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ORIGINAL RESEARCH

Differential growth and productivity of oyster mushroom (*Pleurotus pulmonarius*) on agro-waste substrates in semi-arid regions of Kenya

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Abstract

Purpose Food insecurity and poverty are common challenges in arid and semi-arid regions. Diversification into low input agriculture like mushroom cultivation can help address these challenges. However, recommended mushroom substrates in Kenya (rice and wheat straws) are not widely available cheaply. Crop residues found in semi-arid areas can serve as alternative substrates, but their efficiency has not been adequately evaluated. This study evaluated the potential of various agro-waste materials as alternative substrates for cultivation of phoenix oyster mushrooms (*Pleurotus pulmonarius*) in semi-arid regions.

Method Five agro-waste materials and their combinations were tested: maize stalks, beans straw, maize cobs, rice straw, and *Melia volkensii* leaves. The study assessed the effects of these substrates on different mushroom growth and productivity parameters. The experiment was set in a randomized complete block design, under relative humidity of 80 - 90% and temperatures of 23 - 24°C, over a 75 day period.

Results Substrates containing *M. volkensii* failed to colonize fully except in their combination with bean straw, which yielded little. Yields varied significantly by substrate, ranging from 136.2 g/kg of wet substrate in bean straw + *Melia volkensii* to 434.9 g/kg of wet substrate in rice straw. Mushroom yields from maize stalks + bean straw and maize stalks + maize cobs substrates were not significantly different from those of rice straw, the control substrate.

Conclusion The study showed that combinations of maize stalks, bean straw and maize cobs are suitable alternatives to rice straw, as substrates for oyster mushroom production.

Keywords Oyster mushroom, Substrates, Agro-waste materials, Biological efficiency

Introduction

Food security is paramount to the ever-growing world population of the 21st Century. Therefore, scientists all over the world are continuously exploring ways and means to bring more food on the table. Venturing into edible mushroom cultivation on local substrates is one such effort (Kinge et al. 2016) with about 12 species being grown for food (Marshall and Nair 2009). These species include the oyster mushrooms (*Pleurotus* spp.) that are distributed worldwide (Bernabé-González and Cayetano-Catarino 2009). Small-scale growing of mushrooms does not require any significant capital investment and mushroom substrate can be prepared from various agricultural waste materials (Marshall and Nair 2009). The oyster mushrooms are renowned for good marketability and are relatively easy to grow.

Oyster mushrooms (*Pleurotus* spp.) occupy the third position worldwide (Siqueira et al. 2012) and are also highly ranked in terms of nutritional and medicinal values (Duru et al. 2019). As a nutritious fungus, edible mushrooms can be compared with eggs, milk and meat (Belewu and Belewu 2005). They are good sources of vitamins (B-complex and C), essential amino acids, and carbohydrates. However, they are low in fat and contain no starch. Proximate composition of

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oyster mushrooms (*Pleurotus ostreatus*) on dry weight basis includes, 22.61 ± 0.57% proteins, 5.01 ± 0.13% fat, 47.86 ± 1.04% carbohydrates, 16.28 ± 2.19% fibers, 326.97 ± 4.13 Kcal/100 grams gross energy, while when fresh they have a very high moisture content of around 83.24% (Duru et al. 2019). Mushrooms have minerals like phosphorus, potassium, iron, calcium, zinc and copper. They have high availability of lysine and tryptophan and other amino acids usually absent in cereals making them ideal food for patients suffering from hypertension, diabetes and weight-watchers (Pathania et al. 2017). The oyster mushroom has been reported to lower the cholesterol levels in the body (Poppe 2000) and thus can serve as an alternative source of protein for vegetarians. Mushrooms have components of water-soluble polysaccharides obtained from the fruiting bodies which have the ability to inhibit the growth of tumors. A major fraction of the acidic polysaccharide designated as H51 is reported to have strong antitumor activity, and structurally this component consists of a skeleton of β (1, 3)-linked glucose residues, probably having branches of galactose and mannose residues and also containing acidic sugars (Chang and Miles 2004). Being organically grown, mushrooms are thus most recommended for cancer and HIV-positive victims (Hoa et al. 2015).

Agricultural waste disposal is of great concern in today's world as its mismanagement can pose a great risk in environmental pollution. Mushroom cultivation is one eco-friendly and cost-effective method of agricultural waste management. Mushrooms can thrive on agricultural wastes as the growing media or substrate, thus providing a more profitable disposal system for the agro-wastes (Kimenju et al. 2009). The fungi have a property of breaking down lignin cellulosic components which are always difficult to break down into simpler compounds. Thus, transforming the less useful agricultural waste into valuable products which can later be used as manure on agricultural farms (Kamthan and Tiwari 2017).

Although wild edible mushrooms are popular to people living in ASALs, the majority are not familiar with cultivated mushrooms (Chioza and Shoji 2014). This could be attributed to limited availability and lack of awareness on the economic, nutritional and medicinal benefits of cultivated mushrooms. China is the leading in production of edible mushrooms (Royse et al. 2017). Africa produces very small quantities of cultivated mushrooms, accounting for less than 1% of the world's total tonnage, with most of this production being done in South Africa. However, African countries have high potential for widespread accumulative small-scale production of mushrooms because of availability of abundant materials from agricultural wastes that could be used as substrates.

Kenya produces just 500 tons of mushrooms per year, against an annual demand of 1200 tons (Wangui and Xinyan 2019). The mushrooms are produced by small-scale farmers and mainly in Western, Nyanza and Coastal areas. However, only a handful of cultivators are present in the arid and semi-arid (ASALs) and they mainly use rice straw which is not locally and cheaply available. There is therefore a need for studies to identify suitable substrates that are locally available in the semi-arid areas as cheaper alternatives for oyster mushroom production in these areas. The semi-arid regions of Kenya such as Machakos and Kitui, have high potential for mushroom production (Kimenju et al. 2009; Onyango et al. 2011). *Melia volkensii* is becoming a popular agroforest tree in the ASALs of Kenya (Orwa et al. 2009). This tree is occasionally pruned, making available herbage that could be used as substrates for oyster mushroom cultivation. However, its effectiveness, especially for small-scale production in these regions, has not been adequately evaluated as this study has done.

Material and methods

Experimental site

The study was conducted at Machakos Agricultural Training Center (ATC), in Machakos County (latitude -1.54474 and longitude 37.24098), between 6th March and 20th May, 2019. An average room temperature of 23 -24°C was maintained during the period of cultivation.

Materials used

The materials used during the experiment included; mushroom spawn, steam treatment drums, hand sprayer, wheat bran (supplementation) while substrates included; maize stalk, bean straw, maize cobs, rice straw and *Melia volkensii* leaves. The other routine equipment and chemicals used were thermometer, hygrometer, weighing balance, water, calcium carbonate as buffer, and plastic bags. For each treatment, the substrates materials were used at a rate of 1 kg wet weight, and for the substrate with combined materials, each of the two materials weighed 500 gms wet weight. A total of 15 treatments was used, as shown in Table 1 below.

Table 1 Treatments of substrate and their combinations

Treatment No.	Substrate materials	Treatment abbreviation
T1	Maize stalks	MS
T2	Bean straw	BS
T3	Maize cobs	MC
T4	Rice straw	RS
T5	*Melia volkensii* leaves	MV
T6	Maize stalks + bean straw (1:1)	MSBS
T7	Maize stalks + maize cob (1:1)	MSMC
T8	Maize stalks + rice straw (1:1)	MSRS
T9	Maize stalks + *Melia volkensii* leaves (1:1)	MSMV
T10	Bean straw + maize cobs (1:1)	BSMC
T11	Bean straw + rice straw (1:1)	BSRS
T12	Bean straw + *Melia volkensii* leaves (1:1)	BSMV
T13	Maize cobs + rice straw (1:1)	MCRS
T14	Maize cobs + *Melia volkensii* leaves (1:1)	MCMV
T15	Rice straw + *Melia volkensii* leaves (1:1)	RSMV

The dry maize cobs, maize stalks and dry bean straw were obtained from farms within Machakos County, while *Melia volkensii* leaves were collected from farms in Kitui County and sun dried, and rice straw was obtained from paddy rice farms in Mwea irrigation scheme, Kirinyaga County. Machakos and Kitui are ASAL Counties while Kirinyaga is a non-ASAL County. The mushroom spawn was purchased from Jomo Kenyatta University of Agriculture and Technology (JKUAT).

Preparation of substrates, spawning and spawn-run

The experiment adopted a procedure recommended by the Ministry of Agriculture and a modified protocol by Gregori et al. (2007) and Mamiro et al. (2014). The dry substrates were ground separately into small pieces of 5-10mm using a shredding machine which had a sieve of 10 mm diameter. They were each weighed into 10 kilograms, put in sacks and soaked in water for 24hrs to attain adequate moisture content. The materials were then hanged to drain excess water from the substrate until only 2 or 3 drops came out when the fist squeeze test was applied in order to ensure moisture retention of 65% to 75%. In order to obtain optimal pH range for oyster mushroom cultivation, calcium carbonate was added to all substrates at the rate of 1 % of the wet weight. All substrates were also supplemented with 25% wheat bran on dry weight, in order to raise their nitrogen content. The substrate mixture was then well blended on a polythene sheet and 1 kg of each substrate put into mushroom polythene bags (9 x 15 inches) and pressed firmly. The bags were then closed and plastic neck and sterile cotton wool were introduced to make a breather. To sterilize the substrates, steam pasteurization was used, following Kinge et al. (2016). Steaming was done for 2 hours in clean drums filled with water to about 4 inches height, iron screen was placed inside so it was 1 inch higher than water. The bags were then arranged inside the pasteurization drums until full and the drums tightly covered. Small holes (5 mm in diameter) were made on the drums lids for reducing pressure build up. The drums were left for 12 hours for cooling to attain a temperature of 25 ± 3°C, according to the protocol by Kimenju et al. (2009). Aseptic conditions in the production room were maintained by spraying 99.5% iso-propyl- alcohol on clean working surfaces before spawning was done. The substrates were spawned at the rate of 4 ± 1% and incubated at 24 ± 1°C and 80-85% relative humidity under dark conditions, until the surface of substrates was entirely covered with mycelium. The experiment was set in a randomized complete block design (RCBD), with three replicates per treatment, (six culture bags per treatment). This was

done by having similar experimental units grouped into 3 blocks, or replicates whereby the spawned mushroom bags were tagged properly and arranged in the three shelves in the chamber; the top shelves, middle and the lower shelves. The treatments were randomly distributed within the three blocks. This was done in order to account for any variations in the experiment due to lighting effects within the room.

Fruiting induction and harvesting

Once all the substrates were fully colonized, the humidity of the room was raised to 85-90% by spraying water in the air three times a day, using hand held sprayers. Incubation took about 4 weeks for most substrates, with the end of incubation being marked by a completely white substrate, followed by pinning. After complete colonization, some lighting was allowed into the room by withdrawing the curtains. The mushroom bags were opened by making 3 holes of 5 cm diameter on each bag. Fresh air during the reproductive stage was ensured by opening the windows in order to decrease CO_2 concentration. Harvesting of mature mushrooms was done continuously over a period of 45 days until no more mushrooms could be harvested from most of the treatments. Room temperatures and humidity were recorded daily. Number of mushrooms (fruiting bodies), mushroom mass, stipe length and pileus diameter were recorded in each harvest.

Data analysis

The data were analyzed using computer software Statistical Package for Social Science (SPSS) version 21.0. Duncan's Multiple Range Tests (DMRT) was used to compare the mean differences among treatments. Biological Efficiency (BE) was calculated using the following formula: BE = (mushroom fresh weight /initial substrate dry weight) x 100, while productivity was obtained using the formula: P= (mushroom fresh weight/wet substrate) x 100), according to Philippoussis (2009).

Results and discussion

Spawn run time and fruiting

Among the five substrates, *Melia volkensii* leaves had insignificant mushroom spawn run, with only 5% of colonization. Therefore, the life-cycle ceased and no mushrooms were obtained from this treatment. However, the combination of *M. volkensii* leaves and bean straw resulted in 70% of colonization and some mushroom production. There was no contamination experienced in all the other substrates. There is no report about the use of *M. volkensii* for mushroom production. However, Orwa et al. (2009) reported the potential use of *M. volkensii* leaves extracts as a fly and flea repellent. Furthermore, the *M. volkensii* leaves extract showed anti-feed activity against *Schistocerca gregaria*, and larvicidal and growth inhibitory effects against mosquitoes. Similarly, Kamau et al. (2015) showed that some compounds extracted from different *M. volkensii* plant parts exhibited high antimicrobial activity against *Aspergillus niger*. The authors reported for the first time the existence of toosendanin, scopoletin and kulactone in *M. volkensii*, which had antifungal, antibacterial and antiplasmodial activities. This antimicrobial effect could probably explain why *Melia volkensii* did not perform well in our study.

The days to fruiting varied significantly ($P<0.05$) among the treatments with the mean ranging from 35.1 days to 48.1 days in maize cobs + rice straw combination and bean straw + *M. volkensii* substrate combination, respectively (Table 2). This result was different from that of Kimenju et al. (2009) in their study with *Pleurotus ostreatus* that showed maize cobs taking shorter time to pinning (19.6 days), followed by bean straw (29.8 days) while rice straw took 36.3 days. This variation could have been attributed to the different fungal strain used in this study. The mushroom flushing intervals were significantly affected by substrate type and some substrates exhibited shorter flushing intervals than others, thus giving shorter cropping cycles and therefore more crops in a given length of time (Table 2). Combining maize cobs with rice straws, maize straws with maize cobs and maize straws with bean straw, shortened the time for mushroom fruiting. Different substrates contain different lignin and cellulose levels and that materials with high quality lignocellulose will take different time to fruiting from the lower quality lignocellulosic materials (Kimenju et al. 2009). According to Philippoussis (2009), mushrooms take different time to grow and fruit on different substrates and those that are slow in mycelia colonization are more sensitive to fungal and bacterial competition resulting in lower yields, and therefore the early fruiting substrates are less susceptible to microbial competition.

Table 2 Time from spawning to the beginning of mushroom fruiting, in function of substrate composition

	Time (days) from spawning to harvesting			Time period Between flushes (days)	
Treatments	**Flush[1]**	**Flush[2]**	**Flush[3]**	**Flush[1-2]**	**Flush[2-3]**
Maize cobs + rice straw	35.1[a]	50.3[ab]	66.4[abcd]	15.2	16.1
Maize stalks + maize cobs	36.4[a]	48.2[a]	61.7[abc]	11.8	13.5
Maize stalks + bean straw	37.9[ab]	49[a]	62.6[abc]	11.1	13.6
Rice straw	40.5[bc]	49.9[ab]	60.1[a]	9.4	10.2
Maize stalks	41.7[cd]	53.5[abc]	63.5[abcd]	11.8	10
Bean straw + rice straw	42.8[cde]	53.1[abc]	65.1[abcd]	10.3	12
Bean straw	43.9[cde]	56.3[c]	66.2[abcd]	12.4	9.9
Maize cobs	44.1[cde]	54.7[bc]	60.8[ab]	10.6	6.1
Maize stalks + rice straw	44.8[def]	57.5[c]	67.1[bcd]	12.7	9.6
Bean straw + maize cobs	45.7[ef]	57.3[c]	68.3[cd]	11.6	11
Bean straw + *Melia volkensii*	48.1[f]	56.5[c]	69.8[d]	8.4	13.3
Overall means	**41.9**	**53.2**	**64.4**	**11.3**	**11.2**

Means within the same column followed by the same letters are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test (DMRT)

Stipe length, diameter and number of fruiting bodies in function of substrate composition

Stipe length in function of substrate composition

The tallest mushroom was obtained from bean straw + maize cobs combination (6.1 cm) while the shortest was obtained from bean straw + *M. volkensii* combination (3.8 cm) as shown in Table 3. There was no significant difference ($P<0.05$) in mean stipe length among most of the substrates. Apart from bean straw, all other substrates produced mushrooms that were of statistically similar stipe length to rice straw which is the commonly used substrate. Generally, the results showed that mixing most substrates had no significant effect on the length of mushrooms (Table 3). However, the result showed that adding maize cobs to bean straw increased the stipe length of the mushrooms significantly.

Diameter in function of substrate composition

The overall mean cap diameter was 8.3 cm with the bean straw + maize cob substrate having the largest diameter (9.2 cm) and the maize stalk substrate having the smallest (7.3 cm) as shown in Table 3. The mushroom diameter from bean straw + maize cobs substrate was significantly larger ($P<0.05$) than that of rice straw, maize stalk, bean straw + rice straw and bean straw + *M. volkensii* substrates. On the other hand, mushroom diameter in maize stalks was significantly smaller ($P<0.05$) than all the substrates apart from bean straw + *Melia volkensii* substrate. Rice straw mushroom diameter was only significantly different ($P<0.05$) from bean straw + maize cobs substrate. It was observed that maize cobs yielded mushrooms with wider cap diameter when bean straw was added to it. This result showed that combining substrates had little effects on cap diameter.

Fruiting bodies number in function of substrate composition

The overall mean of mushroom fruiting bodies was 7.8 (Table 3), with maize stalks + bean straw combination recording the highest (9.5), followed by rice straw and maize stalks + maize cobs substrates with a mean of 9.3 each, while bean straw + *M. volkensii* had the lowest number of fruiting bodies (6.2). Among substrates without combinations, the highest number of mushrooms was obtained in the rice straw substrate, as also reported by Tarun et al. (2018). However, the combination of rice straw with other substrates resulted in fewer number of fruiting bodies. On the other hand, the combination of maize stalks with bean straws resulted in the highest number of mushrooms.

Table 3 Stipe length, diameter and number of fruiting bodies in function of substrate composition

Treatment	Mean		
	Stipe length (cm)	Diameter (cm)	Number of fruiting bodies
Rice straw	5.7^{cde}	8.1^{abc}	9.3^{c}
Maize stalks	5.3^{bc}	7.3^{a}	6.6^{a}
Maize stalks + maize cobs	5.9^{de}	8.5^{cd}	9.3^{c}
Maize stalks + bean straw	5.5^{bcde}	8.3^{bcd}	9.5^{c}
Maize stalks + rice straw	5.3^{bc}	8.5^{bcd}	6.7^{a}
Maize cobs	5.8^{cde}	8.3^{bcd}	7.7^{abc}
Maize cobs + rice straw	5.2^{bc}	8.3^{bcd}	8.0^{abc}
Bean straw	4.9^{b}	8.4^{bcd}	8.6^{bc}
Bean straw + rice straw	5.3^{bcd}	8.3^{bc}	7.4^{ab}
Bean straw + *Melia volkensii*	3.8^{a}	7.6^{ab}	6.2^{a}
Bean straw + maize cobs	6.1^{e}	9.2^{d}	6.9^{ab}
Overall	**5.3**	**8.3**	**7.8**

Means within the same column followed by the same letters are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test (DMRT)

Yield, productivity and biological efficiency in function of substrate composition

The overall average mean weight for all the substrates was 303.3 g/kg of wet substrate while the overall mean biological efficiency was 91% as shown in Table 4. Average yields varied from 136.2 g/kg in bean straw + *M. volkensii* to 434.9 g/kg in rice straw, and the two means were significantly different (P<0.05). Rice straw yielded significantly higher (P<0.05) than maize stalks and cobs, an observation that agreed with Tarun et al. (2018), who reported higher mushroom yields in rice straw than in maize stalks in pink oyster mushrooms. Similar results were also found by Kimenju et al. (2009). However, results in Table 4 further show that yields from rice straw were not significantly different from the maize stalk + bean straw and maize stalk + maize cob substrate combinations, while combining rice straw with maize or bean substrates lowered its yield significantly. It was also observed that adding maize cobs to maize stalks increased the weight of the mushrooms, which could be attributed to higher cellulose and hemicellulose contents in maize cobs than it is in the maize stalks. It was further observed that combining bean straws with maize stalks also increased the yields. This could have been attributed to higher nitrogen contents in the bean straw, since beans are leguminous plants. The study showed that there were significant differences (P<0.05) in biological efficiency among substrates used. The average biological efficiency varied from 37.1% to 130.6% for bean straw + *Melia volkensii* and for rice straw respectively. The experiment showed that mixing substrates had significant effects on the yield and biological efficiency of oyster mushrooms. According to Philippoussis et al. (2001), cellulose/lignin ratios of agro-waste substrates were positively correlated to mycelial growth rates and mushroom yields of *P. ostreatus* and *P. pulmonarius*. It was observed that combining rice straw with maize cob, maize straw or bean straw substrates lowered the biological efficiency of the substrates. This was in conformity with the results by Sitaula et al. (2018) who observed that rice alone gave higher biological efficiency (96%) than in combination with maize cob that gave a biological efficiency of 74%. It was also observed that biological efficiency of bean straw increased significantly when maize cobs were added to the substrate while the same increased for maize straw when maize cobs or bean straws were added. Among all the combined substrates, maize straws + maize cobs gave the highest biological efficiency (118.4%) followed by maize straws + bean straws (112.8%), and the two were not significantly

different (P<0.05) from rice straw which was the highest in BE overall. These materials are locally available cheaply within the ASALs and can serve as alternative sources of oyster mushroom substrates. According to Philippoussis (2009), *Pleurotus* spp. are efficient colonizers and bio converters of lignocellulosic residues into palatable human food with medicinal properties using a complete lignocellulolytic enzyme system. Different substrates contain different amounts of cellulose and lignin and thus have different rates and efficiency of biodegradation. In this study, oyster mushroom (*Pleurotus pulmonarius*) was most efficient in degrading rice straw, followed by maize stalks+ bean straw and maize stalks+ maize cobs, and least efficient degrading bean straw+ *Melia volkensii* substrate.

Table 4 Mushroom fresh weight (Ranked - largest), biological efficiency (BE) and productivity in function of substrate composition

Treatment	Overall mean weight (g/kg)	Productivity (%)	Biological efficiency (%)
Rice straw	434.9^{f}	43.5^{f}	130.6^{e}
Maize stalks + bean straw	403.7^{ef}	40.4^{ef}	112.8^{de}
Maize stalks + maize cobs	374.2^{ef}	37.4^{ef}	118.4^{de}
Maize cobs	336.1^{de}	33.6^{de}	106.0^{cd}
Bean straw + maize cobs	303.1^{cd}	30.3^{cd}	90.8^{bc}
Maize cobs + rice Straw	295.7^{cd}	29.6^{cd}	91.0^{bc}
Bean straw	284.1^{bcd}	28.4^{bcd}	80.9^{b}
Maize stalks + rice straw	273.4^{bcd}	27.3^{bcd}	84.4^{b}
Bean straw + rice straw	260.2^{bc}	26.0^{bc}	76.1^{b}
Maize stalks	223.0^{b}	22.3^{b}	71.0^{b}
Bean straw + *Melia volkensii*	136.2^{a}	13.6^{a}	37.1^{a}
Overall means	**302.3**	**30.2**	**91.1**

Means within the same column followed by the same letters are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test (DMRT)

Correlation of different mushroom growth parameters, substrate dry weight and substrate moisture content

The results from this study showed that mushroom stipe length was significantly correlated to several growth parameters as shown in Table 5: the longer the stipe length, the wider was the cap diameter; mushrooms with longer stipe length weighed heavier and had a higher biological efficiency than those with shorter stipe. Cap diameter was significantly negatively correlated to the number of fruit bodies, but positively correlated to mushroom fresh weight and biological efficiency. Mushrooms with larger cap diameters had fewer number of fruit bodies and higher weight as well as a biological efficiency, compared to those with smaller cap diameters. The number of fruit bodies had a significant positive correlation with the fresh weight and biological efficiency of mushrooms, since the more the number, the heavier the mushrooms were and the higher was the biological efficiency. The results further show that fresh weight of the mushrooms, was positively correlated with biological efficiency. Similarly, time to first harvest was positively correlated with fresh weight and biological efficiency. The number of fruit bodies harvested and time taken to first harvest varied greatly, indicating that the two variables were substrate dependent. The earlier producing substrates produced more fruit bodies than the late producing ones, as also reported by Nageswaran et al. (2003), who found the same correlation between the two parameters. The cap diameter and stipe length were positively correlated while it was observed that cap diameter was very much dependent on the number of fruiting bodies per bag. The fewer the fruiting bodies, the wider the cap diameter due to lower competition for space, nutrients and the available moisture (Kimenju et al. 2009).

Table 5 Pairwise correlations between different mushroom growth parameters

Growth parameters	Stipe length	Cap diameter (cm)	Number of fruit bodies	Total fresh weight	BE (%)	Days to first harvest
Stipe length	1					
Cap diameter (cm)	0.398** (0.000)	1				
Number of Fruit bodies	0.060 (0.448)	-0.216** (0.006)	1			
Total fresh weight	0.440** (0.000)	0.290** (0.000)	0.487** (0.000)	1		
Biological efficiency (%)	0.466** (0.000)	0.284** (0.000)	0.472** (0.000)	0.992** (0.000)	1	
Days to first harvest	-0.120 (0.127)	-0.019 (0.813)	-0.416** (0.000)	-0.431** (0.000)	-0.438** (0.000)	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed). N= 164

Conclusion

Choice for the right substrate for oyster mushroom cultivation is very important to growers since it determines mushroom growth and yields. From this study, it could be concluded that *Melia volkensii* leaves are not suitable substrates for oyster mushroom production. The study showed that combining maize cobs with rice straws, maize stalks with maize cobs and maize stalks with bean straw, hastened the days to mushroom fruiting compared to pure substrates. The study further showed that the mean weight, biological efficiency and productivity of oyster mushroom depends on the substrate type used. The performance of the substrates in terms of yields can be arranged in order of decreasing suitability as follows; rice straw, maize stalks + bean straw, maize stalks + maize cobs, maize cobs, bean straw + maize cobs, maize cobs + rice straw, bean straw, maize stalks + rice straw, bean straw + rice straw, maize stalks and bean straw + *M. volkensii*. It can therefore be concluded that some of the locally available materials in the semi-arid areas, viz maize stalks, bean straw and maize cobs and their combinations are suitable substrates for oyster mushroom production. Further research could be done on the specific nutritional contents of mushrooms from different substrates.

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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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