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Growth and yield of *Hypsizygus ulmarius* (bull.) Redhead, on some selected organic wastes

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Hysizygus ulmarius **is an edible fungus cultivated as a source of alternative protein using different agricultural waste thereby playing a significant role in waste management. The aim of this study was to investigate the growth and yield performance of *Hypsizygus ulmarius* (Bull.) REDHEAD on organic wastes. *H. ulmarius* stock was collected from Mushroom Institute while the five waste; sawdust (SD), oil palm fibre (OPF) rice bran (RB), corn husks (CH) and banana leaves (BL) were collected from a saw mill and a farm, all in Osun State, Nigeria. The inoculated substrate bags were laid out in completely randomized design. Seven treatments namely; sawdust (SD), rice bran (RB), corn husks (CH), oil palm fibre (OPF), sawdust + rice bran (SDRB), banana leaves (BL), oil palm fibre + Rice bran (OPFRB) were assessed. Spawn running, pin head formation, cap size, mushroom growth and weight of sun-dried harvested mushrooms were measured daily. SD and CH recorded the longest period (22 days) for spawn run, followed by OPFRB (19 days) while the least was obtained in SDRB (18 days). Data obtained were subjected to Analysis of Variance and Duncan Multiple Range Test. Number of days for pin head formation differed significantly and varied between 5 to 10 days. BL recorded the highest yield (600 g/kg), which was closely followed by SDRB (590 g/kg) while rice bran had the least yield of 130 g/kg. It was also revealed that the BL recorded significantly the maximum biological efficiency (75.00%) while other substrates were at par with SDRB (73.75%). The minimum biological efficiency was recorded in RB only (16.25%). The implications of these findings were discussed.**

Keywords: *H. ulmarius*, Substrates, Rice bran, Mushroom, Spawn.

INTRODUCTION

Hypsizygus ulmarius, commonly known as the Redhead Mushroom, is a species of edible fungi belonging to the family Lyophyllaceae (Ismail *et al*., 2018). It is classified as a saprotrophic fungus that plays a crucial role in decomposing organic matter and recycling nutrients in the ecosystem (Chang and Wasser, 2017).

Mushrooms have not only served as food source for man and other animals in nature they are also involved in the cycling of carbon and other elements through the degradation of lignocellulosic plant residues and animals' dung which formed their substrates (Nagy et al., 2015; Jonathan et al.,2024a). In this way, the fungi as agents of decay prevent the environment from being overwhelmed with the dead organic matter of plants and animals (Jonathan, 2019).

The agricultural and food industries generate substantial amounts of solid waste, including residues and by-products, primarily composed of lignocellulosic biomass (Jonathan et al., 2008). This organic matter can contribute to environmental pollution if not managed properly. However,

Abbreviations: OPF (oil palm fibre), CH (Corn husks), SDRB (saw dust + rice bran), BL (banana leaves), SD (saw dust), OPFRB (oil palm fibre + rice bran), RB (rice bran), SEM (Standard error of mean).

Plate 1. Spawn of *Hypsizygus ulmarius*.

certain mushroom-forming fungi have the ability to break-down these waste materials, utilizing their robust growth and enzyme secretion capabilities to decompose organic matter, making them a valuable tool for reducing environmental pollution (Floudas *et al*., 2015; Jonathan *et al*., 2024b).

In recent years, the use of organic wastes as substrates for the cultivation of *H. ulmarius*, has been explored with promising results. Several species of mushroom such as *Pleurotus ostreatus*, *Calocybe indica*, *Auricularia auricular, Lentinus squarrosulus*, *Pleurotus tuberregium* and *Volvariella volvacea* are edible and successfully cultivated in Nigeria on small-scale basis (Adeleke *et al*., 2020).

In Nigeria, where agricultural waste management poses significant challenges, adopting organic waste-based *H. ulmarius* cultivation can contribute to sustainable waste management practices, provide an alternative income source for rural communities, enhance food security, and support the growth of a sustainable economy (Oluwade *et al.,* 2019). Generally speaking, various agro–industrial wastes have been used for different mushroom cultivation because they contained the required nutrients that are supportive to the growth of both micro and macro fungi (Jonathan *et al.,* 2013a). Therefore, the present study was carried out to evaluate the growth yield of *Hypsizygus ulmarius* on different agro industrial wastes.

MATERIALS AND METHODS

Collection of samples

Stock culture of *Hypsizygus ulmarius* used for the experiment was obtained in November 2022 from Olaitan Mushroom Institute Oshogbo, Osun, Nigeria. Fresh hardwood sawdust of mahogany (*Khaya ivorensis*) and *Gmelina aborea* were collected from a local sawmill in Ilesha, Osun, Nigeria while the oil palm fruit fibre (OPFF), Rice bran (RB), Banana Leaves (BL) and Corn husks (CH) were obtained from a local farm in Erin Ijesa, Osun, Nigeria.

Spawn preparation

The spawn was prepared using *Triticum aestivum* (wheat seed) as substrate. A modified method of Thakur and Rathod (2022) was adopted for spawn preparation. Healthy and fresh wheat seeds were selected, washed 3 times and further decanted to get rid of excess water. The wheat seeds were boiled for 25 min. This is to make the substrate soft afterwards, the wheat seeds were allowed to air dry under shade for 2 h. Calcium carbonate (lime) (1.5%) and gypsum ($CaSO_4.2H_2O$) (0.5%) were carefully mixed into the air-dried wheat seeds. To create a suitable environment for the growth of *Hypsizygus ulmarius*, lime was added to maintain a near-neutral to alkaline pH range, which inhibited the growth of acid-favoring fungi. Gypsum was also added to facilitate seed separation during inoculation. The substrate preparation involved filling empty jars with parboiled wheat seeds, covering them with cotton wool, and autoclaving them at 121°C and pressure of 1.02 $kgcm^2$ for 20 min. After cooling, the jars were inoculated with a pure culture of *H. ulmarius* under sterile conditions. The inoculated seeds were then incubated at 20°C for 8 days, allowing for full colonization (Plate 1). Once colonized, the seeds were stored in a refrigerator at 2°C until needed (Jonathan *et al.,* 2013b).

Substrates preparation

A modified method of Aditya and Jarial (2022) was adopted for substrate preparation. The fresh OPFF was soaked in distilled water overnight in order to wash out the remaining oil in the fibre and air dried to eliminate excess water. The saw dusts were mixed with rice bran in the ratio 70:30 and 1% calcium carbonate was added to the mixture to control the pH level. The moisture content of the Sawdust and Rice bran were adjusted by sprinkling sterilized water. The dried Banana leaves and Corn husks were cut into chunks, washed and allowed to retain moisture. 1200 g of selected substrates were each filled into ten (10) high porosity polypropylene plastic bags measuring 17.5 x 15 cm each. Each substrate bag was fitted with a 5 cm wide and 3 cm long polyvinyl chloride pipe at the top, and the mouth of the bag was sealed with paper foil, secured with rubber bands. The bags were then placed in a clean drum and subjected to pasteurization through local heating for a duration of 8 h (Jonathan *et al.,* 2013b).

Inoculation and incubation

After pasteurization, the bags were allowed to cool to room temperature. They were then randomly selected and inoculated with 60 g of spawn per 1200 g of substrate under sterile conditions. The inoculated bags were subsequently incubated in a dark room at ambient temperature, allowing for the growth of the mycelium.

Fruiting body induction and harvesting

Once primordia had formed, the bags were transferred to a growing room to facilitate further development. To induce fruiting body formation, the bags were subjected to increased ventilation, misting with water, and small cuts were made on the sides of the bags. The fruiting bags were then maintained in a humid environment, with daily spraying of sterile water using a hand sprinkler and a water reservoir on the floor to regulate humidity. The room was illuminated on a 12-h light-dark cycle. The mature fruit bodies were harvested 3-4 days after the emergence of primordia, when the gills were fully exposed, marking the optimal time for collection (Jonathan *et al.,* 2013a).

Plate 2. Substrates bags ready for pasteurization.

Plate 3. Local pasteurization.

Plate 4a. Incubated substrate bags.

Determination of mushroom yield and biological efficiency

Data collection focused on several key parameters, including the average time required for complete mycelial colonization of the substrates, which was approximately 34 days. Additional data points included the time needed for mushroom primordial initiation, as well as various measurements related to fruit body yields, such as stipe height, pileus diameter, and fresh weight. Biological efficiency (BE) was also calculated, defined as the ratio of fresh mushroom harvest (in grams) to dry substrate weight (in grams), is expressed as a percentage (Onyeka *et al.,* 2018). To determine dry weight, harvested mushrooms were laid out on a tray and sundried for 8 h. The weights of the mushroom fruit bodies were measured using an electronic kitchen scale (Model SF-400) with a capacity of 10,000 g and a precision of 1g (Jonathan, 2009).

Plate 4b. Vegetative mycelia growth.

Statistical Analysis

The data obtained were subjected to analysis of variance (ANOVA) using SPSS version 26 and test of significance were separated using Duncans Multiple Range Test (DMRT).

RESULTS

Spawn preparation

Fully ramified spawn of *Hypsizygus ulmarius* ready for inoculation into the various agricultural wastes (Plate 1).

Substrates preparation

Prepared substrates and the local pasteurization are as shown in Plates 2 and 3

Inoculation and Incubation

The inoculated substrates bags kept in a dark room for incubation getting ramified with *H. ulamarius* is shown in plates 4a and 4b.

Fruit bodies induction, maturity and harvesting

The growth of *H. ulmarius* mycelium, fruit bodies induction and maturity are shown in Plates 5-11 while the freshly harvested and dried matured *H. ulamarius* are presented in Plates 12a-12b.

Plate 5a. Fruiting bodies induction on BL

Plate 5b. Matured fruit bodies BL.

Plate 6. Matured fruit bodies on SDRB.

Plate 7. Matured fruit bodies on RB.

Plate 8. Matured fruit bodies on OPF.

Effect of substrate media on mycelia running, pin head formation and cropping period of *Hypsizygus ulmarius*

The study revealed that the media used as substrates had an impact on several aspects of mushroom growth. These included the duration of mycelium running, the formation of pinheads, the number of fruit bodies produced, the cropping time and the size of the cap (pileus diameter). It was also, observed that mycelium running occurred within a span of 17 to 22 days following inoculation (Table 1).

Plate 9. Matured fruit bodies on CH.

Plate 10. Matured fruit bodies on OPFRB.

Plate 11. Matured fruit bodies on SD.

Plate 12a. Freshly harvested *H. ulmarius***.**

Plate 12b. Sundried *H. ulmarius.*

Effect of substrate media on biological efficiency, number of fruiting bodies and cap size of *Hypsizygus ulmarius*

It was observed that the average total fruiting bodies was highest (200) at BL substrate and lowest (43.33) at RB substrate. The range of biological efficiency for all the substrates was from 75.00% at BL to 16.25% at RB. Among the substrates, BL recorded the highest values in all the parameters while RB recorded the lowest values across the parameters examined (Table 2).

Effect of substrate type on yield of *Hypsizygus ulmarius*

Results obtained from the seven substrates as presented in Figure 1, showed that Banana Leaves (BL) had the

Table 1. Effect of Substrate Media on each of the growth parameters.

Substrate	Parameters (in Days)			
	Mycelia running	Pinhead formation	Pin head to harvest	Cropping duration
SD	22	8	4	34
BL	17	7	3	27
OPF	19	5	4	28
SDRB	18	6	5	29
CH	22	10	5	37
OPFRB	19	9	4	32
RB	17	8	3	28
Mean	19 ± 0.80	7 ± 0.65	4 ± 0.31	31 ± 1.41

Key: SD = Sawdust, BL = Banana leaves, OPF = Oil palm fibre, SDRB = Sawdust + Rice bran + $CaCO_3$, OPFRB = Oil palm fibre + rice bran + $CaCO_3$, and RB = Rice bran. The Mean values consist of Mean and Standard Error of Mean (SEM).

Table 2: Effect of Different Substrate Media on the Biological Efficiency, Number of Fruit Bodies and Cap Diameter (Size) of *Hypsizgus ulmarius*.

Substrate	Average Number of Fruit Bodies per Flush (g/kg)	Biological Efficiency (%)	Cap Diameter (cm)	SEM
SD	130.00 (8.33)	48.75	8	±32.15
BL	200.00 (10.67)	75.00	14	±46.19
OPF	73.33 (3.67)	27.50	11	±31.80
SDRB	196.67 (9.00)	73.75	12	±32.83
CH	90.00 (4.33)	33.75	10	±24.66
OPFRB	86.67(4.00)	32.50	8	±34.80
RB	43.33(2.00)	16.25	5	±20.28

Three flushes were conducted for each substrate and their average mean values were calculated.

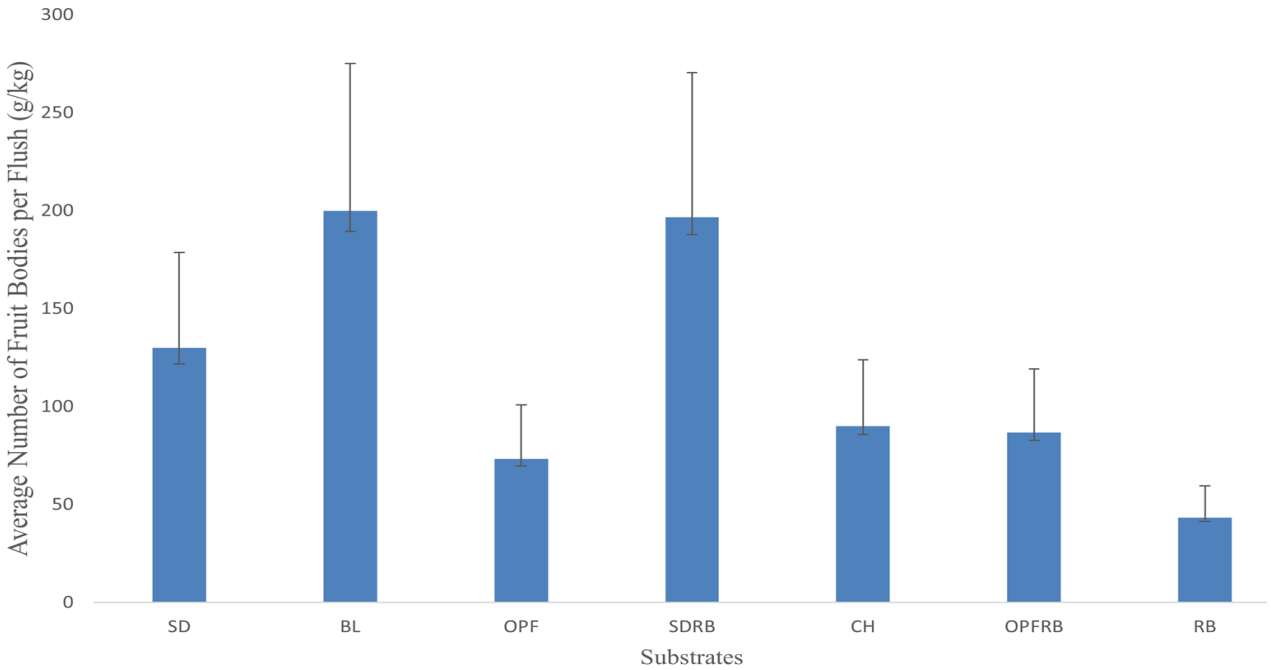

Figure 1. Effect of substrates type on yield of *Hypsizgus ulmarius*.

highest average number of fruit bodies per flush (200 g/kg) and a relatively large cap size (14 cm), indicating its suitability for producing more fruit bodies. It also shows a high biological efficiency (75%), making it an effective substrate for mushroom cultivation. Sawdust and Rice Bran Mix (SDRB) followed closely, with an average of 196.67 g/kg and a high biological efficiency of 73.75%. This substrate also supported a large number of fruit bodies, making it an efficient choice. Sawdust (SD) had a moderate average number of fruit bodies (130 g/kg) and a biological efficiency of 48.75%. Although its efficiency was not as high as BL and SDRB, it still produced a significant number of fruit bodies. More so, Coconut Husk (CH) and Oil Palm Fronds and Rice Bran (OPFRB) were moderate performers, with averages of 90 g/kg and 86.67 g/kg, respectively.

In addition, Oil Palm Fronds (OPF) had a lower average number of fruit bodies (73.33 g/kg) and a biological efficiency of 27.50%. Despite a cap diameter of 11 cm, it was less efficient compared to the other substrates. Rice Bran (RB) showed the poorest performance with the lowest average number of fruit bodies (43.33 g/kg) and the smallest cap diameter (5 cm). Its biological efficiency is also the lowest (16.25%), making it the least suitable substrate for producing fruit bodies (Figure 1).

DISCUSSION

The study investigated the growth and yield performance of *Hypsizygus ulmarius* on five organic wastes: sawdust (SD), oil palm fiber (OPF), rice bran (RB), corn husks (CH), and banana leaves (BL) using seven treatments.

This study showed significant variations in mycelium running, pinhead formation, fruiting body yield, and biomlogical efficiency among the substrates; sawdust (SD), oil palm fiber (OPF), rice bran (RB), corn husks (CH), and banana leaves (BL) used in the cultivation of *H. ulamarius.* From the study, it was demonstrated that these agricultural wastes can be used effectively for cultivation of elm oyster mushroom. These findings agree with the reports of - independently reported that mushrooms can be cultivated on a variety of locally sourced organic substrates.

Additionally, the results also align with the findings of Aliero *et al*., (2016), which highlighted the significance of both the type of waste material and the fungal strain used in influencing colonization rates, as well as the time required for complete colonization and mushroom fructification.

In the present study, completion of spawn run took 17 days for banana leaves and rice bran, 18 days in saw dust supplemented with rice bran 19 days in oil palm fibre mixed with rice bran and 22 days (maximum) in sawdust and corn husk which agrees with the findings of Khade *et al*., (2019) who reported that the spawn run in rice and corn husk inoculated with *H. ulmarius* was completed in 17 to 18 days. It is also supported by Onyeka *et al*., (2018) who also reported that the spawn run in saw dust inoculated with *P. ostreatus* was completed in 14 to 22 days after spawning. The number of days observed for pin head formation that varied between 5 to 10 days is similar to the findings of Jonathan *et al.* (2013) and that of Onyeka *et al*. (2018) who reported that the pin head formation varied between 6 to 10 days after spawning in *P. ostreatus* grown on saw dust, corn wastes, and banana leaves.

The 3 to 5 days range obtained for the first, second and third harvest from pin head formation in the substrates is close to the 3 to 6 days reported by Onyeka *et al*. (2018) required for harvesting from pin head formation.

In the present study, the result showed that the number of fruiting bodies per bags (Table 2) varied from 6 to 32 due to different treatments. Banana leaves produced significantly higher number of fruit bodies (32) per bags, followed by saw dust supplemented with rice bran (27) and saw dust only (25). The minimum number of fruit bodies were found in rice bran only (6), oil palm fibre only (11), oil palm fibre supplemented with rice bran (12) and corn husks (13).

A significant variation in average fruit body weight (130 to 600 g per fruit) were observed due to several treatments and supplementation (Figure 1). This complies with Onyeka *et al*., (2018) who reported the average fruit body weight of *P. ostreatus* ranges from 120 to 580 g, whereas, Kumar *et al*. (2019) also observed in his study that *H. ulmarius* recorded average fruit body weight from 247 to 589 g.

The observations on yield performance (Figure 1) reveals that Banana leaves recorded the highest yield (600 g/kg), which was closely followed by SDRB which recorded 590 g/kg while Rice bran provided the least yield of 130 g/kg. It was also revealed that the banana leaves recorded significantly maximum biological efficiency (75.00%) over rest of the treatments which was found to be at par with treatment SDRB (73.75%). The minimum biological efficiency was recorded in RB only (16.25%). Banana leaves with wheat bran additives, irrespective of their percentage concentration, had better yield and biological efficiency as reported by Jonathan *et al. (*2013a).

The variability in mushroom performance across different waste materials may be attributed to differences in their nutrient content and lignocellulose composition. This is supported by the study of Jonathan *et al.* (2024a), which demonstrated that the nutrient levels in substrates play a crucial role in determining the yield and quality of mushroom crops.

Furthermore, fluctuations in temperature and the accumulation of carbon dioxide in the mushroom house during the growth cycle may have also contributed to the observed differences in mushroom quality, as the environmental conditions in the room were not optimally controlled.

Conclusion

This study revealed the potential of using organic wastes

as substrates for cultivating *H. ulmarius*. Banana leaves and SDRB that were highly efficient in growing *Hypsizygus ulmarius*, producing a high number of fruit bodies with large caps and high biological efficiency showed promising results, indicating their suitability for large scale mushroom production. Rice bran on the other hand may require additional nutrients or adjustments to support optimal growth.

As a substrate, banana leaves offer a sustainable and eco-friendly option, as they are readily available, biodegradable, and non- polluting. Their high yield and biological efficiency can make them an ideal choice for small scale mushroom production. Banana leaves should also be used as an enhancer to boost mushroom growth by mixing them with other substrates, potentially improving overall yield and quality. These substrates could be prioritized by mushroom growers to maximize yield and profitability.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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