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EVALUATION OF SOYBEAN STRAW, BEAN STRAW, MAIZE STALK, AND BANANA LEAF AS SUBSTRATES FOR THE GROWTH AND YIELD OF OYSTER MUSHROOM (*Pleurotus ostreatus*)

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ABSTRACT

Agricultural waste management poses a significant environmental challenge, where crop residues are often underutilized or improperly discarded. Oyster Mushroom (*Pleurotus ostreatus)* is particularly valued due to its adaptability to a wide range of lignocellulosic substrates, high productivity potential, and nutritional benefits. They are widely recognized for their potential to combat malnutrition and enhance food security. In developing regions, the use of locally available and cost-effective agricultural residues is essential for promoting sustainable mushroom production and improving food security. This study evaluated the suitability of four locally available agricultural residues and these were: T_0 = Soybean straw; T_1 = Bean straw; T_2 = Maize stalks, and T_3= Banana leaves. The residues were used to assess the growth performance and yield of *Pleurotus ostreatus* (oyster mushroom) in Chinsali district of Muchinga province of Zambia. A completely randomized design with three replications per treatment was employed. Growth parameters assessed included mycelial colonization period, pinhead initiation, yield, and biological efficiency (BE). Drum method was used to pasteurize the substates and inoculated with grain spawn under controlled environmental conditions. Results indicated significant variations in growth and yield performance across the substrates. Data were analyzed using two-way ANOVA at $p < 0.05$. Soybean straw produced the highest yield (2.92 kg) and biological efficiency (64.9%), followed by banana leaves (2.39 kg; 53.1%), bean straw (1.72 kg; 38.2%), and maize stalks (1.53 kg; 34.0%). Maize stalks exhibited the fastest mycelial colonization (14 days), whereas banana leaves required the longest colonization period (28 days). Substrate type significantly influenced mushroom weight over time, while cap diameter and stipe height showed no significant differences among treatments. The study concludes that while all tested residues are viable, banana leaves serve as an excellent, cost-effective substitute for soybean straw, offering comparable or superior yield performance. It provides practical guidance for smallholder farmers and extension services in Zambia by promoting low-cost substrate options that enhance mushroom production, income generation, and sustainable agricultural waste utilization and management.

Key words: *Pleurotus ostreatus*, substrate, crop residues, yield, biological efficiency, food security, colonization, Zambia

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INTRODUCTION

Agricultural waste disposal remains a major environmental challenge, as improper handling of crop residues can lead to pollution and ecosystem degradation [1]. One sustainable approach to addressing this challenge is mushroom cultivation, which utilizes agricultural residues as growth substrates while simultaneously converting waste into valuable food products. This practice offers an environmentally sound and economically viable option for residue management, particularly in smallholder farming systems [2].

Mushrooms are fungi that play an essential role in nutrient cycling through the decomposition of organic matter, thereby enhancing soil fertility and ecosystem functioning [3]. They obtain nutrients through saprophytic, parasitic, or mutualistic associations [4] and are known to produce bioactive compounds with antioxidant, antimicrobial, and immunomodulatory properties [5]. Edible mushroom species such as *Agaricus bisporus* and *Pleurotus ostreatus* are rich sources of protein, vitamins, and minerals, making them important for dietary diversification and nutrition improvement [6]. In addition, mushrooms have been explored for environmental remediation and the development of sustainable biomaterials [7].

Among cultivated species, *Pleurotus ostreatus* is particularly valued due to its adaptability to a wide range of lignocellulosic substrates, high productivity, and nutritional benefits. Its favorable potassium-to-sodium ratio makes it suitable for individuals with hypertension and cardiovascular conditions [8]. Furthermore, oyster mushrooms are widely recognized for their potential to combat malnutrition and enhance food security in developing countries because of their rapid growth and high yield potential [9]. Optimizing substrate selection is therefore essential for improving production efficiency and expanding cultivation at the local level [10].

In Zambia, agricultural residues such as soybean straw, bean straw, maize stalks, and banana leaves are readily available and often underutilized. Conventional substrates such as wheat straw and sawdust are commonly used elsewhere, but locally available crop residues offer a more affordable and environmentally friendly alternative [4]. Despite the abundance of these materials, limited empirical information exists regarding their comparative suitability for oyster mushroom cultivation under Zambian conditions.

Therefore, the objective of this study was to evaluate the suitability of selected locally available agricultural residues, soybean straw, bean straw, maize stalks, and banana leaves as substrates for the cultivation of *P. Ostreatus* in Zambia.

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Specifically, the study aimed to:

(i) determine the duration from substrate colonization to first harvest; (ii) assess the effect of substrate type on mushroom weight, cap diameter, and stalk height; and (iii) evaluate substrate yield performance using biological efficiency.

METHODOLOGY

Study site

The research was conducted at Kapasa Makasa University (KMU) (Figure 1), located in Chinsali district of Muchinga province. Chinsali is situated about 180 kilometers from Mpika town and approximately 80 kilometers from the Isoka town. Chinsali is the provincial headquarters of Muchinga province. The district falls in Agroecological Zone III of Zambia, with average rainfall ranging between 1000mm to 1500mm per year. The average annual temperature is about 20 degrees Celsius. The experiment was conducted from June to August 2024, in a closed condition for the determination of the effect of substrates on the performance of Oyster mushrooms.

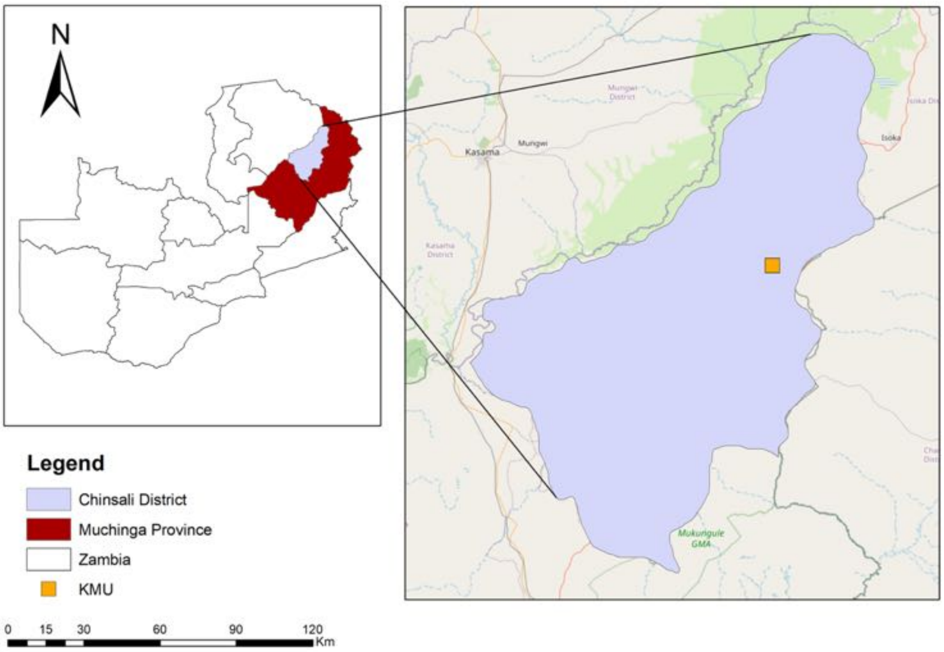

Figure 1: Map showing the study site

Experimental Design, Substrate collection and treatments assigning.

The experiment followed a completely randomized design (CRD), with four treatments randomly assigned and each replicated three times.

The substrates were sourced from two locations, with bean straws and maize stalks from KMU field, and soybean straw and banana leave from Mulakupikwa

Community. Maize stalks, bean straws, and banana leaves were tested against soybean straw, which served as the control due to its common use in Zambia.

Treatments were assigned as follows; T_0 = Soybean straw; T_1 = Bean straw; T_2 = Maize stalks, and T_3= Banana leaves with each substrate weighing 4.5 kg. The experiment followed a completely randomized design (CRD) with three replications per treatment, resulting in 12 bags.

Substrate Preparation and Bag Filling

The collected substrates were prepared by chopping them into 1-2 cm pieces [12], except for those already appropriately sized. They were cleaned thoroughly three times until the water ran clear, and excess water was drained in preparation for sterilization.

Sterilization was carried out using the drum method where moist substrates were submerged in 40 liters of water in a drum, covered with a lid and weighted down to ensure complete immersion during the process. The drum's top was covered with a lid, and a weight was placed on top to ensure the substrates remained submerged. After sterilization, the substrates were spread on a clean plastic mat to cool to 24°C, making them ready for bag filling. Additionally, for spawn inoculation, transparent plastic bags (35.56 cm x 60.96 cm) were used, with one side tied with a rope. The bags were filled with substrates in three layers, each weighing 1.5 kg, for a total of 4.5 kg per bag.

Spawning and Inoculation

Spawning was performed aseptically using grain spawn, which was evenly distributed in each layer of straw and lightly pressed to compact the bag. The final layer was sprinkled with spawn and covered with a thin layer of substrate. After spawning, the mouths of the bags were securely tied with thread, and small holes were made on the lateral sides and top for aeration.

The packed bags were incubated in a well-ventilated dark room at a temperature range of 23 to 25°C, while the floor was kept wet to maintain humidity levels until the mycelium fully colonized the substrates. After full colonization, the bags were transferred to the fruiting room and exposed to natural diffused light, avoiding direct sunlight. Ventilation was maintained through regular air exchange by manually opening windows and doors twice daily, complemented by perforations on the cultivation bags, to prevent carbon dioxide accumulation and support normal fruit body development of *P. ostreatus*.

Colonization and Growth

Colonisation was monitored every day following inoculation of the spawn on the substrates and it was observed from 14 to 28th day, while taking note of the days of colonization for each substrate (Table 1) until the entire bags were covered in white mycelium. During the growth phase, the bags were maintained in a well-ventilated dark room at 23-25°C, with ventilation ensured through perforations in the bags and by manually opening windows and doors once daily to facilitate air exchange. Humidity was maintained by keeping the floor wet. After full colonization, the bags were immediately transferred to a well-ventilated fruiting room with natural diffused light, avoiding direct sunlight. Moisture in the fruiting room was maintained by sprinkling 750 ml of water on the substrates twice daily, in the morning and evening.

Fruiting bodies appeared one week after pinheads were observed and were fully grown, particularly on the banana leaves, which showed a rapid and positive response to the experiment, making them ready for harvest.

Mushroom harvesting and data collection

Harvesting was done weekly for a period of one month when the mushroom caps reached full maturity by gently twisting them to avoid disturbing nearby fruiting bodies [13]. After each harvest, the mushrooms were weighed using a scale, while cap diameter and stalk height were measured with a measuring tape. After harvesting, the substrates were sun-dried, and the final dry weight was recorded for the calculation of Biological Efficiency (BE). Biological Efficiency (BE) was calculated as the ratio of fresh weight of harvested mushrooms to the dry weight of substrate, multiplied by 100 [14].

$$\text{Biological Efficiency}=\frac{\text{Fresh weight of mushrooms harvested}}{\text{Dry weight of substrate}}\times 100 \ldots\ldots\ldots\ldots \text{(EQ 1)}$$

Five mushrooms were randomly selected from each replicate for measurement at each harvest and measurements were recorded. Parameters measured included the number of days to full colonization, number of days to first fruiting, harvesting duration (days), total mushroom yield (kg), mushroom cap diameter (cm), mushroom stalk height (cm), mushroom cap weight (g), and biological efficiency (%).

Data analysis

Data collected on mushroom cap diameter, weight and stalk height were analysed using a two-way ANOVA in IBM SPSS version 29 at a significance level of $p < 0.05$. Furthermore, Biological Efficiency (BE) was calculated using the following formular (Eq 1) adapted from Wang *et al.* [4].

RESULTS AND DISCUSSION

Four different types of substrates were used to determine the growth and yield of oyster mushroom. The present study has demonstrated variations in, days from colonization to harvest, mushroom weight, biological efficiency (BE), and total yield, while mean diameter and height remained similar.

Regarding the investigated substrates on days from Colonization to Harvest (Table 1), the required time for spawn run (14 days), followed by bean and soybean straws (21 days each), whereas banana leaves required the longest duration (28 days). The rapid colonization observed in maize stalk substrates can be attributed to their chemical composition, which includes approximately 44.9% cellulose and 19% lignin [15]. This relatively high cellulose and lower lignin content enhances substrate degradability by fungal enzymes, thereby promoting faster mycelial colonization during mushroom cultivation. These findings are consistent with those of Elattar *et al*. [16], who also reported that maize stalks supported the fastest colonization among the substrates evaluated. The duration of 21 days that bean and soy bean straw demonstrated in the present study may be explained by both substrates containing similar levels of lignin and hemicellulose [17], which support mycelial growth until the substrate is fully colonized. Interestingly, while maize stalks showed rapid colonization, the total time to harvest was longer compared to other substrates. The 28 days required for complete colonization on banana leaves observed in the present study is consistent with the findings of Dubey *et al.* [18], who reported a colonization duration of 27 days. This indicates that banana leaves, while suitable for supporting mycelial development, require a relatively longer period for full colonization due to differences in substrate composition and possibly water retention properties. In contrast, Mondal *et al.* [19] reported significantly shorter colonization times (21 days) on banana leaves and their mixtures with rice straw, particularly at ratios of 3:1 and 1:3, as well as banana leaves alone. However, these shorter colonization durations were not observed in the present study, suggesting that substrate performance may vary due to environmental conditions, strain differences, or substrate preparation methods.

With respect to the mean cap diameter of the mushroom cap (Figure 2), there was no significant difference across the substrates and weeks. Finding does not conform with what was reported by Dubey *et al.* [19] who found differences in the cap diameters of the mushroom and the differences may be partly attributed to variations in the type of straw used (rice straw and wheat) [20] and environmental conditions under which the two studies were conducted.

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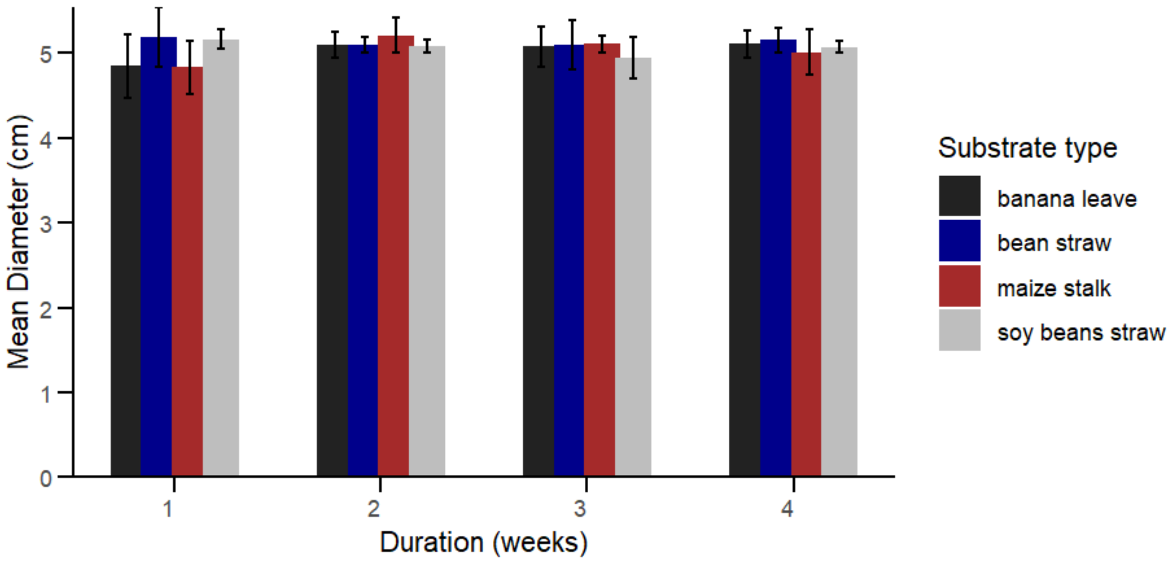

Figure 2: Mean cap diameter (cm) of *Pleurotus ostreatus* per week across four substrates. Values represent mean ± standard error (n = 3). X-axis: week of harvest; Y-axis: cap diameter in centimeters

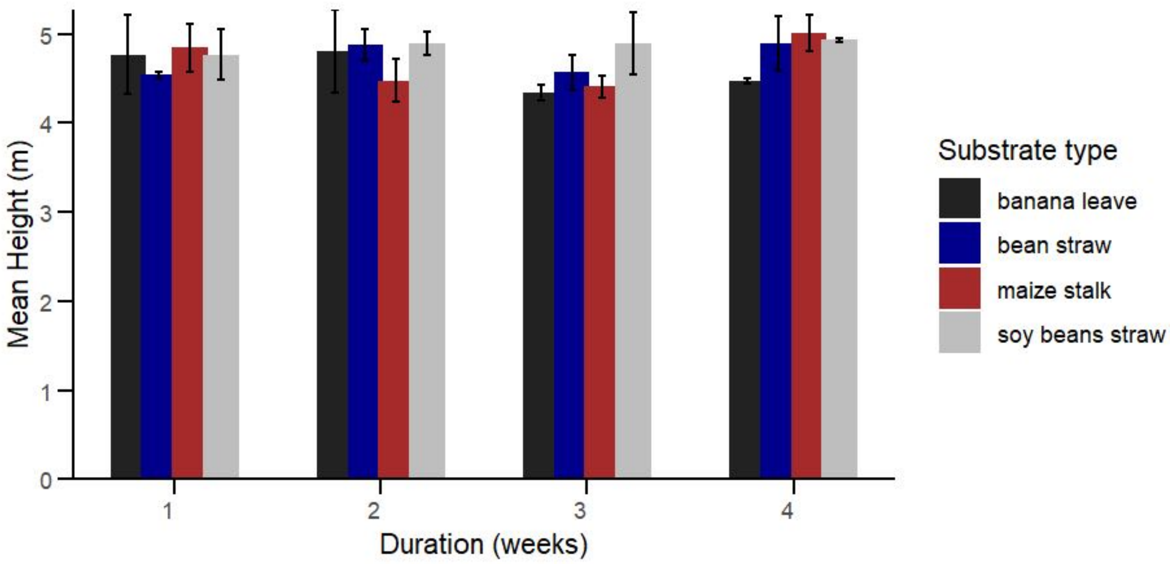

Figure 3: Mean stalk height (cm) of *Pleurotus ostreatus* per week across four substrates. Values represent mean ± standard error (n = 3). X-axis: week of harvest; Y-axis: stalk height in centimeters

With regard to stalk height of the mushroom (Figure 3) similarly to the diameter, no significant differences were attained across the substrates and weeks. This may be ascribed to similarities in effect of substrates used on functional and organoleptic

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characteristics of mushroom [12, 21]. The findings of this study negate those found reported by Chiejina and Olufokunbi [22] who found significant differences in height of mushroom across substrates.

In addition, the current study has shown that there were significant differences in weight across the substrates and weeks (Figures 4). Banana leaf and soybean straw substrates consistently produced superior yields compared to maize stalk and bean straw, particularly during week 3. The observed increase in weight during week 3 followed by a slight decline thereafter may be attributed to differences in substrate chemical composition, nutrient content (total carbon, nitrogen, minerals), pH, and moisture holding capacity, which influence the growth and biomass accumulation of fruiting bodies [20, 23]. This finding aligns with *et al*. [16], who reported that banana leaves yielded the highest average output among substrates such as maize stalk, rice straw, and groundnut pods. Furthermore, as the period increased, there was a noticeable increase with the major weight attained in week 3 and declined in thereafter across the substrates. This may be due to the variations in the chemical composition and properties of the growing substrate causing significant differences in the fruiting bodies as was suggested by Siwulski *et al*. [20] and Rzymski *et al*. [23]. Likewise, differences in the nutrients such as total carbon, nitrogen, minerals, pH, and moisture holding capacity contained in the various substrates may have influenced the availability of the said nutrients in the mushroom and the weight [20, 23].

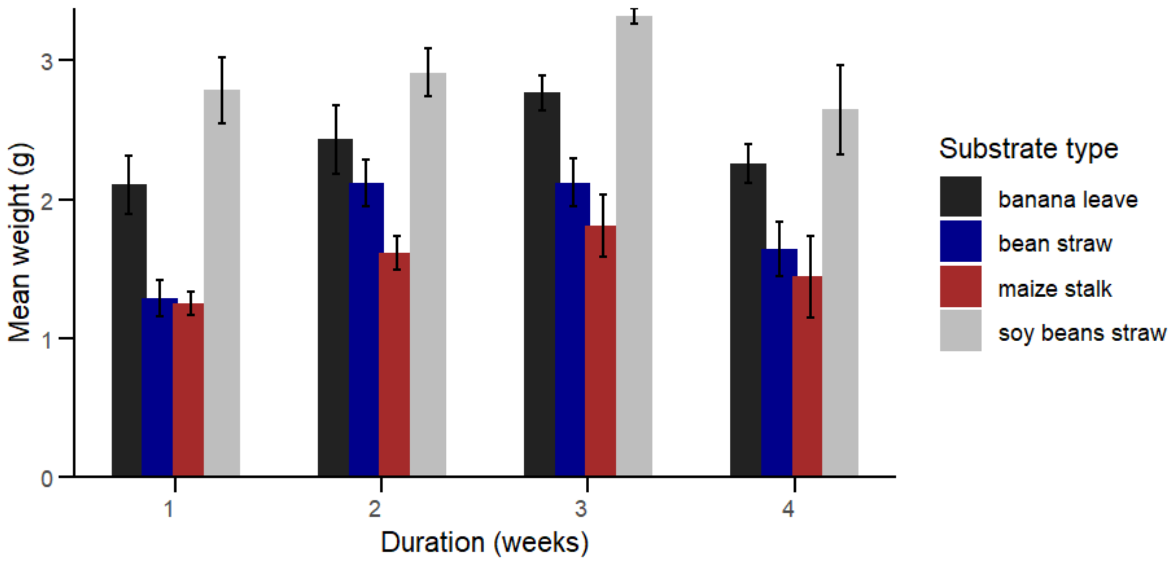

Figure 4: Mean weight (g) of *Pleurotus ostreatus* per week across four substrates. Values represent mean ± standard error (n = 3). X-axis: week of harvest; Y-axis: mushroom weight in grams

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Biological efficiency (BE) is a critical parameter used to assess the productivity of various substrates in mushroom cultivation. It quantifies the effectiveness of a given substrate in converting its dry weight into fresh mushroom biomass [4]. In this study, only banana leaf substrate exceeded 50% BE, whereas bean straw and maize stalk recorded the lowest efficiencies (38.2% and 34%, respectively). These findings differ from Kimenju [2] and Wachira *et al*. [1], likely due to differences in substrate chemical and physical properties, including cellulose/lignin ratio, mineral content, pH, EC, and C:N ratio [25]. The lower percentages of less than 40% calculated in the current study negates those of Shen and Royse [24], whose lowest biological efficiency were around 40%. Moreover, this study found that biological efficiency of Bean straw and Maize stalk were the lowest with 38.2% and 34%, respectively which disagree with the finding of Wachira *et al*. [1] who calculated biological efficiency of Bean straw and Maize stalk of 80.9% and 71%, respectively. The variation observed in the present study with those of other studies can be attributed to differences in physical and chemical composition of substrate such as cellulose/lignin ratio and mineral contents, pH, and EC of the substrate, especially C: N ratio [25].

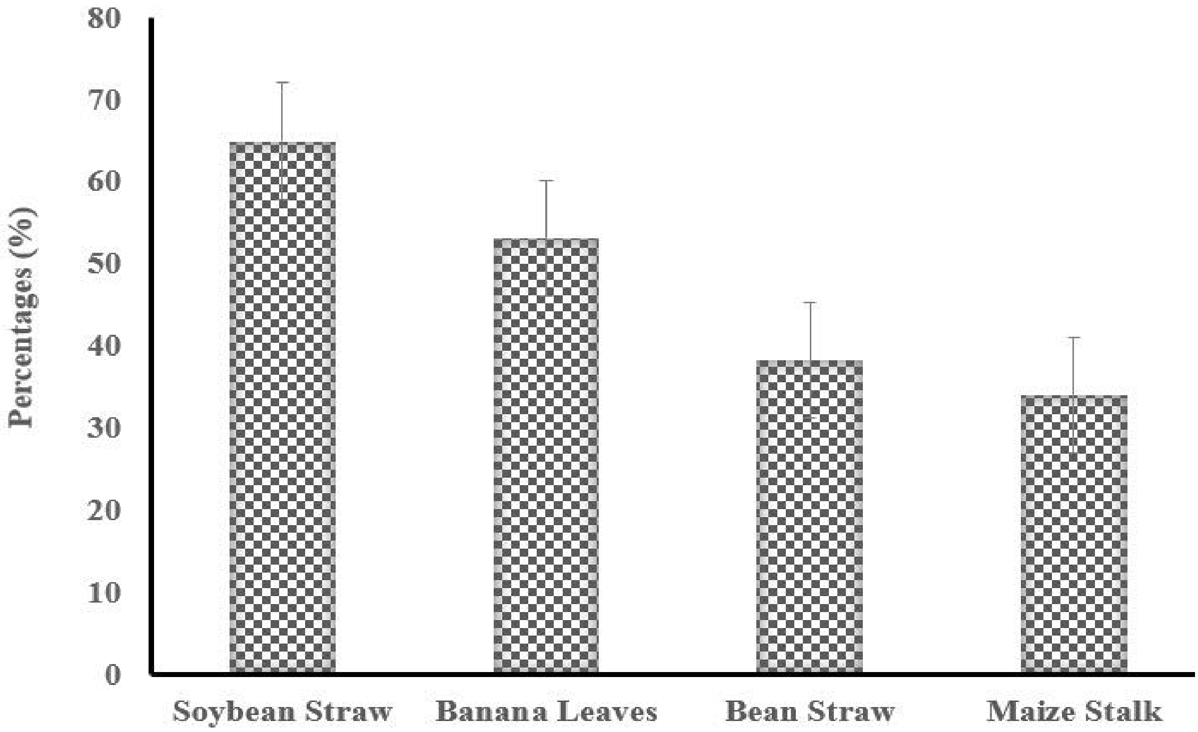

Figure 5: Biological efficiency (%) of *Pleurotus ostreatus* on four substrates. Values represent mean ± standard error (n = 3). X-axis: substrate type; Y-axis: biological efficiency in percent

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

This study demonstrates that oyster mushrooms can thrive on various agricultural wastes, often considered not useful after harvest. Banana leaves were found to be a suitable substitute for the commonly used soybean straw, offering comparable or even better yield, growth parameters, and biological efficiency than Maize stalk and Bean straw.

In light of these findings, it is recommended that oyster mushroom (*Pleurotus ostreatus*) cultivators adopt banana leaves as a viable, cost-effective alternative to traditional soybean straw.

A comparative analysis of the proximate composition (protein, fiber, and minerals) and cost-benefit analysis of mushrooms harvested from banana leaf substrates versus traditional media can be done to determine the scalability of this substrate in different geographical locations and markets.

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DATA ACCESSIBILITY

Data can be made available upon request from the corresponding author.

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Table 1: Colonization and Harvest Time (Days) on Different Substrates

SUBSTRATES	DAYS TO COLONISATION	DAYS TO HARVEST
Maize Stalk	14	42
Bean Straw	21	28
Soybean Straw	21	21
Banana Leaves	28	14

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