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Optimising oyster mushroom (*Pleurotus ostreatus*) cultivation in West Africa: Soybean straw as a promising substrate

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Abstract: Mushroom cultivation has been proposed to valorise several types of lignocellulosic substrates. Soybean straw as the main dish for mushroom cultivation has not really been tried in West Africa, yet soybean cultivation has become very important in this area. The present study evaluates the performance of soybean straw in mushroom cultivation in Benin. We tested the cultivation of *Pleurotus ostreatus* on three different substrates, including rice straw, sawdust and soybean straw. Different water contents of the substrates were tested to identify the best for good biological efficiency. We evaluated the performance of a growing substrate by measuring the days required for complete colonisation, the time until primordia appeared, and the number of fruiting bodies per bag. Using a negative binomial regression model, we assessed the interactive effects of substrate type, moisture content, and their additive effects. To determine significance, we conducted Kruskal's multiple comparison test to rank the means. This study showed that soybean straw was the substrate with the fastest mycelial colonisation (13 days) compared to rice straw or sawdust (2–3 weeks). Similarly, the highest yields were obtained on soybean straw (452.5 g/kg), followed by rice straw (367.8 g/kg) and sawdust (275.2 g/kg). Regarding water content, it was found that 60% was more favourable than 50% for both rapid colonisation of the substrates and a good yield, and the higher the water content, the better the yield. Due to its high biological efficiency, soybean straw has proved to be an excellent substrate for mushroom cultivation.

Keywords: biologic efficiency; lignocellulosic; lignocellulosic substrates; water content; colonisation

Mushrooms are organisms that play a critical role in ecosystems and human industries through multifunction. Ecologically, they are primary decomposers, breaking down complex organic matter and recycling nutrients essential for sustaining life (Chang, Miles 2004; Bani et al. 2018). Their ability to degrade lignocellulosic materials qualifies them as a sustainable tool for bioremediation and waste management (Adebayo, Martinez-Carrera 2015; El-Ramady et al. 2022; Navina et al. 2024). Economically, edible mushrooms hold immense potential to address food insecurity and provide income, particularly in developing regions. Their nutritional richness, proteins, vitamins, and minerals make mushroom cultivation an effective strategy to mitigate malnutrition (Barros et al. 2008; Thakur 2020, Assemie, Abaya 2022; Effiong et al. 2024). They can be used as food supplements

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to improve and address some diseases (Kakon et al. 2012). Beyond nutrition, mushrooms also have medicinal properties, such as immunomodulatory and antioxidant effects, making them valuable for human health (Gregori et al. 2007; Kebaili 2022). Given these benefits, mushroom cultivation is gaining traction to address global challenges (Higgins et al. 2017; Raut 2019).

Mushroom cultivation offers a sustainable strategy for waste recycling and income generation, especially in developing regions. By integrating into agricultural systems, it enhances food security with a nutritious, protein-rich food source (Beetz, Greer 2004; Oei, Nieuwenhuijzen 2005; Rahman, Imtiaj 2008; González et al. 2021). Additionally, the biodegradation of lignocellulosic waste by mushrooms accelerates decomposition, creating nutrient-rich compost that improves soil fertility and supports sustainable farming practices (Rose et al. 2022). This dual role in nutrient recycling and food production is vital for regions facing environmental and economic challenges. However, maximising yields requires careful control of environmental factors like temperature, humidity, light, and substrate quality to reduce contamination risks (Sánchez 2010).

The substrate is one of the most critical factors in mushroom cultivation, as it serves as the primary nutrient source for mycelial growth and fruiting (Zhang et al. 2002). According to Bellettini et al. (2019), mushroom cultivation substrates have chemical, functional and sensory effects on fruiting bodies. A high-performance substrate must meet several criteria, such as being rich in organic matter, retaining adequate moisture, providing good aeration, and resisting contamination by pathogens (Royse et al. 2017). Effective substrates are characterised by their richness in carbon and nitrogen, high water retention capacity, and adequate porosity to ensure oxygen exchange (Fanadzo et al. 2010). Furthermore, the substrate's biodegradability and availability influence its environmental impact and cost-effectiveness in production systems (Royse et al. 2004). The diversity of substrates in mushroom cultivation is enormous, encompassing agricultural and industrial residues. Agricultural residues such as wheat straw, sugarcane bagasse, maize stalks, rice straw, coffee and cotton waste can serve as excellent substrates for mushroom cultivation, yielding high-quality mushrooms while simultaneously addressing waste disposal issues (Magingo 1998; Obodai et al. 2003; Mamiro, Mamiro 2011; Khan et al. 2012; Adjapong et al. 2015; Tarko, Sirna 2018; Thuc et al. 2020). For mushroom cultivation, various other substrates are used, such as sawdust, sisal waste, dried pods, grass straw, corn cobs, banana leaves, peanuts, coffee husks, coconut waste, bean straw, cotton waste, barley straw, sesame stems, teff straw, sorghum stubble, and palm fronds (Mansour-Benamar et al. 2013; Pitta et al. 2020; Boukary et al. 2024). However, the composition of the substrate, including its lignin-to-cellulose ratio and mineral content, significantly impacts mushroom growth and yield (Philippoussis et al. 2001; Hoa et al. 2015). The choice of substrate often depends on its cost and suitability, driving research to explore abundant and low-cost agricultural residues as alternatives (Beetz, Greer 2004; Besufekad et al. 2020). Thus, research into locally available agricultural by-products is critical for identifying cost-effective and sustainable substrates suitable for different regions.

In West Africa, mushroom cultivation remains underdeveloped but has seen growing interest due to its potential to improve livelihoods and valorise agricultural waste (Akinyele, Adetuyi, 2005). Traditionally, substrates such as sawdust, rice straw, and corn cobs have been used, but their performance varies depending on the pretreatment and composition (Obodai et al. 2003, 2011; Adenipekun, Omolaso 2015). Additionally, the region faces challenges such as limited technical knowledge, inadequate infrastructure, and inconsistent substrate quality, which hinder large-scale adoption of mushroom farming (Koutrotsios et al. 2014). The Beninese government has recently introduced policies to promote organic soybean production, driven by its economic value and environmental benefits (FAO 2021). This shift creates an opportunity to use soybean harvest residues, such as straw, as substrates for mushroom cultivation. Soybean straw, abundant and rich in cellulose, hemicellulose, and lignin, can enhance mushrooms' growth, yield, and nutritional quality (Sarker et al. 2007). Furthermore, using soybean straw aligns with sustainable agriculture practices by reducing waste, improving soil health, and contributing to a circular economy (Zhang et al. 2014). This waste can be used as the main ingredient for substrate formulation in mushroom cultivation in West Africa.

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This study aims to evaluate the performance of soybean straw as a substrate for oyster mushroom cultivation and other local species, comparing it with commonly used substrates such as sawdust and rice straw. The central hypothesis is that soybean straw may match or exceed traditional substrates in yield, quality, and sustainability due to its local abundance. The findings of this research could pave the way for the broader use of soybean residues in mushroom production, contributing to food security and sustainable agricultural practices.

MATERIAL AND METHODS

Strain origin. The strain of *Pleurotus ostreatus* used in this study, coded M 2125, was imported from Burundi (Mycelia collection). The strain was multiplied on agar media: potato dextrose agar (PDA) and malt extract agar (MEA) and incubated until sufficient mycelial growth was achieved for mother culture preparation.

Spawn production. For spawn production, locally sourced *Sorghum bicolor* (L.) Moench grain was used as the substrate. After careful sorting and cleaning, the grains were partially cooked on a hot plate for 30 min to reach approximately 60% moisture content. They were then filled into 500 mg sterilised glass bottles and further autoclaved at 121 °C for 15 minutes. The bottles were allowed to cool under a vertical laminar airflow (type BAVnp-01- <<Laminar-S.>>-1,2 LORICA) for a minimum of 5 h before inoculation. Under aseptic conditions, the mother culture derived from *Pleurotus ostreatus* strain M 2125 was transferred into the sterilised sorghum. Inoculated cultures were incubated in a Heratherm IGS 100 incubator (Thermo Scientific, Germany) at 28 °C +/– 1 °C for 10 to 20 days until complete colonisation of the substrate.

Substrates' preparation. Three substrates were tested: S1 (soybean straw), S2 (rice straw), and S3 (sawdust), each prepared at two moisture levels: T1 (50%) and T2 (60%), resulting in a factorial block experimental design with five replicates per condition. Moisture content was adjusted and verified using the Testo 440 (Anatel), which also monitored incubation room temperature (28–32 °C) and cultivation room humidity (70–90%), regulated by routine watering. All substrates were soaked in water for 24 h to soften them, then measured into 500 g portions using a Handle Spring Scale



Figure 1. Substrate preparation and incubation: (A) soybean straw, (B) substrate pasteurisation, (C) substrate bag making, (D) substrate bag weighting, (E) spawning, (F) bag selling, (G) bag makers, (H) incubation (with permission to publish the pictures)

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Figure 2. Fruiting bodies harvested and weighted: (A) fruiting substrate, (B) fruiting bodies harvest, (C) measurement of fruiting bodies weight

(50 000 g/10 g ABS). The substrates were filled into O_2 polypropylene bags with micro-filters for air exchange and visibility, then pasteurised by steam at 100 °C for 1.5 h (Oei, Nieuwenhuijzen 2005). After cooling, 50 g of spawn (10% inoculation rate) was added per bag. The bags were manually shaken for even mycelial distribution and sealed using an impulse sealer (AIE-300) and transferred into the incubation room (Figure 1). Production was monitored with regular watering to balance temperature and relative humidity. The following variables have been recorded during and at the end of the experiment: (1) mycelia growing time, (2) number of fruiting bodies harvested and (3) weight of fresh and dry fruiting bodies, with productivity assessed at harvest (Figure 2).

Substrate component analyses. The substrate samples were initially dried at 105 °C using etuve to remove moisture without degrading the mineral components. The dried sample they were then milled to a minimum particle size of approximately 1 mm and homogenised to ensure even mineral distribution. For mineral analysis, a digestion process was performed using concentrated nitric acid (HNO_3) and perchloric acid ($HClO_4$) in a heated block digestion system. This step was essential for breaking down organic matter and releasing bound minerals. The samples were gradually heated to around 200 °C until a clear solution was obtained, indicating complete mineral solubilization (Standard 1998).

- The atomic absorption spectrometry (AAS) technique was used to analyse trace element content such as Zn, Fe, Ca, Na, K and Mg. Standard solutions for each element were prepared to calibrate the instrument and obtain accurate results.
- The colourimetry method was used to determine phosphorus (P) content where it react with ammonium molybdate to form a coloured complex, which was measured using a spectrophotometer.
- Mineral concentrations are expressed in mg/L of dry substrate. The results were adjusted according to the dilution during sample and solution preparation (Table 1).

Carbon content was determined according to (Nelson, Sommers 1982) and nitrogen content according to the Kjeldahl method (Philippoussis et al. 2007). The carbon/nitrogen ratio was then calculated for each substrate (Table 2).

Date processing and statistical analysis. To ensure robust statistical analysis, each substrate was

Table 1. Mineral composition of substrates used for the cultivation of mushrooms (in mg/L)

Substrates	Na	Mg	K	Ca	P	Zn	Fe
Soybean straw	10.2 ± 0.11^a	0.46 ± 0.08^a	340 ± 2.1^a	0.15 ± 0.01^a	0.031 ± 0.001^a	ND	0.02 ± 0.001^a
Rice straw	38 ± 1.06^b	0.21 ± 0.06^b	525 ± 3.1^b	0.17 ± 0.04^a	0.043 ± 0.002^c	ND	0.013 ± 0.001^a
Sawdust	9.4 ± 0.18^a	0.23 ± 0.02^b	239 ± 0.9^c	0.41 ± 0.03^b	0.012 ± 0.002^b	ND	ND

Different letters within the columns indicate significant differences ($P < 0.05$); ND – no data

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Table 2. Carbon and nitrogen content of the substrates

Substrates	Carbon (%)	Nitrogen (%)	C/N ratio
Soybean straw	50.32 ± 1.2[a]	1.30 ± 0.15[b]	38.70
Rice straw	48.11 ± 0.98[b]	1.06 ± 0.09[c]	45.38
Sawdust	46.35 ± 0.84[c]	0.89 ± 0.16[a]	52.07

Different letters within the columns indicate significant differences ($P < 0.05$)

replicated five times for each moisture level. The study followed a factorial block design. To assess the performance of rice straw, sawdust, and soybean straw for *Pleurotus ostreatus* cultivation, mature fruiting bodies were harvested daily, counted and weighed. Biological efficiency (BE) was determined for each substrate using the formula employed by Liang et al. (2019):

$$BE = \frac{\text{Fresh biomass}(kg)}{\text{Substrate dry weight}(kg)} \times 100$$

During the experiment, the following parameters were recorded: (1) days to full substrate colonisation, (2) the number of days before primordia appearance, (3) the number of fruiting bodies per bag, and (4) the fresh weigh of capophores per collection. To test the effect of substrate and moisture content, respectively, on these parameters, negative binomial regression was used under the MASS package (Venables, Ripley 2002), initially testing the interactive effect between substrate and moisture content, followed by their additive effect and the possibility of no effect from these two explanatory variables. The Akaike information criterion (AIC) was chosen to identify the most parsimonious and satisfactory model. The models were evaluated using the AIC, which balances model fit and complexity by penalising over-parameterisation. Lower AIC values indicate a more parsimonious model that explains the data effectively without unnecessary complexity. Kruskal's multiple comparison test was performed to rank the means. These comparisons were graphically represented using dispersion plots created under the ggpubr package (Kassambara 2023). All these analyses were conducted in the integrated development environment of RStudio software (Ushey et al. 2022) using R software (version 4.3.1.).

RESULTS

Overview of substrate compositions. Analyses of substrate composition provided information on the mineral, carbon and nitrogen composition of the three substrates tested (Table 1 and 2). According to the result, soybean straw has the lowest C/N ratio (38.70), meaning that this substrate is richer in nitrogen than sawdust and rice straw. It has a higher content in magnesium (0.46 mg/L) than the other substrates.

Table 3. Akaike information criterion (AIC) value of the three models considered for number of days until complete colonisation

Models	df	AIC
fit1 < -glm.nb (number of days until complete colonisation ~ substrate × moisture)	6	475.9
fit1a < -glm.nb (number of days until complete colonisation ~ substrate + moisture)	4	474.9
fit1b < -glm.nb (number of days until complete colonization ~ 1)	1	519.3

df – degree of freedom

Table 4. Mean comparison result of the parsimonious model for substrate and water content effect on the number of days until complete colonisation

Variables	Estimate	SE	*z* value	$P (> \lvert z \rvert)$
Intercept	3.0916	0.05443	56.800	< 0.001
Soybean straw substrate	–0.4227	0.06118	–6.908	4.914×10^{-12}
Sawdust substrate	–0.2481	0.06522	–3.804	1.421×10^{-4}
T60%	–0.1443	0.05150	–2.801	5.089×10^{-3}

SE – standard error; *P* – probability; T – water content rate

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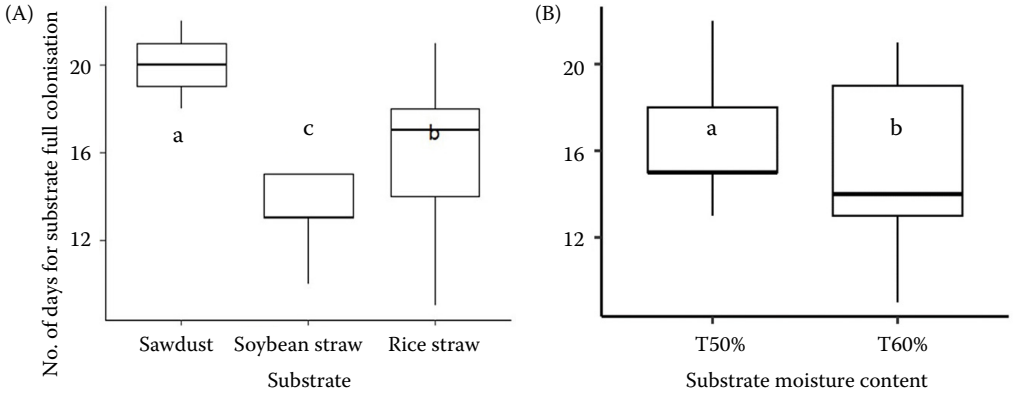

Figure 3. Comparison of the number of days to complete colonisation between substrates (A) and between doses of water content (B)

T – water content rate, different letters on the plots indicate significant differences ($P < 0.05$) according Kruskal's multiple comparison test

Effect of substrate and moisture content on the number of days until complete colonisation. The time required for substrate colonisation by *Pleurotus ostreatus* mycelium was significantly influenced by both substrate type and moisture content, with the additive model (model 1a) identified as the most parsimonious based on the AIC criterion (Tables 3 and 4; Figures 3A, B). Among the substrates tested, soybean straw facilitated the fastest colonisation, requiring significantly fewer days than rice straw and sawdust, which was the slowest ($\beta = 1.42 \times 10^{-4}$, $P < 0.05$). Similarly, moisture content played a critical role, with a 60% water level proving better for rapid colonisation across all substrate types ($\beta = 5.09 \times 10^{-3}$, $P < 0.05$, Table 4). Bags with 60% moisture consistently exhibited the shortest colonisation time, regardless of the substrate used (Figures 3A, B).

Effect of substrate and water content on the number of days to primordia appearance. Tables 5 and 6 and Figures 4A and 4B show the effect of substrate and water content on the number of days to primordia appearance. The number of days for primordia appearance differed significantly between substrates ($P < 0.05$), with fit 2 as the most parsimonious model, showing

Table 5. Akaike information criterion (AIC) value of the three models considered for substrate and water content effect on the number of days to primordia appearance

Models	df	AIC
fit2 < -glm.nb (number of days to primordia appearance ~ substrate × moisture)	7	486.9
fit2a < -glm.nb (number of days to primordia appearance ~ substrate + moisture)	5	492.1
fit2b < -glm.nb (number of days to primordia appearance ~ 1)	2	611.3

df – degree of freedom

Table 6. Mean comparison result of the parsimonious model for substrate and water content effect on the number of days to primordia appearance

Variables	Estimate	SE	*z* value	*P* (> |*z*|)
Intercept	2.61644	0.06640	39.403	P < 0.001
Soybean straw substrate	–0.56947	0.07886	–7.221	5.150×10^{-13}
Sawdust substrate	0.37384	0.07052	5.301	1.152×10^{-7}
T60%	–0.08166	0.05878	–1.389	1.647×10^{-1}

SE – standard error; *P* – probability; T – water content rate

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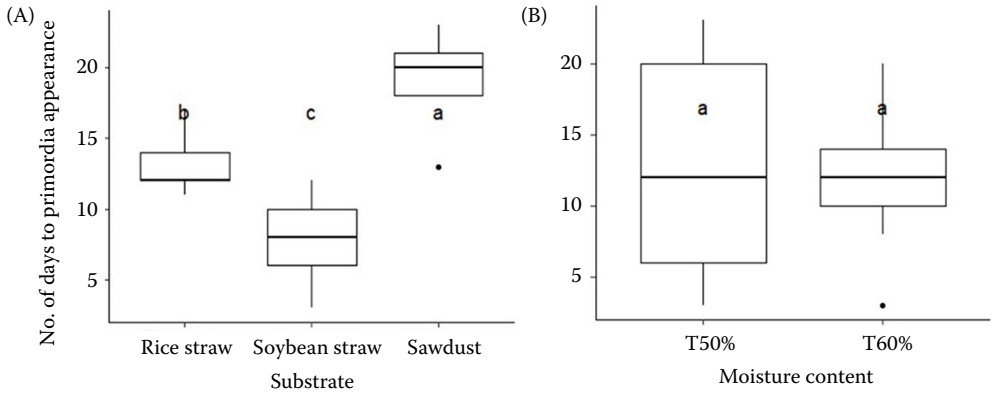

Figure 4. Comparison of the number of days before primordia appearance for each substrate (A) and between substrate moisture content (B)

T – water content rate, different letters on the plots indicate significant differences ($P < 0.05$) according Kruskal's multiple comparison test

the interactive effects of the two variables. However, although fit 2 is the most parsimonious, it is not more informative than fit 2a (Table 5). The Kruskal multiple comparison tests indicated that sawdust takes many more days to give primordia, unlike soybean straw, which took only a few days after complete colonisation formation (Figure 4A). As for the water content, there was total indifference between the two rates ($\beta = 1.647 \times 10^{-1}$, $P > 0.05$), which would mean that the water content did not significantly influence the appearance of primordia (Figure 4B). However, the water content does not significantly influence this appearance

Effect of substrate and water content on the number of fruiting bodies per collection. Tables 7 and 8 and Figures 5A, B present the effect of substrate and water content on the number of fruiting bodies per harvest. Statistical analysis revealed that neither substrate type nor moisture content had a significant influence on fruiting body count, with an additive or an interactive model (model 3b) identified as the most parsimonious model (Table 7). The probability values ($\beta = 0.588$, $P > 0.05$) indicate that neither substrate type nor moisture level significantly affected the number of fruiting bodies (Table 8). Additionally, the Kruskal multiple comparison test assigned the same

Table 7. Akaike information criterion (AIC) value of the three models considered for substrate and water content effect on the number of fruiting bodies per collection

Models	df	AIC
fit3 < -glm.nb (number of fruiting bodies per bag ~ substrate × moisture)	7	537.8
fit3a < -glm.nb (number of fruiting bodies per bag ~ substrate + moisture)	5	535.2
fit3b < -glm.nb (number of fruiting bodies per bag ~ 1)	2	532.3

df – degree of freedom

Table 8. Mean comparison output of the parsimonious model for substrate and water content effect on the number of fruiting bodies per collection

Variables	Estimate	SE	*z* value	P (> |z|)
Intercept	2.21497	0.1004	22.0621	7.317×10^{-10}
Soybean straw substrate	0.05689	0.1050	0.5418	0.5880

SE – standard error; P – probability; T – water content rate

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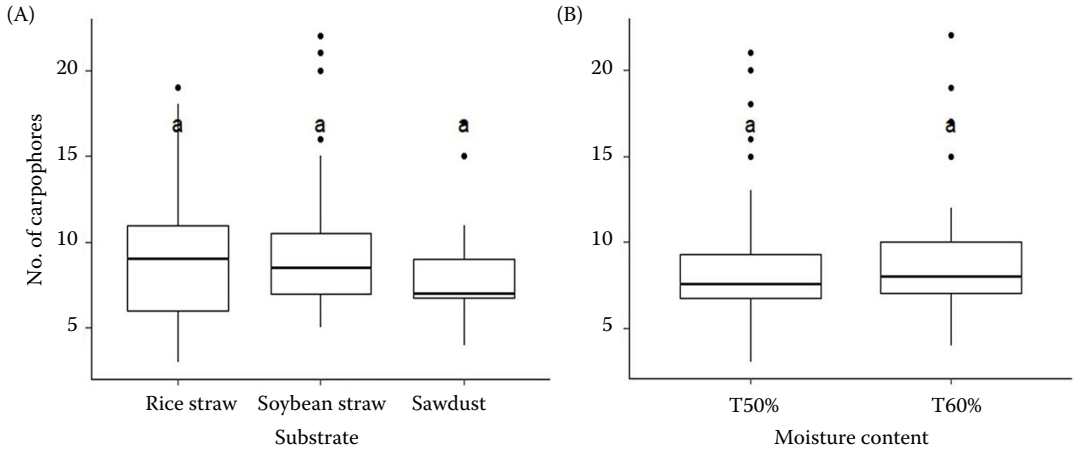

Figure 5. Effect of substrate (A) and water content on fresh weight of carpophores (B)
T – water content rate, different letters on the plots indicate significant differences ($P < 0.05$) according Kruskal's multiple comparison test

grouping label ("a") to all treatments, confirming no statistically significant differences across substrates or moisture levels (Figures 5A, B).

Effect of substrate and water content on fresh weight of carpophores. Tables 9 and 10 and Figures 6A, B present the effect of substrate and water content on fresh fruiting bodies weight. The weight of the carpophore collected was significantly influenced by both the type of substrate and substrate water content, with the additive model (fit 5a) identified as the most parsimonious and informative model (Table 9). Specially, only the probability of soybean straw substrate showed a statistically significant effect ($\beta = 1.118 \times 10^{-7}$, $P < 0.05$), indicating a substantial difference in fruit bodies weight from soybean straw compared to rice straw and sawdust. In contrast, no significant difference was found between sawdust and rice straw ($\beta = 0.508$, $P > 0.05$). The difference observed between the average weight of carpophores on soybean and rice straw was 31.584 g (Table 10). The Kruskal multiple comparison test confirmed these results

Table 9. Akaike information criterion (AIC) value of the three models considered for substrate and water content effect on fresh weight of carpophores

Models	df	AIC
Fit4 < -lm(fresh weight of carpophore ~ substrate × moisture)	7	882.3
Fit4a < - lm(fresh weight of carpophore ~ substrate + moisture)	5	878.5
Fit4b < -lm(fresh weight of carpophore ~ 1)	2	910.9

df – degree of freedom

Table 10. Mean comparison output of the parsimonious model for substrate and water content effect on fresh weight of carpophores

Variables	Estimate	SE	*t*-value	P (> |t|)
Intercept	30.978	5.205	5.9522	4.641×10^{-8}
Soya substrate	31.584	5.491	5.7520	1.118×10^{-7}
Sawdust substrate	3.977	5.987	0.6642	0.5082
T60%	8.898	4.474	1.9889	4.965×10^{-2}

SE – standard error; t – student value; P – probability; T – water content rate

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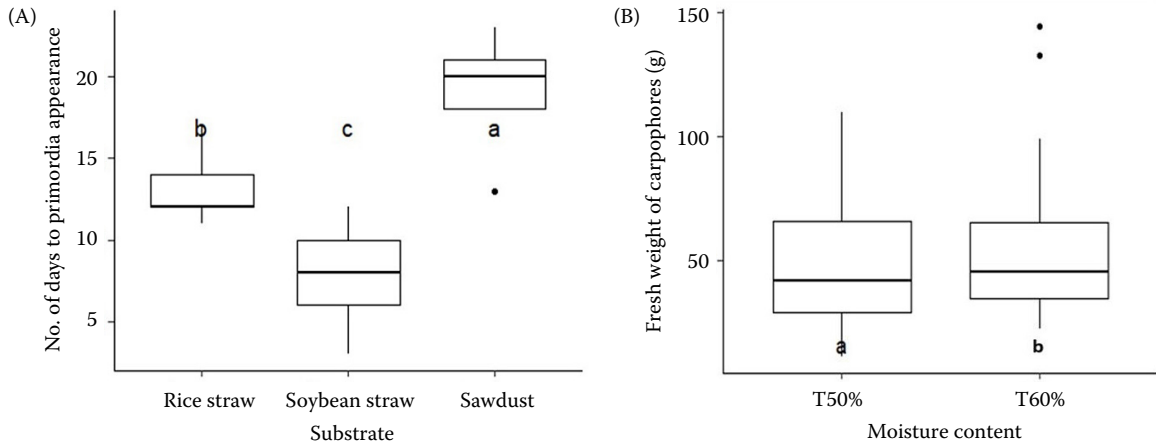

Figure 6. Comparison of fresh weights of carpophores as a function of substrate (A) and between doses of water content (B)
T – water content rate, different letters on the plots indicate significant differences ($P < 0.05$) according Kruskal's multiple comparison test

by the difference observed in the soybean straw substrate, unlike the other two substrates, which were similar. For water content, $\beta = 4.96 \times 10^{-2}$ ($P < 0.05$) and the Kruskal multiple comparison test confirmed this difference (b). The water content, therefore, had no significant effect on the weight of the harvested carpophores (Table 10).

Yield and biological efficiency (BE) of substrates. Figure 7 shows the average sporophore yield of *Pleurotus ostreatus* across different substrates and water content. It shows that the fruit bodies yield varies with substrate and moisture. The average carpophore yields obtained from substrates with 60% water content are higher than those obtained from substrates with 50% water content. In general, the highest yield was obtained on soybean straw (452.5 g/kg), followed by rice straw (367.8 g/kg) with a water content of 60%. The lowest yields were obtained from sawdust with a moisture content of 50% (213 g/kg) and 60% (275 g/kg). Table 11 shows the calculated biological efficiencies for each substrate tested. Table 7 presents the calculated biological efficiency for each substrate. Substrates at 60% moisture consistently showed higher BE values. exhibited the highest BE, closely followed by rice straw, while

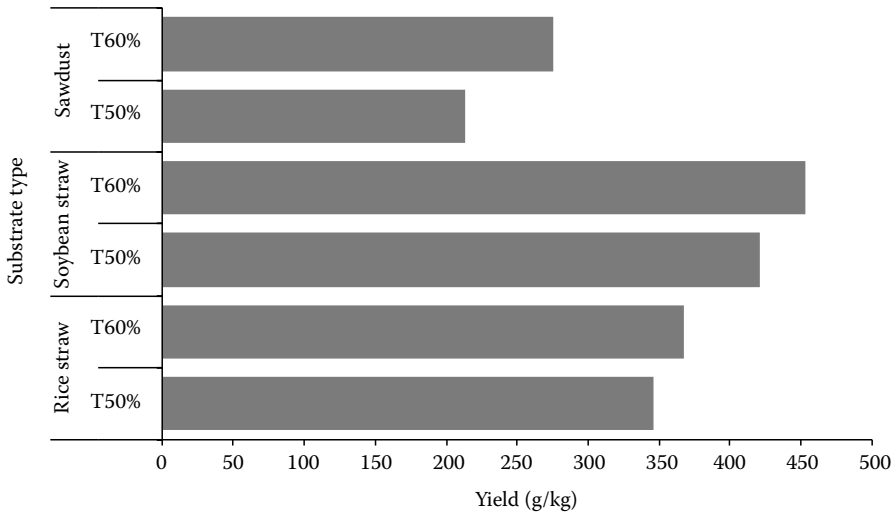

Figure 7. Average yield of Pleurotus ostreatus carpophores as a function of substrate and moisture content

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Table 11. Biological efficiency of each substrate

Substrates	Water content rate (T) (%)	BE	Cycle duration (weeks)
Rice straw	60	61.4	7
	50	57.73	
Sawdust	60	39.31	7
	50	30.48	
Soybean straw	60	64.64	4
	50	60.08	

BE – biological efficiency

sawdust had the lowest. Additionally, the data indicate that soybean straw supports faster crop cycles, with rice straw and sawdust requiring more time to achieve comparable yields.

DISCUSSION

The experimental findings indicated that *Pleurotus ostreatus* mycelium exhibited the most rapid colonisation of soybean straw compared to sawdust and rice straw. Soybean straw required an average of 13 days to colonise a bag of 500 g substrate completely. This is less than the time required for sawdust and rice straw substrates with complete colonisation after 2–3 weeks (average 17 days for rice straw and 20 days for sawdust). Soybean straw is relatively rich in nitrogen and carbon elements that the mycelium needs to grow. Indeed, soybean straw exhibits the lowest carbon/nitrogen ratio (38.70%), reflecting the high nitrogen content of this substrate (1.30%) and the high carbon content of the substrate (50.32%). The rapid growth of *P. ostreatus* mycelium has been reported to be dependent on carbon (Nwokoye et al. 2010; Hoa, Wang 2015; Schoder et al. 2024) and nitrogen sources in the substrate (Cueva et al. 2017; Lin et al. 2022; Hamza et al. 2023). Other authors, such as Hubert (2006) and Li et al. (2013), showed that soybean straw is very rich in fibres and may contain fats that are beneficial for growth.

The result of this study also shows that the effect of substrate on the time to appearance of primordia is significant. Oei and Nieuwenhuijzen (2005) and Nongthombam et al. (2021) evidenced that the choice of substrate plays a crucial role in the dynamics of primordial appearance and development. Soybean straw requires only six days after substrate full colonisation to produce primordia, unlike sawdust and rice straw, which take longer (twelve days on average). This result can also be explained by the fact that soya residues have a lower carbon-nitrogen (C/N) ratio and are therefore favourable for the rapid appearance of primordia. The energy the mycelium uses for fructification is related to the carbon and nitrogen content of the substrate (Ibeghouchene, Slimani 2020). Similar results were found by Muswati et al. (2021).

The type of substrate did not affect the number of fruit bodies. This could be explained by the fact that all substrates, whether rice straw, sawdust or soya, have a similar fruiting potential in terms of the number of fruit bodies. This is not dependent on their physico-chemical or nutritional composition. The substrates studied in this study are all productive and can be converted into fruiting bodies by the mycelium. These results are supported by several authors, such as Leong et al. (2022), Muswati et al. (2021), Bellettini et al. (2019), and Shah et al. (2004), who have all obtained carpophores on rice straw, sawdust, and many other types of substrates. Our work confirms the possibility of obtaining carpophores on soybean straw.

This work shows that each of the substrates studied is productive; there is a significant difference between the fresh weights of fruit bodies harvested from soybean straw and those harvested from rice straw and sawdust (31 584 g difference). This result is supported by Bellettini et al. (2019), Ibeghouchene, and Slimani (2020), who confirm that particular attention should be paid to the quality of the substrate to optimise mushroom production. On the other hand, the absence of any significant difference between the fresh weights harvested from sawdust and those from rice straw indicates that these two substrates perform similarly. Although soybean straw yields better than rice straw, rice straw's mineral composition is better than soybean straw's. Potassium, calcium, sodium and phosphorus are all present. This difference indicates the best substrate in terms of the final mineral composition of the mushrooms that will be harvested on these substrates, given the correlation between the final nutritional content of the mushrooms and that of the substrates. This correlation is well evidenced by (Hoa, Wang 2015; Koutrotsios et al. 2020). However, soybean straw has a higher concentration of magnesium (0.46 mg/L), sodium (10.2 mg/L), potassium

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(340 mg/L) and phosphate (0.31 mg/L) than sawdust. Soybean straw is therefore a substrate with a more moderate mineral composition than rice straw and sawdust, which have long been used in mushroom cultivation.

The results suggest that a water content of 60% promotes faster colonisation of substrates by the mycelium than 50 %. The water content of 60% in a substrate probably provides secure, favourable conditions for rapid enzymatic activities. This result is consistent with that of Damien (2016), who found that higher moisture levels create an environment conducive to the development of microorganisms and promote the proliferation of colonising species, whereas a water content of 50% may provide less optimal conditions for these biological processes, resulting in slower colonisation. Water content does not seem to be a determining factor in the process of primordia formation or the production of fruiting bodies. This could be explained by the fact that primordia appearance, formation, number and development consider other variables or environmental conditions that were not evaluated but controlled in this study. The promotion of fruiting in fungi can be induced by various external stimuli such as temperature decrease (Eger 1976), light exposure (Zadrazil 1980) and nutrient depletion (Eger 1976; Miles, Chang 2004). The 60% regime seems to be the best in terms of yield, regardless of the type of substrate. This water content has already been reported as the best for mushroom cultivation (Obodai, Vowotor 2002; Oei, Nieuwenhuijzen 2005; Tarko, Sirna 2018). The variations observed between our results and those of other studies could be attributed to differences in experimental conditions, fungal strains used, or even methodologies for measuring the number of days to full colonisation. These discrepancies highlight the need for a contextual approach in interpreting results.

The yield differences observed significantly impacted the biological efficacy of the different substrates. Our results are therefore in line with Muswati et al. (2021), who demonstrated that the substrates with higher yields also have a higher EB value. Looking at the results for the biological efficiency of substrates with a moisture content of 60%, we can see that soybean straw has the highest biological efficiency, but this value (BE) is not too different from the value obtained for rice straw. According to Gume et al. (2013), the two substrates can be recommended for oyster mushroom cultivation since they gave an BE greater than 40.0%. Rice straw is just as effective as soybean straw, with the difference that the latter takes less time for the production cycle. The fact that sawdust has the lowest biological efficiency does not make it a bad substrate. These yields can be considered satisfactory as some of them are higher than the 20% economic yield generally recognised for a substrate suitable for mushroom production (Oei, Nieuwenhuijzen 2005; Mpulusu et al. 2010). Indeed, a higher BE was obtained in production work on *Pleurotus ostreatus*, at a water content of between 70% and 80%.

Our work makes significant contributions to our understanding of the effect of substrate, particularly the performance of soybean straw and good water content on mycelial colonisation, primordia and fruit bodies, but interpretation must be made with caution, considering the variations observed in other work. However, there are procedures for improving its performance, such as composting (Adjapong et al. 2015), adding supplements to the substrate (Narh Mensah et al. 2018) and increasing the water content of the substrate.

CONCLUSION

This study highlights the potential of soybean straw as an efficient and sustainable substrate for cultivating especially for *Pleurotus ostreatus* in West Africa. Key findings demonstrate that soybean straw enables faster mycelial colonisation and higher yields compared to rice straw and sawdust. With a water content of 60%, it proved optimal for both biological efficiency and yield, emphasising its practicality in mushroom production. These results provide an innovative pathway for valorising agricultural residues while contributing to waste management and sustainable agriculture in tropical regions. To develop the cultivation of tropical mushrooms, soybean straw could be an effective alternative growing substrate. In addition, the performance observed could positively be improved with the use of supplements.

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