Research Article

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Effect of *Sesbania sesban* on cultivation of *Agaricus bisporus*, Basidiomycota, and properties of spent mushroom compost outcome

https://doi.org/10.1515/opag-2018-0068
received August 14, 2018; accepted November 22, 2018

Abstract: Because wheat straw has a high cost as a feed for livestock, this work aims to use straw of Egyptian pea (*Sesbania sesban*) in compost preparation as an alternative for the cultivation of *Agaricus bisporus*. Six composts were used within this study on two mushroom strains *A. bisporus* (C9 and F599 strains). The type of compost has a significant ($p<0.05$) effect on the size of button mushroom fruits. WHS1 compost exhibited the best diameter of pileus at 5.28 cm while WCS1 compost showed the lowest diameter reaching 4.68 cm. *A. bisporus* C9 had the longest stipe while *A. bisporus* F599 has the greatest cap diameter.*A. bisporus* F599 showed a larger ratio of the diameter of pileus to the length of stipe (DP/LS ratio) (1.14) compared with C9 (1.07). C:N ratios of compost decreased significantly ($p<0.05$) after cultivation of mushrooms because of the high increase of nitrogen content in spent mushroom compost (SMC). Finally, the straw of *S. sesban* is suitable as a supplement for the cultivation of *A. bisporus*.

Keywords: Agro-wastes, Composting, Edible mushroom, Egyptian pea, Quality of fruiting bodies

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1 Introduction

Mushrooms became one of the most popular food resources worldwide and are very much appreciated by consumers (El Sheikha and Hu 2018). Button mushroom (*Agaricus bisporus*) was the first produced globally. It is the most famous edible macrofungus and belongs to Basidiomycota phylum (Chang and Miles 2004). *A. bisporus* is rich in nutrients and various elements, including essential amino acids, vitamins, proteins, and polyphenols. This mushroom has both nutritional and medicinal importance (Owaid et al. 2017). The medical perspective includes various benefits including the use of fungus in the treatment of cancers (Salih and Al-Mosawy 2010), as antioxidants (Kimatu et al. 2017), Larvicidal (Arul et al. 2017), anti-diabetes, antibacterial and antifungal infections (Kumar et al. 2016), as it improves the immune system (Kavyani et al., 2012). More recently, metallic nanoparticles were biosynthesized from fruiting bodies of *A. bisporus* such as silver nanoparticles which are used as a nano-drug (Atila et al. 2017).

A. bisporus has been enabled to biodegrade ligno-cellulosic matters by its ligno-cellulolytic enzymes like cellulases (cellobiohydrolase and α-glucosidase) and ligninases (guaiacol-oxidizing peroxidase and laccase), to utilize agro-substrates as energy and carbon sources (Rana and Rana 2011). The genome of *A. bisporus* encodes a limited repertoire of lignin-modifying enzymes compared to white rot fungi which decayed the plant wood (Morin et al. 2012). *A. bisporus* was grown and cultivated on different composts composed from date-palm (*Phoenix dactylifera*) trunk (Hamoodi and Hameed 2013), sunflower (*Helianthus*) residues (Muslat et al. 2014), wheat (*Triticum*) straw, rice straw, corn stalk (*Zea mays*) (HaoLin et al. 2017), and straw of the reed plant (*Phragmites australis*) (Owaid et al. 2018) mixed with some bio-amenders like urea, chicken manure, and gypsum.

Egyptian pea, *Sesbania sesban*, is a botanical species belongs to Fabaceae (the legume family). *S. sesban* is called Egyptian Riverhemp or the Egyptian pea in English as a common name or seseban in Arabic. The origin of the Egyptian pea is unclear, but it is cultivated and distributed throughout tropical Asia and Africa (Orwa et al. 2009). It contains crude protein levels of 209 g/kg on a dry weight basis (Kiatho 1997). Various parts of the Egyptian pea are used for different purposes like weed control, antimicrobial and anti-oxidant efficacies (Nigussie and Alemayehu 2013).

The straw of *S. sesban* is considered an unused cellulosic matter to feed to livestock. Thus this study aims to propose *S. sesban* straw compost as an alternative for wheat straw as a compost for carbon and nitrogen sources. This straw decreases the cost of production of *A. bisporus* and this test is considered the first attempt to use Egyptian pea straw in the compost of *A. bisporus*. Properties of fruiting bodies of *A. bisporus* and spent mushroom compost (SMC) were investigated.

2 Materials and Methods

2.1 Mushroom strains

Two strains; *Agaricus bisporus* F599 (white button mushroom) and *Agaricus bisporus* C9 (brown button mushroom), were obtained from ITALSPAWN, Italy by Hameediyah Mushroom Farm (HMF), Ramadi, Kilo 18, Anbar, Iraq. They were sub-cultured on potato dextrose agar (PDA) (Oxoid, England) and used in this investigation study.

2.2 Chemicals and organic matters

Six organic matter formulae were obtained by mixing of compounds. The organic matter components.; wheat straw, straw of Egyptian pea (*Sesbania sesban*, Figure 1), horse manure and chicken manure were obtained from agricultural fields in Ramadi, Iraq. The powder of phosphate rock was obtained from State Company For Phosphate in Anbar in a raw form. Calcium sulfate ($CaSO_4$) was obtained from the local market. The six formulae were prepared as in table 1, after going through the composting processes described previously (Alheeti 2009).

2.3 Physicochemical characteristics of compost extracts

One gram (1 g) of the dried powder of each formula (compost) was taken individually as in table 1, mixed with 5 ml distilled water (D.W) and put in a shaker for 1 hr. These aqueous samples were used to determine electrical conductivity (EC) and hydrogen ion concentration (pH) by EC and pH meters respectively. Also, the C:N ratios were calculated after assessing the carbon content as in the method of Page (Page, 1982) and the nitrogen content by the Kjeldahl method using Gallenkamp Kjeldahl Apparatus (Sawhney and Singh, 2000).

Figure 1: *Sesbania sesban* plant

Table 1: Compositions of composts and their carbon:nitrogen (C:N) ratio (By dry weight)

Treatments	Wheat straw	Horse manure	Chicken manure	Sesbania sesban straw	CaSO4	Phosphate rock	C:N ratio
WH	45%	45%	-	-	5%	5%	42.5:1
WHS1	40%	20%	-	30%	5%	5%	38.8:1
WHS2	30%	45%	-	15%	5%	5%	35.8:1
WC	45%	-	45%	-	5%	5%	37.5:1
WCS1	40%	-	20%	30%	5%	5%	36.6:1
WCS2	30%	-	45%	15%	5%	5%	30.8:1

Legend: C:N ratio of Wheat straw: 60:1, horse manure: 25:1, chicken manure: 15:1, Egyptian pea (*Sesbania sesban*) straw: 20:1.

2.4 Statistical analysis

Statistical significance was determined using a Two-Factor Experiment in a C.R.D (Completely Randomized Design) in two-ways using GenStat program (VSN International Ltd., UK). Values at $p<0.05$ were considered significant. Three replicates were performed within this work.

Ethical approval: The conducted research is not related to either human or animal use.

3 Results and Discussion

3.1 Size of fruiting bodies of *Agaricus bisporus*

The highest diameter of pileus was recorded as 5.62 cm for *Agaricus bisporus* F599 on WHS1 compost, followed 5.37 cm, 5.32 cm and 5.30 cm for the same strain on WSC2, WC, and WH composts respectively. This difference was significant ($p<0.05$). The lowest diameters were 4.28 cm and 4.32 cm for *A. bisporus* C9 on WCS1 and WC composts, followed 4.44 and 4.46 cm for this strain on WH and WCS2 composts respectively. Generally, *Agaricus bisporus* F599 was larger than *A. bisporus* C9 in terms of diameter of pileus reaching 5.29 and 4.50 cm respectively (Table 2), which was significantly different ($p<0.05$). Indeed, the type of compost had a significant effect ($p<0.05$) on the sizes of button mushroom fruits. WHS1 compost exhibited the largest diameter of pileus (5.28 cm) while WCS1 compost showed the smallest diameter reaching 4.68 cm. The increased size of fruiting bodies is a reflection on improving the quality of *A. bisporus* as shown in WHS1 compost which was composed from horse manure instead of chicken manure with 30% *Sesbania sesban* straw, which is in agreement with previous results (Rashid et al. 2018). This issue relates with which plant which improves the properties of the compost, in addition to the good characteristics of horse manure compared with chicken manure toward growing *A. bisporus*. The composted horse manure is stable, while the composted chicken manure is very unstable (Vukobratović et al. 2013). Also, the C:N ratio of WHS1 reaching 38.8 may positively influenced the increased size of pileus (Table 1).

Shorter stipe is essential in mushroom production, even more so compared to the diameter of pileus (Owaid et al. 2015a). Table 3 shows the shortest length of stipe wass 3.88 cm for *A. bisporus* C9 fruits on WCS2 compost, followed by 4.07, 4.21 and 4.24 cm for fruiting bodies of *A. bisporus* C9 on WC, WHS2 and WCS1 composts respectively. The longest stipe was 4.82, 4.80 and 4.78 cm for fruits of *A. bisporus* F599 on WC, WCS2, and WH composts respectively. Generally, WHS2 had the shortest stipes of 4.27 cm followed by 4.28 and 4.34 cm on WCS1 and WCS2 composts respectively, while the longest stipe was 4.54 cm for the control fruits (WH). *A. bisporus* F599 showed a stipe length of 4.58 cm compared with *A. bisporus* C9 (4.17 cm). The quality of fruiting bodies is related to a short stipe and wide pelius before the cap opens and that reflects on the texture (McGarry and Burton 1994).

A. bisporus F599 has shown bigger ratios 1.25, 1.18 and 1.16 on WHS1, WHS2, and WCS1 composts respectively, whereas the smaller ratios of 1.0, 1.02 and 1.05 were recorded on WCS1, WH and WC composts using *A. bisporus* C9, respectively (table 4). Generally, *A. bisporus* F599 showed a larger ratio (1.14) compared with C9 (1.07). The type of compost effects on this parameter varied significantly ($p<0.05$). WHS1 and WHS2 composts showed bigger ratios of 1.19 and 1.13 respectively, while smaller ratios of 1.07 and 1.08 were recorded on WH and WC composts, respectively.

A. bisporus C9 has the best length of stipe while *A. bisporus* F599 has the best diameter of the cap. The last property reflects on the suitable size and quality of mushrooms especially on the ratio of the diameter of pileus to the length of stipe (DP/LS ratio) as in table 1 (Owaid et al. 2015b).

Table 2: Diameter of pileus of *A. bisporus* on various composts (cm)

Strains	WH	WHS1	WHS2	WC	WCS1	WCS2	Mean
F599	5.20	5.62	5.17	5.32	5.08	5.37	5.29
C9	4.44	4.95	4.56	4.32	4.28	4.46	4.50
LSD (p<0.05)				1.5			0.12

Legend: WH compost (control): 45% wheat straw, 45% horse manure, 5% $CaSO_4$ and 5% phosphate rock. **WHS1** compost: 40% wheat straw, 20% horse manure, 30% Egyptian pea (*Sesbania sesban*) straw, 5% $CaSO_4$ and 5% phosphate rock. **WHS2** compost: 30% wheat straw, 45% horse manure, 15% Egyptian pea (*Sesbania sesban*) straw, 5% $CaSO_4$ and 5% phosphate rock, **WC** compost: 45% wheat straw, 45% chicken manure, 5% $CaSO_4$ and 5% phosphate rock. **WCS1** compost: 40% wheat straw, 20% chicken manure, 30% Egyptian pea (*Sesbania sesban*) straw, 5% $CaSO_4$ and 5% phosphate rock. **WCS2** compost: 30% wheat straw, 45% chicken manure, 15% Egyptian pea (*Sesbania sesban*) straw, 5% $CaSO_4$ and 5% phosphate rock.

Table 3: Length of stipe of *A. bisporus* on various composts (cm)

Strains	WH	WHS1	WHS2	WC	WCS1	WCS2	Mean
F599	4.78	4.45	4.34	4.82	4.33	4.80	4.58
C9	4.30	4.34	4.21	4.07	4.24	3.88	4.17
Mean	4.54	4.39	4.27	4.44	4.28	4.34	
LSD (p<0.05)				0.24			0.09

Table 4: Ratios of the diameter of pileus to the length of stipe (DP/LS ratio) of *A. bisporus* on various composts

Strains	WH	WHS1	WHS2	WC	WCS1	WCS2	Mean
F599	1.08	1.25	1.18	1.10	1.16	1.11	1.14
C9	1.02	1.13	1.08	1.05	1.00	1.14	1.07
Mean	1.05	1.19	1.13	1.07	1.08	1.12	
LSD (p<0.05)				0.06			0.02

Table 5: Carbon:Nitrogen (C:N) ratio of composts

Features	WH	WHS1	WHS2	WC	WCS1	WCS2	LSD ($p<0.05$)
Compost	29.10	14.80	16.90	15.90	12.60	12.70	1.29
SMC of F599	17.61	11.42	14.38	13.00	10.43	9.50	0.05
SMC of C9	17.24	11.03	13.51	12.64	10.33	9.59	0.05
Mean of SMC	17.42	11.22	13.94	12.82	10.38	9.55	0.03

Table 6: Electrical Conductivity (EC) of composts (dS/m)

Features	WH	WHS1	WHS2	WC	WCS1	WCS2	LSD ($p<0.05$)
Compost	9.58	11.86	11.22	14.74	17.67	15.08	0.09
SMC of F599	8.20	9.87	9.63	13.13	14.25	11.67	0.12
SMC of C9	8.48	9.24	9.11	12.65	13.02	11.60	0.12
Mean of SMC	8.34	9.55	9.37	12.89	13.63	11.63	0.08

3.2 Physicochemical properties of the compost and spent mushroom compost

Carbon:nitrogen (C:N) ratio in table 5 showed that C:N ratios declined significantly ($p<0.05$) after cultivation of mushrooms because of the high increase of nitrogen content in spent mushroom compost (SMC) (Owaid et al. 2017). Mycelial and biomass mushrooms raised the nitrogen content of compost that reflects on the quantity of proteins in SMC, in addition, to decomposing of carbon sources and release of CO_2 which gives a low C:N ratio. This ratio is essential for using these organic matters as a casing layer of button mushrooms after mixing with other supplements or a substrate for oyster mushroom cultivation performance (Owaid et al. 2017). The highest C:N ratio before cultivation was 29.10 in WH compost (control) which significantly ($p<0.05$) declined to 17.24 and 17.61 in SMC of *A. bisporus* C9 and *A. bisporus* F599 respectively. The lowest C:N ratio was 12.6 in WCS1 which reduced after cultivating *A. bisporus* F599 and *A. bisporus* C9 respectively. Generally, from the results, straw of Egyptian pea (*S. sesban*) raises nitrogen content in SMCs and composts because of its content from nitrogen (Kiatho 1997; Nigussie and Alemayehu 2013).

Table 6 showed decreasing EC in SMC after mushroom cultivation that agrees with (Owaid et al. 2017). The highest EC before the cultivation in composts was 17.67 dS/m in WCS1 compost which declined to 13.02 dS/m and 14.25 dS/m with significant differences ($p<0.05$) after cultivating *A. bisporus* C9 and *A. bisporus* F599 respectively. Nevertheless, the lowest EC is 9.58 dS/m in the control compost (WH) then declined to 8.20 dS/m and 8.48 dS/m in SMC of *A. bisporus* F599 and *A. bisporus* C9 respectively. Generally, use of *S. sesban* (Egyptian pea) straw led to an increased EC of the substrate because of its composition from minerals (Nigussie and Alemayehu 2013).

The values of the pH in composts and SMC was affected significantly ($p<0.05$) after growing mushrooms. The highest pH was 7.75 in WHS2 compost which decreased to 6.88 and 6.90 in SMC of *A. bisporus* F599 and *A. bisporus* C9 respectively. The lowest pH value

Table 7: The pH of composts

Features	WH	WHS1	WHS2	WC	WCS1	WCS2	LSD (p<0.05)
Compost	7.67	7.73	7.75	7.64	7.58	7.24	0.02
SMC of F599	6.94	6.64	6.88	6.87	7.01	6.99	0.02
SMC of C9	6.79	7.01	6.90	6.73	7.17	6.70	0.02
Mean of SMC	6.86	6.82	6.89	6.80	7.09	6.84	0.01

7.24 in WCS2 then decreased to 6.70 and 6.99 in SMC of *A. bisporus* C9 and *A. bisporus* F599 respectively. All results of pH in table 7 exhibit declining pH values from light alkaline to light acidic because secretions of *A. bisporus* biodegradable enzymes which are produced various organic acids in compost which were unused after cultivation of mushrooms (Jurak 2015). The proccess take places especially with existence rock phosphate in these agricultural formulas, also thermophilic bacteria, which were found naturally in composting processes, using up this fertilizer for their growth.

Phosphorus can become bioavailable from the manure and the phosphate rock (PRock) in two forms organic and inorganic phosphorus and can improve the properties of composts (Pagliari and Laboski 2012) repeated manure application has shown adverse effects on environmental quality due to phosphorus (P. These may be returned to the alkaline and acid phosphomonoesterases in composts included chicken and horse manure. Phosphomonoesterases play useful roles in the biochemical mineralization of organic ester phosphates in the compost and are considered suitable representatives of biodegradative enzymes in the compost (Vuorinen 1999). Using SMC as a biofertilizer is useful in land application in soil or organic systems (Pagliari and Laboski 2012)repeated manure application has shown adverse effects on environmental quality due to phosphorus (P.

4 Conclusion

This study is seeking use straw of Egyptian pea (*Sesbania sesban*) in compost preparation as an alternative for the cultivation of *Agaricus bisporus* (C9 and F599 strains). Indeed, the type of compost has a significant effect (p<0.05) on the sizes of button mushroom fruits. WHS1 compost exhibited the best diameter of pileus at 5.28 cm. Generally, *A. bisporus* C9 has the best length of stipe, while *A. bisporus* F599 has the best diameter of the cap. Generally, *A. bisporus* F599 showed a larger ratio of the diameter of pileus to the length of stipe (DP/LS ratio) (1.14). C:N ratios of compost decreased significantly (p<0.05) after cultivation of mushroom because of the high increase of nitrogen content in spent mushroom compost (SMC). Finally, straw of *S. sesban* is suitable as a supplement for the cultivation of *A. bisporus*.

Acknowledgment: Authors wish to thank Hameediyah Mushroom Farm (HMF), Ramadi, Kilo 18 for obtaining spawn of mushrooms, and the College of Agriculture, University Of Anbar in Iraq for achieving this study.

Conflict of interest: Authors declare no conflict of interest.

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