8.1^{b}±1.05	37.7^{bc}±0.67	27.3^{ab}±0.01	30.1^{bc}±2.32	37.6^{bc}±1.01
B. eurycoma	9.5^{b}±0.05	22.2^{b}±0.13	2.7^{b}±0.01	1.5^{a}±0.05	16.4^{a}±0.32	41.1^{b}±0.24	28.2^{a}±0.05	34.4^{b}±1.07	44.1^{b}±1.13
G. arborea	11.7^{b}±0.19	30.2^{a}±0.4	5.4^{a}±0.2	0.8^{a}±0.02	10.6^{b}±0.10	44.3^{ab}±0.33	29.1^{ab}±0.03	27.6^{bc}±1.88	47.7^{ab}±2.22
N. diderrichii	17.7^{a}±0.66	28.7^{a}±1.2	3.8^{b}±0.01	1.2^{a}±0.01	15.5^{a}±0.44	40.8^{b}±1.05	29.5^{ab}±0.01	45.5^{ab}±3.30	50.6^{ab}±0.86
F. elastic	10.7^{b}±0.04	20.3^{b}±0.23	5.8^{a}±0.02	0.5^{a}±0.00	7.7^{bc}±0.51	50.1^{a}±0.77	30.1^{ab}±0.01	35.7^{b}±2.28	47.9^{ab}±1.12
T. scleroxylon	15.1^{a}±0.22	27.6^{a}±0.50	3.2^{b}±0.05	0.3^{a}±0.03	5.2^{bc}±0.19	47.7^{ab}±0.14	28.4^{a}±0.04	50.8^{a}±3.07	42.8^{b}±2.77
C. pentandra	5.8^{c}±0.31	23.7^{b}±0.44	0.4^{c}±0.04	1.1^{a}±0.04	11.5^{b}±1.08	46.1^{ab}±0.10	30.7^{a}±0.03	44.2^{ab}±2.97	60.4^{a}±4.63
A. boonei	9.3^{b}±0.1	28.0^{a}±0.71	4.7^{a}±0.1	0.77^{a}±0.02	10.2^{b}±0.22	51.5^{a}±0.38	28.8^{a}±0.01	40.71^{ab}±0.84	51.1^{ab}±0.11

*Values expressed as mg100gm^{-1} dried mushroom. Values were expressed as mean ± SE and as mg 100g^{-1}. Means followed by the same superscripts letter along a column are not significantly different using Least Significant Difference ($P<0.05$).

Ash and lipid contents of all the mushrooms harvested from the different substrates were generally low with values that ranged between 0.4% - 5.4% and 0.3% - 1.5%, respectively. *Brachystegia eurycoma* produced mushrooms with the highest moisture content of 16.4% after drying while those cultivated on *T. scleroxylon* substrate had the least amount of water (5.2%). Carbohydrate content varied among harvested mushrooms from all the substrate (37.7-51.1%) while they all contained significant amounts of calcium, magnesium and phosphorus. There was significant difference among the treatments ($P= 0.05$). However, mushrooms from all the test substrates did not differ significantly ($P>0.05$) in their lipid content.

Discussion

There was considerable variability in the mycelial density of *P. sajor-caju* grown on the eight substrates, which ranged from weak to uniformly dense growth. This result agrees with the findings of Obadai and Vowotor (2002) and Obadai *et al.* (2003) who reported differences in mycelial density and growth rates of eight *P. ostreatus* strains on composted sawdust. There was a direct relationship between mushroom yield on each substrate and ramification time. Substrates that had the shortest ramification time of 21 days had higher yield while those with longer spawn run period of 24-29 days had lower yield. The poor growth and yield of some of the *treatments* might be due to inadequate nutrients that support their growth as well as the nature of the lignocelluloses present coupled with their synergistic enzymatic activities (Oei, 2003).

The type of substrate, the environmental conditions, and the fungus species used in cultivation all have a large influence on the growth and chemical composition of fruiting bodies (Miles and Chang, 1997). The addition of rice bran in the substrate as a nutrient supplement in this study could also have promoted the growth and yield of *P. sajor-caju.* This result is consistent with the work of Thomas *et al.* (1988) and Obadai and Vowotor (2002) that reported mushroom yield to be directly related to the spread of the mycelia into the supplemented substrate but in conflict

with Oei (1991) who observed a negative correlation between mycelial growth and mushroom yield using rice husk supplement as substrate. The discrepancy could be due to the fact that rice husk as a substrate is vulnerable to drying, which affects sporophore formation. Also, the physical nature and high porosity of rice husk, makes it an additive to sawdust instead of being mushroom substrate (Obadai and Vowotor, 2002).

The use of supplements is optional, but it is added to make the substrate more compact and to increase yield. Lime is added to improve and maintain a favourable pH. Rapid decrease in pH, which implies increased acidity, has been experienced after substrate fermentation if no lime is added (Jagadeesh *et al.,* 2010). The effect of supplements on mushroom yield has been reported (Obadai *et al.,* 2003; Adejumo and Awosanya, 2005; Nurudeen *et al.,* 2014). The higher fruit body yield of *B. eurycoma, G. arborea* and *T. scleroxylon* in this study showed their suitability in the production of mushroom. Mushroom yield decreased progressively across the test substrates from Flush 1 to flush 4. This result reaffirms the submission of Obadai and Vowotor (2002) and Obadai *et al.* (2003) that reported a consistent decrease in yield of mushroom from the first to the last flush.

Biological efficiency (BE), Productivity (P) and Production rate (TP) are significantly affected by the interaction among genotype, spawn run time and substrate formulation (Royse and Bahler, 1986). It was observed in this study that substrates with the shortest spawn run period of 21days had the highest BE, P and TP. This result agrees with earlier work of Obadai and Vowotor (2002) who observed a positive correlation between mycelial spread in the substrate and the BE. However, the result disagrees with Royse and Bahler (1986) who opined that longer spawn run periods increases BE of mushrooms. Differences in BE of *P. sajor-caju* grown on the different substrates may have affected the yield. The BE value, which implies the yield of mushroom in relation to the total weight of substrate of spawning, indicate how mushrooms utilize different substrates (Chang and Miles, 1982; Muller *et al.,* 1985). *Pleurotus* spp. are reported to efficiently colonize and degrade lignocellulose. The fungus accomplishes enzymatic degradation of the lignocellulosic portion of substrates by using enzymes such as endoglucanase, β-glucosidase, Xylase, laminarinase, laccase and polyphenol oxidase that are involved in the degradation of lignocelluloses (Muller *et al.,* 1985; Obadai *et al;* Sachan *et al.,* 2013). Low values of BE can be explained by the organism genetics, culture conditions, substrates composition and its proportion used in the process. Besides, it can be influenced by environmental factors such as temperature, humidity, luminosity and pH (Patrabansh and Madan 1997; Manzi *et al.,* 2001; Oliveira *et al.,* 2007).

Growth performance and productivity of *P. sajor-caju* depend largely on the cellulose and hemicelluloses content of its substrate as well as the total carbon and nitrogen content (C: N ratio). The higher P and TP of *B. eurycoma* and *G. arborea* substrates may be attributed to increased cellulose concentration and higher C: N ratio. This result agrees with the findings of Biswas and Layak (2014) that reported the BE and P of *Volvariella volvacea* to be dependent on hemicelluloses, cellulose and C: N ratio. On the contrary, A. *leiocarpus* and *A. boonei* substrates had comparatively low BE, P and TP. These may be due to compactness and high lignin content of both substrates (Collop, 2008). The occurrence of active volatile sulphur compounds may result in higher substrate temperature

which may injure mushroom spawn, reduce mycelial growth rate, and leave the substrate vulnerable to competitor moulds and this could be the reason for lower yield and BE of paddy straw mushroom **(**Biswas and Layak, 2014). Mushrom productivity is also influenced by the availability and ease of absorption of nutrients in the substrate. The better performance of *B. eurycoma* and *G. arborea* substrates was probably enhanced by movement of air and water thereby increasing mushroom productivity. This agrees with the findings of Jonathan *et al.* (2009) who reported that compact substrate restricts water and light movement into the substrate bed and thus prevents the fungus growth and primordial fruit body formation. The differences in terms of TP and BE of mushroom grown on different substrate types were due to the differences in physical and chemical composition of substrate such as cellulose and lignin ratio, mineral content, pH and carbon-nitrogen ratio (Adebayo *et al.,* 2014). The nutrient composition of substrate is one of the factors limiting the saprobiotic colonization of mushroom substrate. The growth of mushroom as well as quantitative and qualitative yield of the desired product depends on the utilization of nutrients and physicochemical environment. Substrates enriched by plant based materials often lead to slow release of organic materials which could be taken by mycelium structures. Thus, low nitrogen content is a critical factor affecting overall TP and BE.

Crude fibre and crude protein content of the harvested mushrooms were similar to those reported for several leguminous crops in West Africa, except for groundnut and soybean (Aletor and Aladetimi, 1995). The protein composition of *P. sajor-caju* in this study varied between 18.2-30.2%. This agrees with previous findings of Kumar *et al.* (2013) that reported protein composition of *Pleurotus* sp. ranging between 8.9 and 38.7% on dry weight basis. Similarly, 27.8% protein had been reported in *P. florida* (Davidson *et al.,* 2012). In terms of the amount of crude protein, mushrooms rank below animal meat but well above most other foods including milk (Das, 2010). Mushrooms in general have higher protein content than most other vegetables (Kumar *et al.,* 2013). Thao and Singdevsachan (2014) reported that mushrooms are very useful for vegetarians because they contain some essential amino acids which are found in animal proteins. Fat content was considerably low among the harvested mushrooms from all substrates with values that ranged between 0.3-1.5%. This confirms earlier reports that mushrooms contain low fat content which makes it relatively cholesterol-free (Adejumo and Awosanya, 2005, Kumar *et al.,* 2013). The differences in nutrient contents of the mushrooms could be attributed to the variation in rate of absorption and utilization of nutrients from the different wood substrates.

The choice of substrate for production of mushroom is largely determined by its abundance and cost. The most widely used substrate for cultivation of mushroom in Nigeria is sawdust. It has been observed in this study that sawdust from different wood species hold tremendous prospect in mushroom cultivation. However, further research is needed to determine the phytochemical composition of the different wood substrates. This will help to establish if the active ingredients in the substrates have any undesirable effect on the nutritional quality of the harvested mushrooms.

References

Adebayo, E.A., Alao, M.B., Olatunbosun, O.O., Omoleye, E.O. and Omisakin, O.B. (2014). Yield evaluation of *Pleurotus pulmonarius*

(Oyster mushroom) on different agricultural wastes and various grains for spawn production. *Ife Journal of Science* 16(3):475-480.

Adejoye, O.D., Adebayo-Tayo, B.C., Ogunjobi, A.A., Olaoye, O.A. and Fadahunsi, F.I. (2006). Effect of carbon, nitrogen and mineral sources on growth of *Pleurotus florida*, a Nigerian edible mushroom. *African Journal of Biotechnology* 5: 1355-1359.

Adejumo, T.O. and Awosanya, O.B. (2005). Proximate and mineral composition of four edible mushroom species from south western Nigeria. *African Journal of Biotechnology* 4(10): 1084-1088.

Ajankora, C.H. (2002). *Cultivation of edible mushroom. Food Science Journal* 30: 399-401.

Aletor, V.A. and Aladetimi, O.O. (1995). Compositional studies on edible tropical species of mushrooms. *Food Chemistry* 54(3): 265-268.

APHA (American Public Health Association) (1995). Standard Methods for Examination of Water and Waste Water, 19th ed.; Washington, DC. Pp 113-114.

Amin, S.M.R., Nirod, C.S., Moonmoon, M., Khandaker, J. and Rahman, M. (2007). Officer's Training Manual: National Mushroom Development and Extension Centre, Savar, Dhaka, Bangladesh. Pp 7-17.

AOAC (Association of Official Analytical Chemists) (1995). Official Methods of Analysis, Association of Official Analytical Chemists, 16th Ed., Arlington, TX, USA. Pp 88-95.

Belewu, M.A. (2003). Nutritional qualities of corn cobs and waste paper incubated with edible mushroom (*Pleurotus sajor-caju*). *Nigerian Journal of Animal Production* 30 (1): 20-25.

Benjamin, D.R. (1995). Mushroom, Poisons and Panaceas: A handbook for naturalists, mycologist and physicians. W. H. Freeman & Company, New York. 96p.

Biswas, M.K. and Mrinmoy, L. (2014). Techniques for increasing the biological efficiency of paddy straw mushroom (*Volvariella volvacea*) in Eastern India. *Food Science and Technology* 2(4): 52-57.

Bonatti, M., Karnopp, P., Soares, H.M. and Furlan, S.A. (2004). Evaluation of *Pleurotus ostreatus* and *Pleurotus sajor-caju* nutritional characteristics when cultivated in different lignocellulosic wastes. *Food Chemistry* 88(3): 425-428.

Chang, R. (1996). Functional properties of edible mushrooms. *Nutrition Research* 54: 391-393.

Chang, S.T. and Miles, P.G. (1982). Introduction to mushroom science. In: Tropical mushrooms: Biological nature and cultivation methods, Chang CT, Quiimio TH (Eds.). The Chinese University Press. Pp 3-10.

Cheung, L.M. and Cheung, P.C.K. (2005). Mushroom extracts with antioxidant activity against lipid peroxidation. *Food Chemistry* 89: 403–409.

Collop, C. (2008). Cotton classroom: Chemical composition of cotton fibre. Department of Textile and Apparel Management, University of Missouri. Pp 11-15. http://cotton.missouri.edu/Classroom-Chemical%20Composition.

Das, K. (2010). Diversity and conservation of wild mushrooms in Sikkim with special reference to Barsey Rhododendron Sanctuary. *North East Biodiversity Journal* 1(2):1-13.

Davidson, S.S., Johnsy, G., Selvin, S.A. and Kaviyarasan, V. (2012). Mushrooms in food culture of the Kaani tribe of Kanyakumari district. *Indian Journal of Traditional Knowledge* 11(1): 150-153.

Dias, E.S., Koshikumo, S.E.M., Schwan, R.F. and Silva, R. (2003). Cultivation of *Pleurotus sajor-caju* mushroom in different agricultural residues. *Ciênc. e Agrotecnology* 27(6): 1363-1369.

Ekpo, E.N. and Aluko, A.P. (2002). Cultivation strategies and nutritive values of edible mushrooms (*Lentinus tuber–regium*) as a component of sustainable livelihood. *Proceedings of 28th Annual Conference of Forestry Association of Nigeria, Akur*e, Ondo State. Pp 114-118.

Eswaran, A. and Ramabadran, R. (2010). Studies on some physiological, cultural and

postharvest aspects of oyster mushroom, *Pleurotus ostreatus* (Berk.) Sacc. *Tropical Agricultural Research* 12: 360-374.

FAO (Food and Agricultural Organization) (2009). Information network on post-harvest handling of mushrooms. Available at: www.fao.org/inpho. 84p

Holtz, M., Borges, G.M., Furlan, S.A. and Wisbeck, E. (2007). Cultivation of *Pleurotus ostreatus* using cotton residues of textile industry. *Reviata Ciênc Amba* 3(1): 37-51.

Jagadeesh, R., Raaman, N., Periyasamy, K., Hariprasath, L., Thangaraj, R., Srikumar, R. and Ayyappan, S.R. (2010). Proximate analysis and antibacterial activity of edible mushroom, *Volvariella bombycina. International Journal of Microbiology Research* 1(3): 110-113.

Johnsy, G., Davidson, S.S., Dinesh, M.G. and Kaviyarasan, V. (2011). Nutritive value of edible wild mushrooms collected from the Western Ghats of Kanyakumari District. *Botany Research International* 4(4): 69-74.

Jonathan, S.G., Bawo, D.D.S., Adejoye, D.O. and Briyai, O.F. (2009). Studies on biomass production in *Auricularia polytricha* collected from Wilberforce Island, Bayelsa State, Nigeria. *American Journal of Applied Science* 6 (1):182-186.

Khaund, P. and Joshi, S.R. (2013). Wild edible macro-fungal species consumed by the Kashi tribe of Meghalaya, India. *Indian Journal of Natural Product Research* 4(2): 197-204.

Kumar, R., Tapwal, A., Pandey, S., Borah, R.K., Borah, D. and Borgohain, J. (2013). Macro-fungal diversity and nutrient content of some edible mushrooms of Nagaland, India. *Nusantara Bioscience.* 5(1): 1-7.

Mane, V.P., Patil, S.S., Syed, A.A. and Baig, M.M.V. (2007). Bioconversion of low quality lignocellulosic agricultural waste into edible protein by *Pleurotus sajor-caju* (Fr.) Singer *Zhejiang. Universal Science Journal* 8(10): 745-751.

Manimozhi, M. and Kaviyarasan, V. (2013). Nutritional composition and antibacterial activity of indigenous edible mushroom *Agaricus heterocystis. International Journal of Advanced Biotechnology Research* 4(1): 78-84.

Manzi, P., Aguzzi, A. and Pizzoferrato, L. (2001). Nutritional value of mushrooms widely consumed in Italy. *Food Chemistry* 73: 321-325.

Marcelo, F.P, Carlos, A.P., Rafael, F.L. and Manuel, S.V.P.O. (2012). Determining the basic composition and total phenolic compounds of *Pleurotus sajor-caju* cultivated in three substrates by solid state bioprocess. *Journal of Biotechnology Diversity* 3(2): 11-14.

Miles, P.G. and Chang, S.T. (1997). Mushroom Biology. World Scientific Press, Hong Kong. pp. 1-96.

Mshandete, A.M. and Cuff, J. (2008). Cultivation of three types of indigenous wild edible mushrooms: *Coprinus cinereus*, *Pleurotus flabellatus* and *Volvariella volvocea* on composted sisal decortications residue in Tanzania. *African Journal of Biotechnology* 7(24): 4551-4562.

Muller, J.C., Gawley, J.R. and Hayes, T. (1985). Cultivation of the shaggy mane mushroom (*Coprinus comatus*) on cellulosic residues from pulp mills. Mushroom Newsletter for the Tropics 6: 21-27.

Nurudeen, T.A. Ekpo, E.N., Olasupo, O.O., Okunrotifa, A.O and Haastrup, N.O. (2014). Effect of supplements on the yield and nutritional composition of oyster mushroom (*Pleurotus sajor-caju*) cultivated on sawdust. *Journal of Environmental Computer Science and Engineering Technology* 3 (3): 1242-1251.

Obadai, M., Cleland-Okine, J. and Vowotor, K.A. (2003). Comparative study on the growth and yield of *Pleurotus ostreatus* mushroom on different lignocellulosic by-products. *Journal of Industrial Biotechnology* 30: 146-149.

Obadai, M. and Vowotor, K.A. (2002). Performance of different strains of *Pleurotus* species under Ghanaian conditions. *Journal of Food Technology* 7 (3): 98-100.

Oei, P. (1991). Manual on mushroom cultivation: Techniques, species and opportunities for

commercial application in developing countries. CTA, Wageningen. The Netherlands. 44p.

Oei, P. (2003). Mushroom cultivation, appropriate technology for mushroom growers. Backlings publishers, Leiden. The Netherlands. 429pp.

Ojo, M.O., Akoun, J., Aderounmu, A.F., Adeniji. R.T. and Adebagbo, C.F.A. (2010). Yield and nutritional value of *Pleurotus florida* (Oyster mushroom) grown on different substrates. Proceedings of the 2nd Biennial National Conference of the Forests and Forest products Society, Federal University of Technology Akure. Pp 300-303.

Oliveira, M.A., Donega, M.A., Peralta, R.M and Souza, C.G.M. (2007). Spawn production of the edible mushroom *Pleurotus pulmonarius* from agro-industrial. *Ciência e Tecnologia de Alimentos* 27: 84-87.

Patrabansh, S. and Madan, R. (1997). Mineral content of the fruiting bodies of *Pleurotus sajor-caju* (Fr.) Singer cultivated on different kinds of biomass. *Acta Biotechnologica* 19 (2): 101-109.

Pedra, W.N., Carnelossi, M.A.G., Silva, G.F., Yaguiu, P., Lira, M.L., Gonçalves, G.B. and Marino, R.H. (2009). Chemical and sensorial analysis of *Pleurotus ostreatus* cultivated in coconut exocarp supplemented with wheat bran and/or rice bran (Análise química e sensorial de *Pleurotus ostreatus* cultivado em casca de coco suplementada com farelo de trigo e/ou de arroz). *Arquivos do Instituto Biologico* 76 (1): 91-98.

Pelczar, M.J., Chan, E.G. and Krieg, C. (1986). Microbiology (5th ed.). McGraw Hill Book Company, Singerpore. 142p.

Pokhrel, C.P., Kalyan, N., Budathoki, U. and Yadav, R.K.P. (2013). Cultivation of *Pleurotus sajor-caju* using different agricultural residues. *International Journal of Agricultural Policy Research* 1(2): 19-23.

Royse, D.J. and Bahler, C.C. (1986). Effect of genotype, spawn run time, and substrate formulation on biological efficiency. *Journal of Applied Environmental Microbiology* 52(6): 145-1427.

Sachan, S.K.S., Patra, J.K. and Thatoi, H.N. (2013). Indigenous knowledge of ethnic tribes for utilization of wild mushrooms as food and medicine in similipal biosphere reserve, Odisha, India. *Journal of Agricultural Technology* 9 (2): 335-348.

Statistical Package for the Social Sciences (SPSS) (2002). Version 11.5. Command Syntax Reference, Inc., Chicago, Ilinois.

Stanley, R.P. (2011). Enumerative combinatorics. Cambridge University Press, 49:7-14.

Thao, H. and Singdevsachan, S.K. (2014). Diversity, nutritional composition and medicinal potential of Indian mushrooms: A review. *African Journal of Biotechnology* 13(4): 1324-1326.

Thomas, G.V., Prablu, S.R., Reeny, M.Z. and Bopaiah, B.M. (1998). Evaluation of lignocellulosic biomass from coconut palm as substrate for cultivation of *Pleurotus sajor-caju* (Fr.) Singer. *World Journal of Microbial Biotechnology* 14(6): 879-882.