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ORIGINAL RESEARCH

Banana residue could be a viable rice straw alternative for Pleurotus mushroom production

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Abstract

Purpose Oyster mushroom (*Pleurotus ostreatus*) is becoming more popular as an efficient biotechnological procedure for upcycling agricultural by-products into valuable human food. This study looked into the possibility of employing banana residue (BR) and sorghum stalks (SS) as localized feasible rice straw (RS) substitutes for cultivating *P. ostreatus*. This has the potential to improve the livelihoods of rural agricultural communities in Egypt, as well as those in other parts of the world.

Method For two successive trials, three sole substrates (BR, SS, and RS) and six various combinations of SS and BR each with rice straw at 1:1, 1:2, and 2:1 ratio were tested. Agronomic features, antioxidant capacity, and crude protein contents of mushroom basidiocarps were measured. The chemical profile of the three raw and spent sole substrates was also studied.

Results The sole BR substrate was superior to both RS and SS in terms of basidiocarps yield and both exterior (average cap weight, diameter, and thickness) and interior (crude protein and total antioxidant activity, phenols and flavonoids contents) quality attributes. The yield of basidiocarps developed on the sole SS substrate was far lower than that of the other substrates. It is worth mentioning that, BR tended to contain high initial potassium, phosphorus, cellulose, and total carbohydrates concentration.

Conclusion Sole BR could entirely substitute sole RS as a substrate for the production of *Pleurotus ostreatus*.

Keywords Antioxidants, Banana biomass, Ligninolytic fibers, *Pleurotus*, Sustainable development

Introduction

The accumulation of agro-waste materials generated annually as a result of agricultural activities is classified as one of the world's most serious issues. The main issue with such wastes is that they are difficult to dispose of due to their high levels of enzymatic activity, ability to undergo rapid autoxidation, and pathogenic potential (Ritota and Manzi 2019). Many researchers have turned their attention to the recycling of agricultural leftovers. The challenges linked with the annual generation of agro-wastes, on the other hand, have not yet been fully resolved (Clauser et al. 2021). Much further research on the use of agricultural by-products is still needed. Thanks to mushrooms which have the potential to significantly reduce negative environmental impacts by recycling agricultural by-products into important food items (Thongklang and Luangharn 2016). Mushrooms include fiber, vitamins, and minerals in addition to proteins (Papadaki et al. 2019). They also have antioxidant activity and are used as therapeutic agents (Ruthes et al. 2016). Due to their ability to secrete both cellulose and lignin-degrading enzymes (Bellettini et al. 2016), oyster mushrooms *Pleurotus* spp. offer the highest utilizable potential for agro-waste decomposition (Adebayo and Martinez-Carrera 2015). They are also incredibly

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adaptable to a wide range of temperatures and do not require any expensive or difficult growing conditions (Sekan et al. 2019).

Mushroom production is steadily expanding around the world (Mahari et al. 2020), but it is insufficient to meet the market demands in Egypt. The mushroom grower's reliance on limited waste materials as growing media is one of the most significant production challenges. Farmers' decisions to grow mushrooms are primarily influenced by the availability of inexpensive substrates. Rice straw (RS) is the most extensively used and recognized substrate for mushroom production (Mohamed et al. 2016). However, it has other potential agro-industrial uses such as composting, livestock feed, and energy generation in the form of biogas (FAO 2009). Further, it is not widely available in Egypt. Alternatively, searching for available valueless agricultural residues will lead to mushroom cultivation expansion. Banana cultivation covers a wide area in Egypt since it is a major producer, particularly, in the southern regions where rice straw is scarce. Banana production generates a large amount of rich agricultural waste (pseudo-stems, leaves, and rachis). Leaves are not ideal for biofuel generation, therefore their usage in mushroom growing would be highly feasible (Santa-Maria et al. 2013). Sorghum stalks (SS) are also abundant in Egypt's southern regions, however, the low nutritional value of such lignocellulosic material as well as their cyanogenetic effect limits its usage as animal feed. After the grain harvest, 75% of farmers used to burn SS completely, resulting in soil fertility loss and the production of enormous volumes of air pollutants (Bhatia et al. 2014). The current framework was developed to assess the potential of BR and SS as possible alternatives to RS substrate to produce oyster mushroom fruiting bodies.

Materials and methods

This assessment was conducted at the Mushroom Cropping Unit, Department of Horticulture, Faculty of Agriculture, Sohag University, Egypt. The experiment was performed in duplicate during the period from December to March in two consecutive years. Rice straw (RS), sorghum stalks (SS), and banana residue (leaves and stalks) were the three main lignocellulosic agricultural wastes utilized to grow the oyster mushroom. They were gathered from the agricultural farm of Sohag University's Department of Horticulture as well as local farms in governorates of Sohag and Assuit. *Pleurotus ostreatus* mother culture was received from The Agricultural Research Center, Cairo, Egypt.

Experimental design

There were nine treatments that were performed (3 sole substrates and 6 different mixture substrate formulae). Rice straw (RS), sorghum stalks (SS), and banana residues (BR) were the sole substrates. Three distinct ratios of combined SS or BR with RS were used to make the six mixture formulations (i.e., 1SS:1RS, 2SS:1RS, 1SS:2RS, 1BR:1RS, 2BR:1RS, and 1BR:2RS). As a base media, the sole RS was used (control). A randomized complete block design (RCBD) with three replicates containing a total of 27 bags (i.e., 3 bags of each treatment) was used to test the nine treatments. The entire experiment was carried out twice (i.e., 2 trials).

Culture preparation

Throughout the experiment, a pure culture of the fungus was maintained on malt extract agar 2% (MEA) slants. Sub-culturing was made by transferring a piece (4 mm × 4 mm) of fleshy tissue to Petri-plates incubating it at 25 °C for 7 days. The culture was used for spawn preparation once the mycelia had completely covered the agar medium (Biswas and Layak 2014).

Spawn preparation

Sorghum grains were rinsed, half-cooked, and the excess water drained away before being allowed to cool to room temperature. After filling around 2/3 of each 0.5 L spawn bottle with sorghum grains, they were autoclaved for 30 minutes at 121 ºC under 1.5 PSI. Sterilized bottles were then allowed to cool before being aseptically inoculated with a 6 mm diameter agar disc containing *P. ostreatus* mycelium. The bottles were then incubated in the dark for 18 days at 24 ± 3 °C until the mycelia fully invaded the grains. The mushroom had colonized after 15 days, and the grain spawn was ready to use (Saskiawan et al. (2016).

Substrate processing and spawning

To facilitate shredding, the substrates were left to dry in the sun for 10 days to remove any extra moisture. To enhance the surface area for mushroom mycelium growth, they were chopped into small pieces of roughly

3-5 cm. The substrate was then immersed in tap water overnight. Following the draining of excess water, the wet substrates were pasteurized at 80°C for 2 hours, or until the moisture content reached 65–70%. The substrate was placed into clear polythene bags after being inoculated by spawn at a rate of 5% of the wet weight of the substrate. Every bag (sized 25x15 cm) contained 500 g of a wet inoculated substrate (Hend et al. 2021).

Incubation and cropping

Mushroom cultures were kept in dark rooms to induce mycelial growth (incubation) for 15-18 days (Chang and Miles 2004). The incubated bags were placed on an aluminum shelf under room temperature conditions (24–27°C). Bags were transferred to the growth chamber after colonization was complete, and the temperature was kept at 18°C using an electric air conditioner. The mist irrigation unit was calibrated to provide 85-90% relative humidity in the room (Abed et al. 2021). Cool fluorescent lights (20–50 lux) were set to provide a daily photoperiod of 12 h. In the cropping room, an air hood was also employed to allow gas exchange and fresh air to pass (Mohamed et al. 2020). To assist the development of fruiting bodies, the bags were entirely opened from the top. To keep the mycelia wet, the inoculated bags were irrigated daily with tap water. Pinheads appeared 3-4 days after opening the bags, and mushrooms ripened 3-4 days after that. The fruiting bodies were collected at a week interval after reaching the right size, and the cropping period lasted 45-50 days (Owaid et al. 2017).

Measurements

Mushroom growth and yield performance

Mushroom basidiocarps produced from the different substrates were evaluated for the fruiting bodies yield (g / 500 g substrate) across all flushes. Ten basidiocarps from each treatment in each flush were randomly sampled to determine the average fruiting body weight (g).

Mushroom crude protein

Protein analysis was conducted in the Department of Chemistry and Food Science, Faculty of Agriculture, Sohag University. Total protein content present in fruiting bodies was determined on a fresh weight basis according to the method described by AOAC (2016).

Total antioxidant activity (TAA)

The DPPH method (Chirinang and Intarapichet 2009) was used to determine the radical-scavenging activity of *P. ostreatus* with minor modifications. The absorbance of a standard solution of L. Ascorbic acid, BHT, and Torlex was measured. After that, a blank was made by combining 1 mL methanol: water (60:40) and 2 mL DPPH. 2 ml DPPH was added to the mushroom extract samples. All samples were shacked and kept in the dark for 30 minutes. A spectrophotometer was used to measure the absorbance of the samples at 517 nm (Shimadzu UV-2550, Tokyo, Japan). DPPH scavenging activity (total antioxidant activity) was calculated using the following equation: Total antioxidant activity = (A- B)/ A×100; where: A -Absorbance of the Blank, B- Absorbance of the sample.

Total phenolic content (TPC)

TPC in mushroom extracts was determined using (de Souza et al. (2014) technique with minor adjustments. 100 ml Folin-phenol Ciocalteu's reagent was combined with 1 ml of the sample. After 15 minutes, 2.0 mL sodium carbonate (7.5%) was added to the mixture which was then increased to 10 mL by adding a 60:40 methanol: water mixture. The mixture was vortexer thoroughly mixed before being stored at room temperature for 2 hours in the dark. At 760 nm, the absorbance was compared to a blank. The standard curve was created using a stalk of (10 mg/100 ml) with concentrations of (0.5,1,1.5,2,2.5,3,3.5,4, 4.5). The total phenol content is expressed as mg of gallic acid equivalent (GAE)/100 g of sample on a fresh basis by using the following equation: Y=0.047X-0.0028, Where: X =Absorbance, Y=Concentration, $R^2 = 0.9891$.

Total flavonoids content (TFC)

With minor adjustments, TFC was calculated as defined by (Choi et al. 2007). 1.0 ml of the sample was mixed with 0.2 ml of 10% aluminum chloride+0.2 ml of (1M) potassium acetate and it was made up to 10 ml by distilled water. The mixture was shaken well using a vortexer and kept at room temperature in the dark for 15 min. At 420 nm, the absorbance was measured against a prepared blank using a spectrophotometer. (+)-catechin was used as the reference standard using stalk of (10 mg/100 ml) with (0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5) con-

centration. The following equation was used to convert the results into micrograms g of (+)-catechin equivalents per 100 g fresh mushrooms: Y=175.82X-3.4048 Where: X =Absorbance, Y=Concentration, R^2=0.9957.

Substrate analyses

All substrate analyses were carried out at Cairo University's Desert Soils Reclamation and Development Center in Cairo. The chemical composition of the three primary fresh substrate materials, RS, SS, and BR (leaves and stalks), as well as their spent (substrate remnants after mushroom harvest), were investigated. For the analyses, three replicates of each substrate material were prepared. Samples were ground into a fine powder. The percentages of total N, P, K, organic carbon, and total ash were calculated using the methods of (Metcalfe 1987; George et al. 2013). Total carbohydrates (g/100 g) were determined using (Dubois et al. 1956) technique**.** Lignin, cellulose, and hemicellulose (%) were determined following the method described by (Ayeni et al. 2015).

Statistical process

The SAS version 17.0 software package was used to conduct statistical analysis on all data. The results of each trial were expressed as means with associated standard error values. Statistical significance was determined by analyses of variance procedure (ANOVA) pertinent to RCBD. Duncan's Multiple Range Test was used to compare means at a 5% significance level (Gomez and Gomez 1984).

Results and discussion

For almost all variables, significant differences were found for the effect of both the study trials and substrates, as well as their interaction (Tables 1 to 3 and Figs. 2 to 7). Finding competent substrates for oyster mushroom production among the abundantly available agricultural wastes in a particular region is a key issue for establishing this industry. In this respect, the current work suggests that rice straw (RS) (as a potential common standard substrate) could be replaced partially or completely with banana resides (BR).

Table 1 Fruiting bodies yield of oyster mushroom (*P. ostreatus*) produced on three sole substrates and six different mixtures of SS and BR with rice straw at 1:1, 1:2, and 2:1 ratio

Treatments	Fruiting bodies yield (g/ 500 g substrate) (1)	
	Trial 1	Trial 2
Sole substrate		
RS (Rice straw)	182.00 ±3.27 ^{e} (1)	160.16±7.32 ^{c}
SS (Sorghum stalks)	154.16±6.93 ^{f}	125.50±6.76 ^{e}
BR (Banana residues)	198.00±6.72 ^{d}	159.66±0.28 ^{c}
RS and Sorghum stalks mixture		
Rice + Sorghum 1:1	212.50±8.67 ^{cd}	180.50±0.50 ^{b}
Rice + Sorghum 1:2	173.83±3.75 ^{e}	135.00±2.78 ^{d}
Rice + Sorghum 2:1	231.66±13.89 ^{ab}	184.00±5.22 ^{b}
RS and Banana residues mixture		
Rice + Banana 1:1	202.33±4.64 ^{d}	167.50±7.08 ^{c}
Rice + Banana 1:2	226.16±2.25 ^{bc}	165.16±4.85 ^{c}
Rice + Banana 2:1	244.33±14.63 ^{a}	226.16±3.51 ^{a}
C.V. %	**4.10%**	**3.13%**

Source of variation	Degree of freedom	**Mean square**
Trials (T)	1	17209.1**(2)
Replicates within (T)	4	37.504
Substrate (S)	8	4874.6**
S X T	8	255.68**
Error	32	48.317

(1) Means were separated using Duncan's Multiple Range Test and means within a column followed by the same letter$_{(s)}$ are not significantly different at 0.05 probability level. (2) ** significant at 0.0l level of probability.

The basidiocarp yield of oyster mushrooms (*P. ostreatus*) cultivated in sole BR was remarkably similar to that of mushrooms growing in sole RS substrate according to our findings (Table 1). Similarly, when compared to straw and grasses, Belewu and Belewu (2005) found that banana leaves were a good substrate for paddy straw mushroom (*Volvariella volvacea*) development as well as oyster mushroom (*Pleurotus* spp.) culture. De Siqueira et al. (2011). reported, banana stalks without any supplementation, as a very simple technique for substrate preparation, was efficient in the development of mushroom *Pleurotus Sajor-caju* with a biological efficiency of 74.4 percent.

On the other hand, sole SS substrate performance was noticeably far lower than sole RS and sole BR. Reduction of 18.7% and 21.8% relative to RS and BR, respectively, were found in fruiting bodies yield of the mushroom grown in sole SS substrate (Table 1). Markedly, we observed during our study that some of the emerged pinheads did not grow to marketable basidiocarps when used SS substrate. Incidence of competitor mold contaminants was also observed. This is probably due to the poor nature of SS substrate concerning the water holding capacity. Suitable moisture of the substrate is on average, around 65% to 70% (Mahari et al. 2020), and it is a limiting factor for optimum mushroom growth.

Both RS and BR have a structure with high porosity which allows adequate aeration. However, SS has a compact structure that maintains water much longer and might hinder fungi respiration. Besides, contamination that retarded substrate colonization and inversely affected productivity occurred.

Another factor that may contribute to producing a lower fruiting bodies yield from SS substrate is the higher nitrogen content. The concentration of N was high compared to RS and BR substrates (Fig. 6). Nitrogen is an extremely important factor in mushroom cultivation (Rizki and Tamai 2011) However, high concentrations of nitrogen in the cultivation substrate may burden the cultivation of *Pleurotus* mushrooms (Mohamed et al. 2020). The low nitrogen level can stimulate ligninolytic enzyme production, whereas a high nitrogen level represses it. As reported by Schneider et al. (2018), oyster mushrooms require relatively less nitrogen and more carbon source. It has been shown in previous studies that nitrogen levels near to or above 1.5% blocked the mycelia growth of *P. sajor-caju* (Silva et al. 2007).

On the average of the two study trials, the use of sole BR substrate yielded 4% mushroom basidiocarps greater than the sole RS. Furthermore, mushroom grown in BR substrate had superior external quality characteristics [(greater cap diameter and thickness but thicker shorter stems (Fig. 1) and greater cap weight (Fig. 2)], as well as interior quality parameters [(protein (Fig. 3), antioxidant activity (Fig. 4), and contents of phenols and flavonoids (Table 2)].

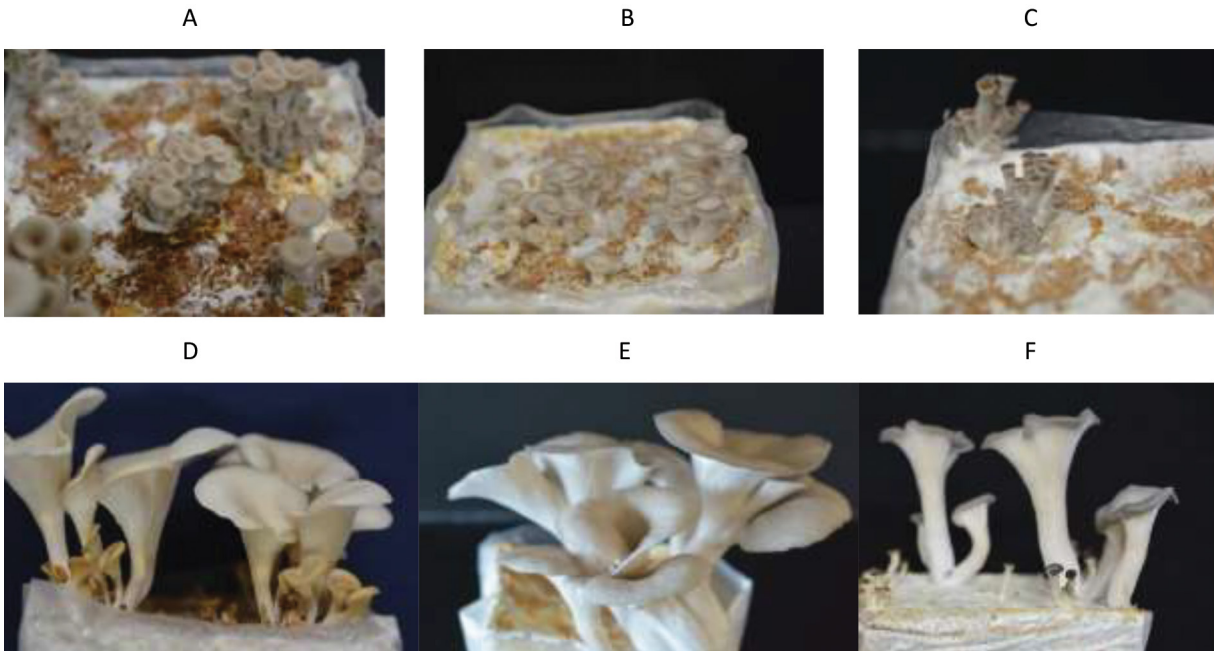

Fig. 1 Primordia (A, B, and C) and fruiting bodies (D, E, and F) of oyster mushroom (*P. ostreatus*) produced on the three sole substrates

A and D are rice straw (RS): B and E are banana residues (BR): C and F are sorghum stalks (SS).

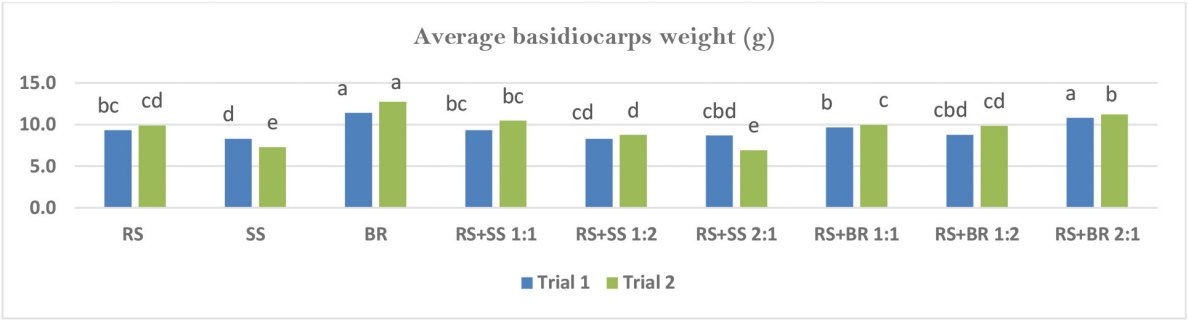

Fig. 2 Average basidiocarps weight of oyster mushroom (*P. ostreatus*) produced on three sole substrates (RS=rice straw, SS= sorghum stalks, and BR= banana residues) and six different mixtures of SS and BR with rice straw at 1:1, 1:2, and 2:1 ratio.

Growth medium may have influenced not only the agronomic but also the nutritional qualities of the fruiting bodies (Alzagameem et al. 2018). Oyster mushroom fruiting bodies grown on all substrate formulae are obviously rich in protein (Fig. 3). The protein content of oyster mushroom basidiocarps ranges from 22.16 % when grown on sole sorghum stalks (SS) to 43.75 % when grown on sole banana residue (BR). The most superior mixes among all six mixtures were rice straw: sorghum stalks RS: SS 1:1 and rice straw: banana residue RS: BR 1:2 (30.33 and 36.16 percent, respectively) (Fig. 3). These results back to previous findings from prior studies by Owaid et al. (2017) who found that the protein content of oyster mushroom basidiocarps differed significantly when grown on different substrates. Also, Ritota and Manzi (2019) reported a wide variation in the protein content of *Pleurotus* spp. produced from different substrates. They reported that protein content in the fruiting bodies ranged from 14.10% using sunflower stalks to 29.36% using wheat straw, and it increased to 34.76% when 20% mahua cake detoxified with methanol was added to the wheat straw.

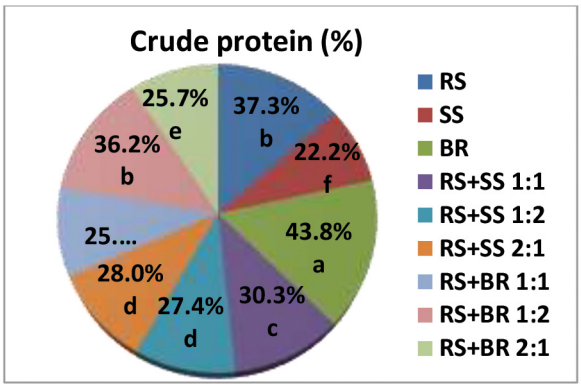

Fig. 3 Crude protein of oyster mushroom (*P. ostreatus*) produced on three sole substrates (RS=rice straw, SS= sorghum stalks, and BR= banana residues) and six different mixtures of SS and BR with rice straw at 1:1, 1:2, and 2:1 ratio

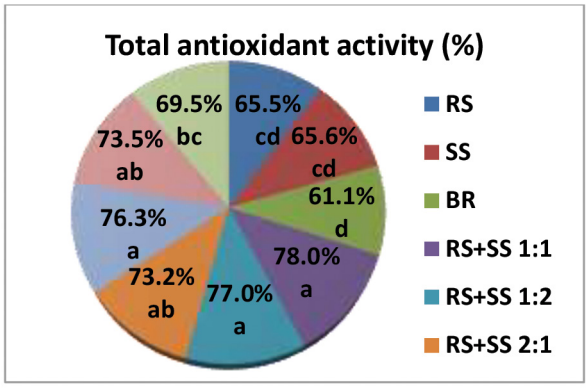

Fig. 4 Total antioxidants activity of oyster mushroom (*P. ostreatus*) produced on three sole substrates (RS=rice straw, SS= sorghum stalks, and BR= banana residues) and six different mixtures of SS and BR with rice straw at 1:1, 1:2, and 2:1 ratio

Phenolic compounds act as reactive oxygen species (ROS) scavenging agents and their synthesis is triggered in response to biotic and abiotic stresses (Onuegbu et al. 2017). In polymeric composite materials, lignin has great potential as an antioxidant to prevent oxidation. Oyster mushroom fruiting body production appeared to have no or only a weak connection with antioxidants (Table 2). For example, while the RS: BR (2:1) mixture was shown to be the best substrate in terms of fruiting body yield, it did not correspond to its antioxidant potential. It is reasonable to think that the high-yielding treatments were not stressed. The results showed that the yield of fruiting bodies was negatively related to total phenol (-0.320) and total flavonoids (-0.320) levels (Table 3).

Table 2 Total phenols and flavonoids of oyster mushroom (*P. ostreatus*) produced on three sole substrates and six different mixtures of SS and BR with rice straw (RS) at 1:1, 1:2, and 2:1 ratio

Treatments		Total phenols (1) (mg/100g)	Total flavonoids (1) (µg /100g)
Sole substrate			
RS (Rice straw)		14.34±0.48 f	4.67±0.45 g (1)
SS (Sorghum stalks)		14.89±0.26 ef	7.03±0.16 e
BR (Banana residues)		16.52±0.28 b	7.75±0.57 d
RS and Sorghum stalks mixture			
Rice + Sorghum 1:1		15.96±0.05 bcd	7.01±0.27 e
Rice + Sorghum 1:2		17.48±0.24 a	11.64±0.20 a
Rice + Sorghum 2:1		15.39±0.43 de	9.70±0.20 c
RS and Banana residues mixture			
Rice + Banana 1:1		15.72±0.31 cd	10.63±0.40 b
Rice + Banana 1:2		16.08±0.64 bc	9.37±0.53c
Rice + Banana 2:1		14.27±0.60 f	5.50±0.10 f
C.V. %		**2.49%**	**4.56%**
Source of variation	Degree of freedom		**Mean square**
Replicates (T)	2	0.3070	0.0635
Substrate (S)	8	3.2535**(2)	16.507**(2)
Error	16	0.1518	0.1386

(1) Means were separated using Duncan's Multiple Range Test and means followed by the same letter$_{(s)}$ are not significantly different at 0.05 probability level. (2) ** significant at 0.0l level of probability.

Table 3 Correlation coefficients (r) between fruiting bodies yield (g/500 g substrate) and some traits of oyster mushroom (*P. ostreatus*) produced on three sole substrates (sorghum stalks SS, banana residues BR, and rice straw RS) and six different mixtures of sorghum stalks (SS) and banana residues (BR) with rice straw (RS) at 1:1, 1:2, and 2:1 ratio

Trait	Correlation coefficients (r)(1)
Average basidiocarps weight (g)	0.403
Total antioxidant activity (%)	0.206
Total phenols (mg/100g)	-0.320
Total flavonoids (µg /100g)	-0.193
Crude protein (%)	0.092

(1) d.f. = 7; * and ** are significant at 0.05 and 0.01 probability levels, respectively.

The quantitative and qualitative yield of cultivated mushrooms is influenced by the substrate's nutritional composition (Agba et al. 2021). Nitrogen stimulates the synthesis of ligninolytic enzymes, whilst P and K regulate the growth of hyphal apices and the creation of branches. Total nitrogen levels in the current study ranged from 0.77 percent in RS substrate to 1.35 percent in SS substrate, which were equivalent to or greater than those reported by Peksen and Yakupoglu (2009) and lower than those published by Silveira et al. (2008). As demonstrated in (Figs. 5, 6), the banana residue (BR) had significantly higher total ash, phosphorus, and potassium content than the RS. Pekşen et al. (2011) and Atila (2017) also reported an increase in ash content as well as P and K macro elements during mushroom growth. In all tested substrates, we found an increase in Ash, P, and K macro-nutrient mineral components, whereas nitrogen decreased as mushrooms convert nitrogen to protein.

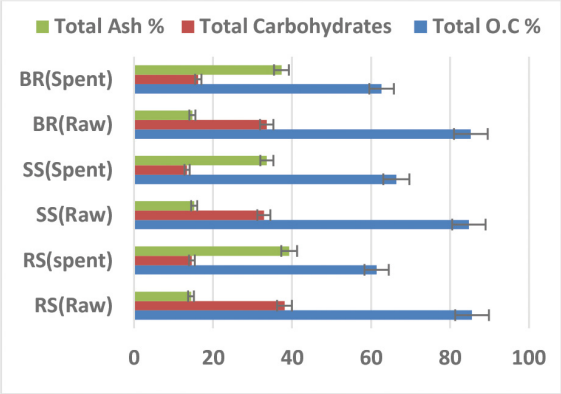

Fig. 5 Total ash, total carbohydrates, and total organic carbon percentage (O.C%) alteration in substrate materials (RS, SS, and BR) before and after oyster mushroom cultivation
RS=rice straw, SS= sorghum stalks, BR= banana residues; lines above the columns refer to standard error values (SE); n = 3.

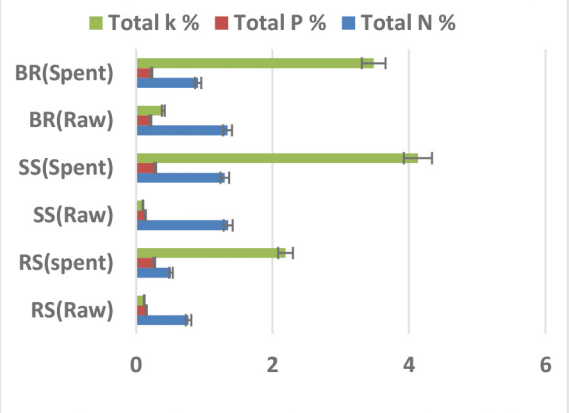

Fig. 6 Total N, P, and k% alteration in substrate materials (RS, SS, and BR) before and after oyster mushroom cultivation
RS=Rice straw, SS= Sorghum stalks, BR= Banana residues; lines above the columns refer to standard error values (SE); n = 3.

Carbohydrates are one of the primary nutrients in mushrooms, accounting for 40-70 percent of the dry weight (Zhou et al. 2016). They are degraded by glycolysis in fungi to provide energy for growth, reproduction, and development, and they can protect cells from environmental stresses such dehydration, temperature, food constraint, and oxygen radicals. In our investigation, the maximum total carbohydrates content was found in fresh banana residue substrate (16.22%), while the least value was determined in sorghum stalks substrate (13.39%). As shown in the paper, significant fluctuations in carbohydrate levels have been linked to mushroom formation (Fig. 5). This is due to oyster mushrooms' need for carbon sources in order to grow. Furthermore, as stated by Horn et al. (2012) and Adebayo and Martinez-Carrera (2015), the production of cellulolytic, xylanolytic, and ligninases enzymes during mushroom mycelial growth makes the sugars in the substrate three to five times more soluble, making it more digestible. The activity of these enzymes is largely determined by the substrate composition, which could explain the high biological efficiency of sole banana residue and its mixtures with rice straw (Assan and Mpofu 2014). Carbon is abundant in cellulose and hemicellulose, which is mycelium's primary food supply. The amounts of organic carbon in all of

the substrates studied were quite similar, and they all decreased dramatically as a result of mushroom development (Fig. 5).

lignocellulosic content degraded by the fungus is crucial to help us interpret our research findings related to the differences in substrate medium productivity. The main function of the growth substrates tested for ligninolytic fungi (*P. ostreatus*) production is to provide a reservoir of cellulose, hemicellulose, and lignin macromolecules, that can be used during the mycelial growth and basidium development. As a result, the ability of a substrate to induce or increase the formation of lignocelluloses is another component that indirectly confers the ability for growth and fruiting. determining the amount of the major component of lignocellulosic materials is cellulose, along with lignin and hemicellulose. Lignin is an aromatic polymer made from phenylpropanoid precursors, while cellulose and hemicellulose are macromolecules made from various polysaccharides. According to our findings presented in (Fig. 7), the various types of raw materials have varying amounts of those macromolecules, similar to Bellettini et al. (2016) research.

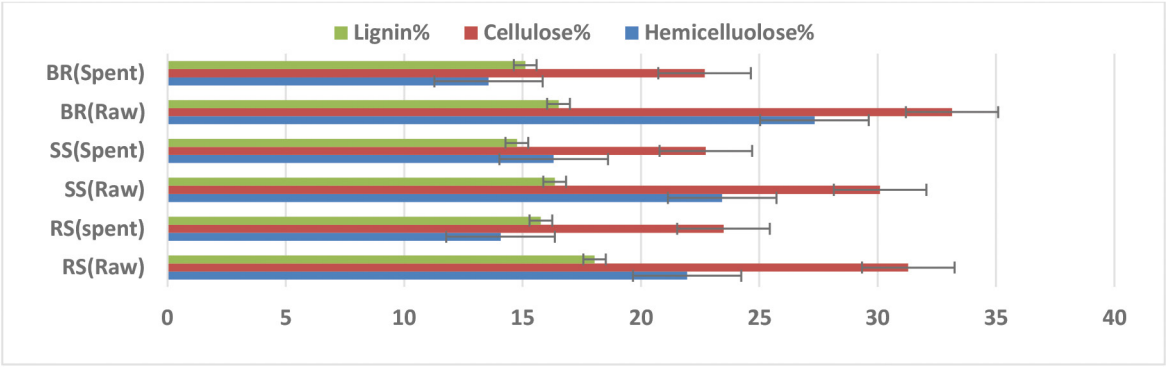

Fig. 7 Hemicellulose, cellulose, and lignin % alteration in substrate materials (RS, SS, and BR) before and after oyster mushroom cultivation

RS=rice straw, SS= sorghum stalks, BR= banana residues; lines above the columns refer to standard error values (SE); n = 3

Furthermore, after being exposed to *P. ostreatus*, all crude fiber fractions showed a decrease according to the current study. Enzymatic breakdown of cellulose appears to be more susceptible than that of hemicellulose, whereas lignin degradation appears to be slower than that of cellulose and hemicellulose (Fig. 7). The structural intricacy of lignin, as well as its large molecular weight and insolubility, make it difficult to degrade. Atila (2019), and Umor et al. (2021) came to similar conclusions. According to Obodai et al. (2003), white-rot fungi (*Pleurotus*) prefer substrates with higher cellulose/lignin ratios. and a previous study by Subagyo and Chafidz (2018) reported that banana plant fibers are high in cellulose, making their breakdown by mushrooms easier. We found that BR (leaves and stalks) had significantly higher cellulose levels and a higher overall breakdown rate than RS and SS, which is considered important evidence of *P. ostreatus*'s great assimilation capacity to banana wastes. The report by Adenipekun and Omolaso (2015) came to similar conclusions. Our findings support the hypothesis that substrates rich in cellulose are good materials for mushroom growing, which could explain the tendency toward higher productivity shown when BR was used alone, as well as the enhanced yield observed when BR was combined with RS at various ratios.

Conclusion

For *Pleurotus ostreatus* mushroom production, sole BR could be a viable RS option. It has the potential to convert low-quality biomass into higher-quality human food. It provided *Pleurotus* with the optimal nutrients required resulting in a high yield with combined high BE and good quality mushrooms. However, its mixture with RS is not recommended as far as the protein and antioxidant contents of the mushroom are concerned. We can also deduce from our research that SS was inferior to all other substrates tested.

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Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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