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Evaluation of yield, biological efficiency and proximate composition of *Pleurotus* species cultivated on different wood dusts

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Cultivation of edible fungi, notably *Pleurotus* species, have been considered as alternative food supplement due to their functional qualities. In this study, the effect of different substrates on the yield, biological efficiency and proximate composition of *Pleurotus* spp. was evaluated. Proximate analysis of the substrates and cultivated mushrooms was carried out using standard methods.

Pleurotus ostreatus harvested from *Terminalia ivorensis* and *Triplochiton scleroxylon* had the highest yield of 46.97 g and 45.81 g, respectively, with a biological efficiency (BE) of 48.83% and 48.40%, which were significantly different from other mushrooms cultivated on wood dusts. *Pleurotus pulmonarius* cultivated on *T. ivorensis* and *Gossypium hirsutum* had a BE of 43.54 % and 42.28%, which are similar values to the BE of *P. "florida"* (43.09 %) cultivated on *Ceiba pentandra*. *Pleurotus ostreatus* cultivated on *Terminalia ivorensis* and *Alstonia congensis* have the highest protein and crude fibre contents of 30.09% and 21.06%, respectively. *Pleurotus "florida"* harvested from *Gossypium hirsutum*, *Persea americana* and *T. ivorensis* have the highest values of moisture (4.91%), fat (3.96%) and ash (13.98%), respectively, while *P. pulmonarius* cultivated on *Ficus mucuso* has a carbohydrate content of 57.66%.

The cultivated *Pleurotus* mushrooms on wood dusts are means of providing foods that are richly endowed with nutritive components, which can be supplemented to low dietary foods to eliminate malnutrition.

Key words: edible fungi, nutraceuticals, *Pleurotus ostreatus*, *Pleurotus pulmonarius*, *Pleurotus "florida"*, agro wastes.

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Pěstované jedlé houby a především hlívy jsou pro své funkční vlastnosti považovány za vhodný doplněk stravy. Předložená studie hodnotí vliv různých substrátů na výnos, biologickou účinnost a látkové složení vybraných druhů tohoto rodu. Analýza substrátů a plodnic hub byla provedena s využitím standardních metod.

Nejvyšší výnosy (46,97 g a 45,81 g) a biologickou účinnost (48,83 % a 48,40 %) má *Pleurotus ostreatus* pěstovaná na dřevě *Terminalia ivorensis* a *Triplochiton scleroxylon*. *Pleurotus pulmonarius* pěstovaná na *T. ivorensis* a *Gossypium hirsutum* má účinnost 43,54 % a 42,28 %, což jsou hodnoty srovnatelné s účinností *P. "florida"* pěstované na *Ceiba pentandra* (43,09 %). Nejvyšší obsah bílkovin a vlákniny (30,09 % a 21,06 %) má *P. ostreatus* pěstovaná na *Terminalia ivorensis* a *Alstonia congensis*. *Pleurotus "florida"* má nejvyšší zbytkovou vlhkost (4,91 % při pěstování na *G. hirsutum*) a obsah tuku (3,96 % na *Persea americana*) a popelovin (13,98 % na *T. ivorensis*), zatímco nejvyšší obsah cukrů (57,66 %) má *P. pulmonarius* pěstovaná na *Ficus mucuso*.

Pěstování hlív na dřevním odpadu tak může být dobrým prostředkem k získání potravy s obsahem výživných látek, jež může být vhodným doplňkem nízkokalorických potravin pro eliminaci podvýživy.

INTRODUCTION

Edible fungi in the group of higher basidiomycetes have been treasured as a source of food nutrients and biological compounds for medicinal purposes. The regular consumption of different edible and medicinal mushrooms prevent some dietary aliments associated with deficiency of food nutrients (Valverde et al. 2015). Edible mushrooms are prepared and consumed by man in the form of soup, tablets, tea, capsules and extracts to complement food diets with various bioactive ingredients which are deficient in foods of plant and animal origin (Rai et al. 2005, Lee et al. 2012). Several macrofungi and their metabolic compounds have been reported to protect man against cancer formation, free radical generation and colonisation of pathogenic microorganisms (Rahi & Malik 2016, Carrasco-González et al. 2017).

The genus *Pleurotus* is a cosmopolitan group of mushrooms with high nutritional values and therapeutic benefits (Corręa et al. 2016). In tropical and subtropical rainforests, *Pleurotus* species are naturally found in favourable conditions which support their growth. They can also be cultivated artificially, using a variety of agricultural wastes (Chang & Miles 2004, Chirinang & Intarapichet 2009). The cultivation of *Pleurotus* spp. has been characterised to possess efficient colonisation and bioconversion of lignocellulosic agro-industrial residues and other complex organic compounds, reducing the problem of waste disposal and creating a safe environment (Sanchez 2010).

The ability of edible fungi to utilise different wastes plays a key role in the decomposition of organic substances, formation of simple organic byproducts and enrichment of soil microbes leading to soil fertility (Heilmann-Clausen & Boddy 2005, Pavlík & Pavlík 2013). Hence, the degrading enzymes in mycelia of *Pleurotus* spp. enable them to store some metabolic products such as polysaccharides, sterols, triterpenes and phenolic compounds.

Today, the popularity of *Pleurotus* species is due to their culinary values, favourable organoleptic properties, potential source of protein enriching human

diets, and being a healthy substitute for meat (Gregori et al. 2007, Guinard et al. 2016). However, cultivation of edible mushrooms for commercial purposes is still dawdling in Nigeria, where huge amounts of lignocellulosic agricultural residues and agro-industrial products are generated. This is happening as a result of low skills in mushroom cultivation, scarcity of mushroom farmers and scientists, unavailability of some edible fungi spawns, poor knowledge of the diversity of indigenous mushroom species, lack of knowledge in mushroom biotechnology and shortage of mushroom taxonomists (Okhuoya et al. 2010).

Successful cultivation of *Pleurotus* spp. is a way of utilising different agro-waste materials, increasing the application of mushrooms in food processing and solving some critical challenges such as imbalanced diets, malnutrition, economic depression, unemployment and poverty (Osemwegie et al. 2014). The availability of agro-industrial wastes (wood dusts) in Nigeria is a rich source of substrate for the cultivation of edible fungi. This study therefore investigates the yield, biological efficiency and proximate composition of cultivated *Pleurotus* mushrooms on different wood dusts from economically important trees.

Material and methods

Substrate collection. Waste of *Gossypium hirsutum*, Upland Cotton, was collected from Allied Textile Mill (ATM) in Oshodi, Lagos. Agricultural wastes (saw dusts) of the trees *Alstonia congensis*, *Spondias mombin*, *Ceiba pentandra*, *Terminalia superba*, *Terminalia ivorensis*, *Mangifera indica*, *Ficus mucuso*, *Triplochiton scleroxylon*, *Heisteria parvifolia*, *Ricinodendron heudelotii* and *Persea americana* were collected from sawmills in Akure, Southwest Nigeria. The wood dusts used for this study were not fumigated before their use in mushroom cultivation.

Source of fungi. The studied fungi, *Pleurotus pulmonarius* (IIFO-I07) and *P. ostreatus* (IIFO-I09), were obtained from the culture collection of edible fungi at the Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos, Nigeria, while *P. "florida"* (NF-02) originated from the National Horticulture Research Institute (NIHORT), Ibadan, Nigeria.

Although the name *Pleurotus florida* is commonly used in many studies dealing with mushroom cultivation, the official world databases MycoBank and Index Fungorum (www.mycobank.org, www.indexfungorum.org) do not register this taxon at the species level. Cetto (1987) classified it at the form level as *Pleurotus ostreatus* f. *florida*, but unfortunately this name was not validly published. As the focus of this study is an analysis of mushroom cultivation (not taxonomy or nomenclature of particular species), we maintain the name *Pleurotus*

"florida" as commonly used in applied mycology; the name is quoted to highlight its formal invalidity. To avoid possible confusion, this species is not identical with *Pleurotus floridanus* Singer (1948); only the names are similar.

Preparation of *Pleurotus* spawn. Fungal isolates were cultivated on Potato dextrose agar (PDA; Merck, Darmstadt, Germany) and incubated at 25 ± 1 °C for seven days. After full growth of the fungi on the plate, they were inoculated on sterilised sorghum and incubated to produce *Pleurotus* spawns.

Substrate preparation and mushroom cultivation. Each substrate was soaked in 2% w/v of $Ca(OH)_2$ for 18 h. Excess water was pressed out. After sterilisation, each substrate was weighed (300 g) and put into bags under aseptic conditions. The spawns of *P. ostreatus*, *P. pulmonarius* and *P. "florida"* were inoculated on the substrates and incubated at room temperature (26 ± 1 °C). The bags (n = 5) were monitored daily until fungal mycelia covered the substrates, any contaminated bags observed were removed to prevent spread of contamination. Thereafter, bags with primordia were transferred to the cultivation room (26 ± 2 °C in 92 ± 2 % air humidity), where fruiting induction and watering were carried out. Mushrooms were harvested when there a slight upturning of their caps and twisting of the stipe at their attachment to the substrate was indicated. Thereafter, bags were prepared for the second flush.

Determination of yield and biological efficiency. Fresh mushrooms were harvested and the obtained yield was measured as the weight (in grams) of the first and second flushes from one substrate bag (300 g of dry substrate). The biological efficiency was therefore calculated as:

BE = (total weight of fresh mushrooms divided by dry weight of substrate) × 100.

Proximate analysis of substrates used and produced *Pleurotus* mushrooms. Before the proximate analysis, the mushrooms were dried at room temperature (26 ± 1 °C) for 5 days. The percentage of moisture content (see below) means the proportion of water after this time.

The proximate composition of substrates and dried mushrooms was determined according to the methods of the Association of Official Analytical Chemists (2012). Briefly, the moisture content in samples was determined with the air-oven drying method at 110 °C for 2 h. The ash content was determined by incinerating the samples at 550 °C for 4 h, while the crude fibre in the samples was determined by dilute acid and alkali hydrolysis. The fat content in the samples was determined by extracting samples with diethyl ether in a Soxhlet apparatus, crude protein was estimated by the Kjeldahl method (protein = N × 4.38) and total carbohydrates were calculated using the formula:

total carbohydrates (%) =

= 100 – [moisture (%) + protein (%) + crude fibre (%) + fat (%) + ash (%)].

Data analysis. The experiment was carried out using a completely randomised design (CRD). Data obtained in replicates during the experiment were subjected to the analysis of variance (ANOVA). Means were separated and compared using Duncan's new multiple range test at 5% probability level. Statistical analysis was carried with the aid of the Statistical Package for Social Sciences (SPSS, Version 17.0, Chicago, Illinois, USA).

RESULTS AND DISCUSSION

Proximate composition of the substrates

The moisture content in the wood dusts ranged from 5.6 to 9.2%, while fat, protein, ash, crude fibre and carbohydrate contents ranged from 5.2 to 13.4%, 4.2 to 9.6%, 3.1 to 6.4%, 17.8 to 46.7% and 22.0 to 52.0%, respectively (Tab. 1). The nutrient composition of the wood dusts and agro-industrial residues supported the cultivation of *Pleurotus* species except wood dust from *Mangifera indica*, on which no fructification was observed.

This deviated from the findings by Otunla & Idowu (2012), who cultivated *P. "florida"* on *M. indica*. The difference may be due to the method of cultivation, quantity of substrate and type of fungi. In studies by Philippoussis (2009), Khan et al. (2012), and Oyetayo & Ariyo (2013) some woody substrates of *Pycnanthus ongoleubis*, *Terminalia ivorensis*, *Ceiba pentandra*, *Cananium* sp., *Acacia nilotica*, *Bombax cieba*, *Triplochiton scleroxylon*, *Gossypium hirsutum* and *Pinus wallichiana* were successfully used for the cultivation of *Pleurotus* mushrooms. Sanchez (2010) revealed that *Pleurotus* mushrooms are largely cultivated on a wide range of waste materials due to their rapid mycelial growth, inexpensive cultivation technique, availability of different fungal species for cultivation, utilisation of agro-industrial wastes and growth under specific conditions. Hence, the growth of *Pleurotus* species on agricultural substrates will increase their availability as medicinal foods with suitable nutrients for man.

Mycelial colonisation and primordial development

The average number of days required for complete colonisation, rate of colonisation and primordial development of the studied *Pleurotus* species differed between the type of substrate and fungal species (Tab. 2). Full colonisation of fungal mycelia of *P. pulmonarius* and *P. "florida"* on substrates was reached within 14.3 to 25.0 days and took 14.0 to 23.3 days for *P. ostreatus*. The primordial emergence of *P. pulmonarius*, *P. "florida"* and *P. ostreatus* was observed within 22–24, 18–25 and 19–24 days, respectively.

Tab. 1. Proximate composition (%) of wood dusts used for the cultivation of *Pleurotus* mushrooms. Values are mean ± standard deviation (SD) of triplicates (n = 3); means with different letters within a column are significantly different (P < 0.05) according to Duncan's new multiple range test.

Substrates	Moisture	Fat	Protein	Ash	Crude fibre	Carbo-hydrates
Gossypium hirsutum	$8.6^{d} \pm 0.03$	$12.6^{e} \pm 0.00$	$9.6^{d} \pm 0.04$	$4.1^{b} \pm 0.36$	$43.1^{c} \pm 1.00$	$22.0^{a} \pm 0.00$
Alstonia congensis	$7.6^{c} \pm 0.73$	$5.2^{a} \pm 0.03$	$4.8^{a} \pm 0.01$	$3.1^{a} \pm 0.37$	$46.2^{d} \pm 0.88$	$33.1^{b} \pm 0.57$
Spondias mombin	$5.6^{a} \pm 0.13$	$8.1^{b} \pm 0.00$	$6.8^{b} \pm 0.02$	$3.4^{a} \pm 0.02$	$46.7^{d} \pm 1.13$	$29.4^{b} \pm 0.89$
Ceiba pentandra	$6.3^{b} \pm 0.20$	$11.3^{d} \pm 0.50$	$4.2^{a} \pm 0.00$	$3.8^{ab} \pm 0.04$	$41.6^{c} \pm 0.90$	$33.8^{b} \pm 0.19$
Terminalia superba	$7.2^{c} \pm 0.00$	$7.3^{b} \pm 0.23$	$6.7^{b} \pm 0.00$	$4.5^{b} \pm 0.00$	$25.3^{b} \pm 0.50$	$49.0^{c} \pm 1.67$
Terminalia ivorensis	$8.3^{d} \pm 0.01$	$7.6^{b} \pm 0.11$	$7.8^{c} \pm 0.00$	$6.3^{c} \pm 0.00$	$46.4^{d} \pm 0.78$	$23.6^{a} \pm 0.98$
Mangifera indica	$9.2^{d} \pm 0.00$	$8.0^{b} \pm 0.00$	$6.2^{b} \pm 0.12$	$3.1^{a} \pm 0.00$	$44.2^{cd} \pm 0.00$	$29.3^{b} \pm 0.94$
Ficus mucuso	$6.2^{b} \pm 0.20$	$7.5^{b} \pm 0.00$	$4.6^{a} \pm 0.02$	$6.4^{c} \pm 0.21$	$45.0^{cd} \pm 0.11$	$30.3^{b} \pm 0.07$
Triplochiton scleroxylon	$6.8^{b} \pm 0.00$	$11.3^{c} \pm 0.41$	$4.3^{a} \pm 0.00$	$4.0^{b} \pm 0.02$	$40.8^{c} \pm 0.56$	$32.8^{b} \pm 0.47$
Heisteria parvifolia	$7.1^{c} \pm 0.03$	$10.3^{c} \pm 0.37$	$6.4^{b} \pm 0.21$	$6.4^{c} \pm 0.22$	$17.8^{a} \pm 0.12$	$52.0^{c} \pm 1.35$
Ricinodendron heudelotii	$8.6^{d} \pm 0.00$	$7.3^{b} \pm 0.30$	$5.8^{b} \pm 0.23$	$4.7^{b} \pm 0.00$	$23.4^{b} \pm 0.56$	$50.2^{c} \pm 1.02$
Persea americana	$6.3^{b} \pm 0.00$	$13.4^{d} \pm 0.00$	$5.0^{ab} \pm 0.17$	$5.4^{c} \pm 0.00$	$18.6^{a} \pm 0.71$	$51.3^{c} \pm 0.97$

Tab. 2. Duration (days) of full colonisation and primordial development during cultivation of edible fungi on wood dusts. Values are mean ± SD of triplicates (n = 3); means with different letters within a column are significantly different (P < 0.05) according to Duncan's new multiple range test.

Substrates	*Pleurotus pulmonarius*		*Pleurotus "florida"*		*Pleurotus ostreatus*	
	complete colonisation	primordial emergence	complete colonisation	primordial emergence	complete colonisation	primordial emergence
Gossypium hirsutum	$19.3^{c} \pm 0.0$	$23.3^{ab} \pm 0.0$	$17.0^{b} \pm 0.1$	$21.0^{b} \pm 0.0$	$14.3^{a} \pm 0.0$	$20.0^{a} \pm 0.1$
Alstonia congensis	$20.0^{c} \pm 1.0$	$24.0^{b} \pm 0.1$	$20.0^{c} \pm 0.0$	$25.0^{d} \pm 0.2$	$19.0^{c} \pm 0.7$	$21.3^{b} \pm 0.2$
Spondias mombin	$15.0^{a} \pm 0.3$	$22.0^{a} \pm 0.2$	$15.0^{a} \pm 0.0$	$21.0^{b} \pm 0.7$	$15.0^{a} \pm 0.3$	$19.0^{a} \pm 0.0$
Ceiba pentandra	$14.3^{a} \pm 0.1$	$22.3^{a} \pm 0.0$	$14.3^{a} \pm 0.5$	$18.0^{a} \pm 0.0$	$14.0^{a} \pm 0.0$	$20.3^{a} \pm 0.0$
Terminalia superba	$17.0^{ab} \pm 0.0$	$25.0^{bc} \pm 0.0$	$17.6^{b} \pm 0.4$	$23.0^{c} \pm 0.0$	$15.0^{a} \pm 0.0$	$21.3^{b} \pm 0.1$
Terminalia ivorensis	$15.0^{a} \pm 0.0$	$22.0^{a} \pm 0.1$	$16.0^{b} \pm 0.0$	$23.7^{c} \pm 1.1$	$14.3^{a} \pm 0.2$	$22.0^{b} \pm 0.2$
Mangifera indica	$24.0^{d} \pm 0.0$	PNS	$25.0^{d} \pm 0.0$	PNS	$23.3^{e} \pm 0.7$	PNS
Ficus mucuso	$16.7^{ab} \pm 0.5$	$25.0^{bc} \pm 0.0$	$16.0^{b} \pm 0.0$	$21.3^{b} \pm 0.4$	$18.0^{bc} \pm 0.0$	$23.3^{c} \pm 0.5$
Triplochiton scleroxylon	$18.3^{b} \pm 0.0$	$24.0^{b} \pm 0.0$	$17.0^{b} \pm 0.3$	$22.3^{b} \pm 0.1$	$17.0^{b} \pm 0.0$	$21.7^{b} \pm 0.0$
Heisteria parvifolia	$18.0^{b} \pm 0.2$	$24.0^{b} \pm 0.4$	$17.3^{b} \pm 0.1$	$23.0^{bc} \pm 0.6$	$20.0^{cd} \pm 0.0$	$24.0^{c} \pm 0.0$
Ricinodendron heudelotii	$25.0^{d} \pm 0.0$	PNS	$24.0^{d} \pm 0.0$	PNS	$21.0^{d} \pm 0.0$	$24.0^{c} \pm 0.0$
Persea americana	$16.0^{ab} \pm 0.8$	$23.3^{ab} \pm 0.0$	$15.3^{a} \pm 0.4$	$21.0^{b} \pm 0.0$	$16.0^{b} \pm 0.3$	$22.0^{b} \pm 0.0$

PNS: Primordium not seen.

This is in line with the findings by Girmay et al. (2016) and Li et al. (2017). These researchers indicated 14.0 to 40.67 days for mycelial growth, fungal colonisation on substrates, primordial formation and harvesting of *Pleurotus* spp.

cultivated on cotton seed, paper waste, wheat straw, sawdust and perilla stalks. The disparity observed in the growth rate of *Pleurotus* species may not only be based on substrate composition but also on the physiological requirements for the cultivation of mushrooms. This fact was supported by the findings of Akinyele et al. (2012), who highlighted some important biofactors such as temperature, pH, presence of inhibitory agents and sterilisation technique, which adversely affected the growth of *P. ostreatus*.

Yield and biological efficiency of *Pleurotus* species

The total yields of *Pleurotus* spp. cultivated on wood dusts are shown in Fig. 1. The highest yield of 46.97 g was obtained for *P. ostreatus* cultivated on *Terminalia ivorensis*, which is significantly different ($P < 0.05$) from the yields of *P. pulmonarius* harvested from *T. ivorensis* (40.84 g) and *Gossypium hirsutum* (40.46 g), and from *P. "florida"* harvested from *Ceiba pentandra* (39.42 g).

The highest biological efficiencies (48.83% and 48.40%, respectively) were obtained for *P. ostreatus* cultivated on *T. ivorensis* and *Triplochiton scleroxylon*. This was significantly different from *P. pulmonarius* and *P. "florida"*, which have a maximum BE of 43.54% and 43.09%, respectively (Tab. 3).

Tab. 3. Biological efficiency (%) of *Pleurotus* mushrooms obtained from different wood dusts. Values are mean ± SD of triplicates (n = 3); means with different superscripts in a column (letter) and within a row (number) are significantly different ($P < 0.05$) according to Duncan's new multiple range test.

Substrates	*Pleurotus pulmonarius*	*Pleurotus "florida"*	*Pleurotus ostreatus*
Gossypium hirsutum	$42.28^{f,2} \pm 2.00$	$25.08^{d,1} \pm 1.05$	$44.30^{e,2} \pm 1.30$
Alstonia congensis	$20.21^{b,1} \pm 2.00$	$20.02^{c,1} \pm 1.50$	$31.40^{c,2} \pm 1.10$
Spondias mombin	$24.26^{c,1} \pm 0.10$	$33.38^{e,2} \pm 1.30$	$39.10^{d,3} \pm 0.70$
Ceiba pentandra	$38.08^{e,1} \pm 1.47$	$43.09^{f,2} \pm 2.50$	$41.30^{d,3} \pm 1.10$
Terminalia superba	$20.70^{b,12} \pm 1.06$	$17.54^{c,1} \pm 1.70$	$27.29^{c,3} \pm 1.50$
Terminalia ivorensis	$43.54^{f,2} \pm 1.50$	$36.10^{e,1} \pm 1.40$	$48.83^{f,3} \pm 0.60$
Mangifera indica	0.00^{a}	0.00^{a}	0.00^{a}
Ficus mucuso	$28.14^{cd,2} \pm 1.30$	$14.19^{b,1} \pm 0.90$	$38.54^{d,3} \pm 1.40$
Triplochiton scleroxylon	$20.19^{b,1} \pm 0.80$	$19.12^{c,1} \pm 1.90$	$48.40^{f,2} \pm 1.90$
Heisteria parvifolia	$40.14^{e,23} \pm 2.20$	$34.10^{e,1} \pm 0.40$	$37.30^{d,2} \pm 1.10$
Ricinodendron heudelotii	$0.00^{a,1}$	$0.00^{a,1}$	$16.30^{b,2} \pm 0.30$
Persea americana	$38.75^{e,2} \pm 1.50$	$15.06^{b,1} \pm 1.60$	$15.01^{b,1} \pm 0.70$

Yang et al. (2013) reported a BE of 44.3–125.6% for oyster mushroom cultivated on rice or wheat straw basal substrate supplemented with cotton seed hull. From the literature, the BEs of cultivated mushrooms always differ between

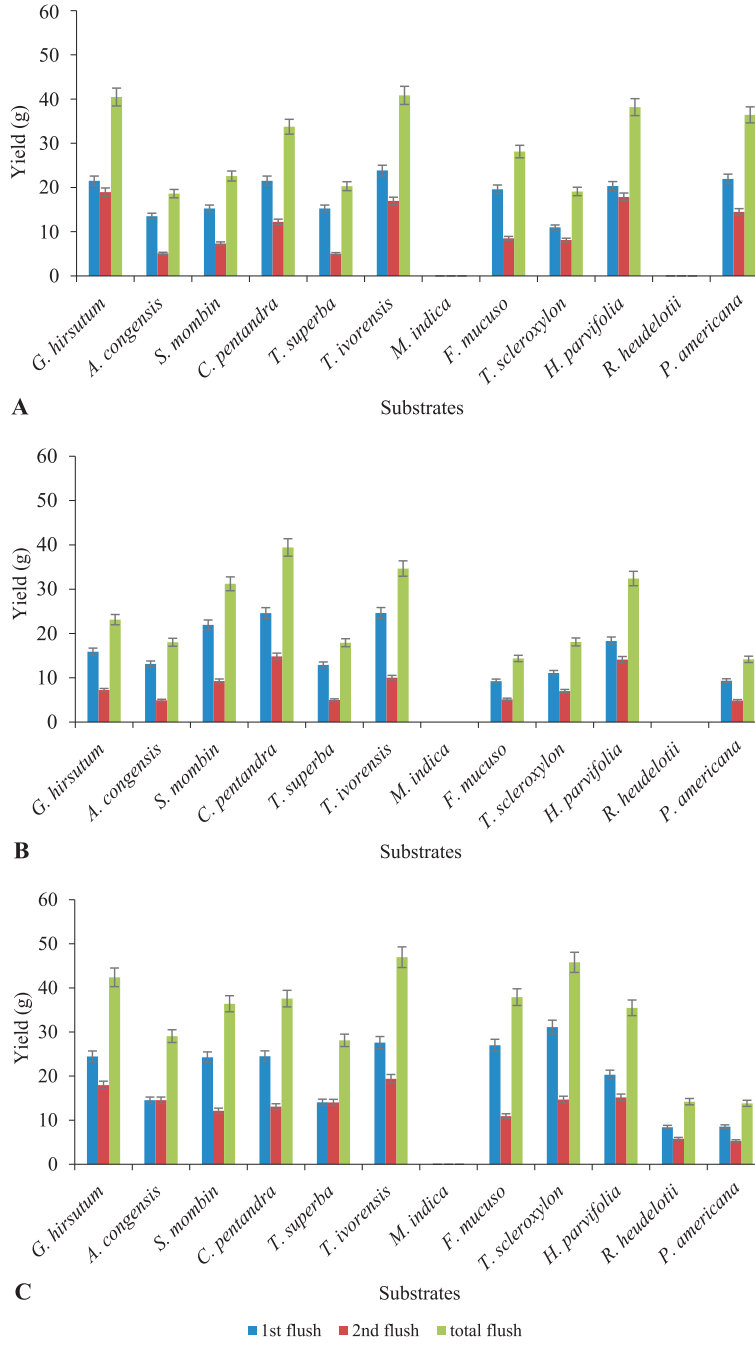

Fig. 1. Yield performance of cultivated (A) *Pleurotus pulmonarius*, (B) *P. "florida"*, and (C) *P. ostreatus* on different wood dusts. The error bars represent standard deviation.

fungal species, type or size of substrate used, supplementation of substrates and other varying growth factors. Hoa et al. (2015) associated the variability of BE to the differences observed in the physical and chemical compositions of the substrate, which include cellulose/lignin ratio, mineral contents, pH, electrolyte conductivity (EC) of the substrate and ratio of carbon to nitrogen (C : N).

In this study, the yield and biological efficiency did not correspond with the rate of colonisation and primordial initiation. The findings by Obodai et al. (2003) and Liang et al. (2005) revealed that the fastest mycelial growth may not correspond to the time of primordial formation, harvesting periods, mushroom size and yield, thus indicating that mycelial growth, primordial emergence and fructification require different nutrients. The variability of nutrient contents in cultivated mushrooms may be based on species and substrate composition. Narain et al. (2009) reported that nutrient contents are dependent on the C : N ratio in lignocellulosic materials.

Proximate analysis of produced mushrooms

The proximate composition of harvested *Pleurotus pulmonarius*, *P. "florida"* and *P. ostreatus* on wood dust, as shown in Fig. 2, significantly differs ($P < 0.05$), particularly between tree species. The study by Maftoun et al. (2015) revealed that the proximate composition of *Pleurotus* species is highly variable according to mushroom species and the substrate used.

The moisture contents of *P. pulmonarius*, *P. "florida"* and *P. ostreatus* cultivated on different woody dusts are similar: their values ranged from 4.05 to 4.70%, 4.16 to 4.91% and 4.04 to 4.68%, respectively. The fat contents of cultivated *P. pulmonarius*, *P. "florida"* and *P. ostreatus* were 1.84 to 3.56 %, 1.04 to 3.96% and 1.29 to 3.23 %, respectively. The finding by Valverde et al. (2015) revealed low fat contents in some edible mushrooms (1.0–4.3% of dry weight).

Pleurotus ostreatus harvested from *Terminalia ivorensis* had the highest protein content with a value of 30.09% followed by *Gossypium hirsutum* (29.92%) and *Spondias mombin* (29.50%), while *Persea americana* had the lowest value of 16.72%. *Pleurotus pulmonarius* harvested from *G. hirsutum* and *Triplochiton scleroxylon* had the highest protein content of 29.07%, whereas the lowest value of 12.53% was obtained for *P. pulmonarius* harvested from *Persea americana*. *Pleurotus "florida"* harvested from *T. ivorensis* had a protein content of 29.72% followed by *Ceiba pentandra* (29.58%), *G. hirsutum* (29.07%) and *S. mombin* (28.85%). The protein contents (12.53 to 30.09%) in cultivated mushrooms are in line with the findings by Cheung (2010), who revealed protein contents in oyster mushroom as 10.5–30.4%.

There were significant differences in ash content; 7.90 to 12.80%, 6.96 to 13.98% and 7.20 to 12.77% of cultivated *Pleurotus pulmonarius*, *P. "florida"* and

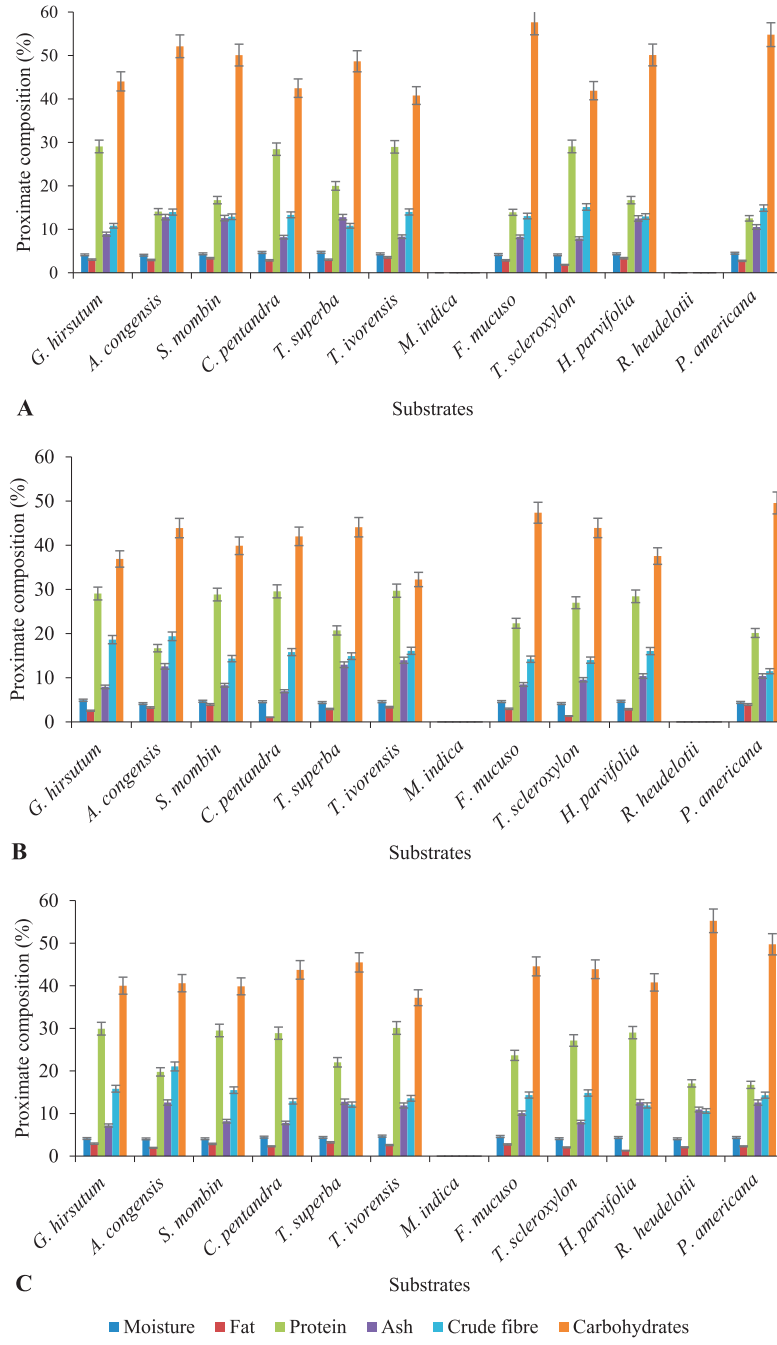

Fig. 2. Proximate composition (dry weight basis %) of harvested fruitbodies of (A) *Pleurotus pulmonarius*, (B) *P. "florida"*, and (C) *P. ostreatus* from different wood dusts. The error bars represent standard deviation.

P. ostreatus, respectively, on different substrates. *Pleurotus ostreatus* harvested from *Alstonia congensis* had a crude fibre content of 21.06%, which was not significantly different from that of *P. "florida"* harvested from *A. congensis* (19.40%). In the current study, the cultivated mushrooms contained 10 to 21% of crude fibre. Findings by Cheung (2013) also revealed crude fibre contents (1.4 to 44.0%) in some edible mushrooms commonly used as food and medicine. Hence, mushrooms contain dietary fibre, which benefits human health.

The carbohydrate contents of the harvested mushrooms ranged from 40.80 to 57.66%, 32.26 to 49.58% and 37.19 to 55.25% for *P. pulmonarius*, *P. "florida"* and *P. ostreatus*, respectively. The carbohydrate content reported for *P. ostreatus*, *P. sajor-caju*, *P. "florida"*, *P. cystidiosus*, *P. geesterani*, *P. eryngii*, *P. tuber-regium* and *P. flabellatus* ranged from 36 to 60% (Khan & Tania 2012). These researchers attributed the carbohydrate contents to the presence of polysaccharides and glycoproteins in mushrooms.

The findings by Papaspyridia et al. (2011) revealed nutritional qualities of some edible mushrooms and their potential applications in food and pharmaceutical industries. A variety of branded products from oyster mushrooms have been created and marketed as nutraceuticals. Hence, *Pleurotus* mushrooms have some economic uses, ecological values and medicinal properties.

Conclusion

Terminalia ivorensis and *Triplochiton scleroxylon* supported the cultivation of *Pleurotus ostreatus* with the highest yield. *Terminalia ivorensis* and *Gossypium hirsutum* were the most suitable for the cultivation of *P. pulmonarius*, while *P. "florida"* grows better on *Ceiba pentandra*. Supplementation of substrate, especially *Mangifera indica* with wheat bran, rice bran or straw, will boost the mushroom yield.

Cultivation of *Pleurotus* species on wood dusts which have not been chemically treated are safe and eliminate the need to burn wood wastes. Moreover, the cultivation of mushrooms on generated wood dusts, which are environmentally challenging in developing countries, can produce edible mushrooms and reduce environmental pollution. Hence, utilisation of wood dusts for the cultivation of *Pleurotus* species will produce healthy foods which can be added to foods of low nutrients to achieve high nutraceutical potentials.

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