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The Utilization of Spent Oyster Mushroom Substrates Into Compost and Its Effect on the Growth of Indian Mustard (*Brassica juncea* (L.) Czern.) in the Screenhouse

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Abstract Spent mushroom substrate is a byproduct of mushroom industries that created various environmental problems.The utilize spent oyster mushroom substrate which mainly contains sawdust to be made as organic fertilizer was investigated. Fresh sawdust, sawdust from the spent oyster mushroom substrate and cow manure was composted and its effects on the growth of Indian mustard (*Brassica juncea*) were determined. The composition of compost substrate was sawdust (L1) or spent oyster mushroom substrate (L2) in combination with cow manure ratio of 100% (P1), 75% (P2), 50% (P3), 25% (P4), and 0% (P5). Composting parameters were pH, temperature, water content, organic C, total N, P, K content, and C/N ratio, while the plant growth parameter was the plant height, total leaves, and wet weight per plant. The study showed that the best produced compost was from the combination of sawdust or spent oyster mushroom substrate and cow manure (L1P2 and L2P2). It is suggested that a problem for organic waste utilization into compost can be solved.The highest plant height, total leaves, and wet weight per plant of Indian mustard were obtained from the plant fertilized with the compost from cow manure alone, which were not significantly different with that 25% sawdust and 75% cow manure (L1P2) or 25% spent oyster mushroom substrate and 75% cow manure (L2P2).

Keywords: compost, organic waste, *Pleurotus ostreatus, Brassica juncea* (L.) Czern. spent oyster mushroom substrate

Introduction

Oyster mushroom (*Pleurotus ostreatus*) cultivation in Indonesia has increased in line with the demand of this mushroom due to its high nutritional value and pharmaceutical component (Saskiawan *et al.*, 2016). A study conducted by Choudhury *et al.* (2013) supported the findings that this mushroom can reduce plasma cholesterol. According to BPS-Statistics Indonesia (2017), national mushroom production in 2016 was 40,914,331

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quintals. It has been known that about 2.5 – 5 kg of the spent mushroom substrate (SMS) is produced for each kilogram of mushroom (Medina *et al.*, 2012; Priadi, *et al.,* 2016). SMS is a byproduct of mushroom cultivation and it can be utilized as biofertilizer or soil conditioner. According to Gümüs and Seker (2017), spent mushroom compost (SMC) application is an effective way to improve soil physicochemical properties. Sawdust is an organic substrate containing 40-44% cellulose, 20-32% hemicellulose and 25-35% lignin (Haygreen and Bowyer, 1989). Sawdust is commonly used for making handicraft in the wood industry and it is also containing organic materials that used to improve the soil fertility and plant growth. The physical and chemical properties of the sawdust such as its small size and the porous particle would be able to facilitate the water, air, and odor adsorption, therefore, the sawdust is proper material for the compost (Djaja *et al.,* 2003). SMS and sawdust have not been properly utilized yet in Indonesia, therefore, it can be an environmental problem. In several countries, SMS management has become a major problem faced by farmers. (Phan and Sabaratnam, 2012). In this study, spent oyster mushroom substrate and sawdust and in the addition of cow manure were composted and applied as compost for Indian mustard (*Brassica juncea*). According to Raj *et al.* (2014), cows manure can maintain soil health and enhance microbial population. Therefore, it is a most important source of biofertilizer in developing countries.

Indian mustard is one of favorite leafy vegetable in Indonesia with a variety of vegetable uses, forage, and medicinally. It assumed that center of origin of Indian mustard is several regions of western and central Asia and presently cultivated throughout southern and eastern Asia (Schippers and Mnzava, 2004).

The objective of the study was to produce compost from both spent oyster mushroom substrate and fresh sawdust and cow manure with the addition of compost bioactivator of *Ikokasmur* and its application on Indian mustard *(Brassica juncea*) in the screen house condition.

Materials and methods

Composting substrates

The study was conducted during February to May 2016 at the Laboratory of Food Microbiology of Research Center for Biology, Indonesian Institute of Sciences (LIPI). Hereafter, the application of produced compost on Indian mustard was conducted at the screenhouse of Germplasm Garden of Research Center for Biotechnology-LIPI, Cibinong, West Java.

The compost bioactivator of *Ikokasmur* and spent oyster mushroom substrate were obtained from the Laboratory of Food Microbiology and mushroom cultivation house of Research Center for Biology-LIPI respectively, whereas the sawdust was from the traditional sawmill of a small-scale wood industry in Cibinong district.

Composting parameters

Temperature and pH of the substrate were measured every 3 days until the end of the composting process by measuring the substrate at the center of the composter. Meanwhile, the organic C, total N, and C/N ratio were measured in 0, 15, 30, and 45 days of the composting process. The water content of the produced compost was measured in the initial and the end of the composting process. All parameters were measured in triplicates.

Compost production

Compost substrate i.e. sawdust (L1), spent oyster mushroom substrate (L2), 100% cow manure (P1), 75% cow manure (P2), 50% cow manure (P3), 25% cow manure (P4), and 0% cow manure (P5). Compost was produced in the following ratio:

- 0% sawdust + 100% cow manure (L1P1)
- 25% sawdust + 75% cow manure (L1P2)
- 50% sawdust + 50% cow manure (L1P3
- 75% sawdust + 25% cow manure (L1P4)
- 100% sawdust + 0% cow manure (L1P5)
- 0% spent oyster mushroom substrate + 100% cow manure (L2P1)
- 25% spent oyster mushroom substrate + 75% cow manure (L2P2)
- 50% spent oyster mushroom substrate + 50% cow manure (L2P3)
- 75% spent oyster mushroom substrate + 25% cow manure (L2P4)
- 100% spent oyster mushroom substrate + 0% cow manure (L2P5)

Each treatment consists of three replications, and each replication has 20 kg of the substrate so that the total weight of the substrate was 600 kg (150 kg sawdust, 150 kg spent oyster mushroom substrates, 300 kg cow manure), and 0.04 kg bioactivator of *Ikokasmur*. The substrates were mixed and kept in closed black polybags (80 x100 cm) in the bamboo basket and composted anaerobically for 45 days.

Indian mustard cultivation

The Indian mustard seed (*Tosakan, East-West Seed*) were obtained from a farm shop in Bogor, West Java. The seed was germinated in rice husk charcoal medium in the plastic trays for 7 days prior cultivation in the soil beds (2 x 1 m) with the plant spacing of 25 x 25 cm in the screenhouse. A total of 30 soil beds were made for all those compost applications. A 45 gram of compost was applied to each plant hole of Indian mustard on the seedbeds before 2 days of transplanting. The seedlings were maintained and watered 1-2 times a day or as needed.

Plant growth observation

The growth parameter measurement is taken from 12 plants of each bed. Plant height and total leaves were evaluated every week until harvesting time (35 days). Plant height (cm) was measured from the base of the ground to the top of plant shoots using a metal ruler. The plant was harvested by cutting off the plant base with the knife. Fresh weight (gram) of the plant without roots was measured at the end of the experiment using a digital scale.

Data analysis

The experiments were arranged in Completely Randomized Design (CRD) with three replications. Obtained composting and growth of Indian mustard data were analyzed using Analysis of Variance (ANOVA) followed by Duncan Multiple Range Test (DMRT) and processed using SPSS 16.0 statistical software.

Results

Physical and chemical properties of the substrate

The result of physical and chemical analysis of the substrates before composting process is shown in Table 1. The pH, as well as temperature, were not significantly different among the substrates. The water content of the sawdust was significantly higher compared to cow manure, however, were not significantly different with the spent oyster mushroom substrate. The highest organic C and total N was obtained from the sawdust and cow manure respectively. The C/N ratio of sawdust was the highest among other substrates.

Table 1. Physical and chemical properties of the compost substrate in the initial composting process

Substrates	pH	Temperature (℃)	Water content (%)	Organic C (%)	Total N (%)	C/N ratio
Cow manure	7.89 a	29.00 a	62.68 b	20.00 c	0.85 a	24.02 c
Sawdust	7.91 a	27.67 a	72.28 a	56.00 a	0.29 c	192.00 a
SOMS[1]	8.02 a	28.33 a	68.90 ab	40.33 b	0.58 b	70.37 b

1/: Spent oyster mushroom substrate; Means followed by different letter(s) within columns are significantly different ($p<0.05$) by Duncan's multiple range test (DMRT).

pH

In general, the highest pH of the composting process was in day-18, however, it was gradually decreased by day-45 (Figure 1). It means that the composting process has finished. The highest pH value was obtained from L2P5. The pH value of the produced compost was in the range of 7.30 – 8.15 has met the quality standard of organic fertilizer based on the Regulation of Minister of Agriculture No.70/Permentan /SR.140/10/2011 and or Indonesian National Standard (SNI).

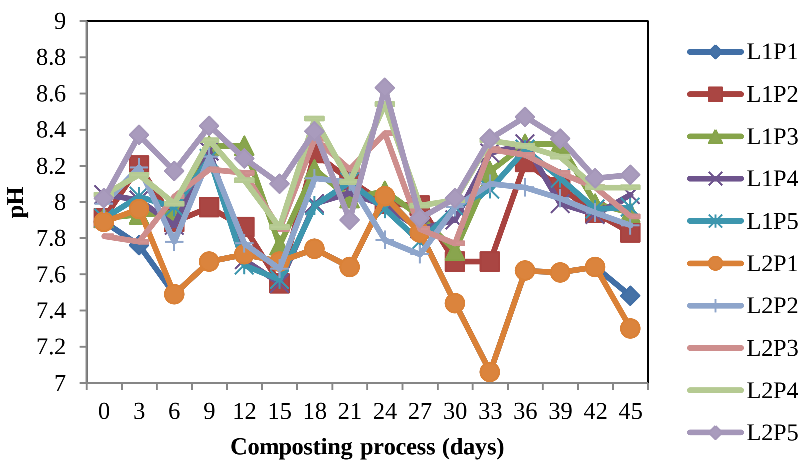

Figure1. pH value change of compost substrates during the composting process

Temperature

The change of temperature during the composting process was fluctuated as shown in Figure 2.

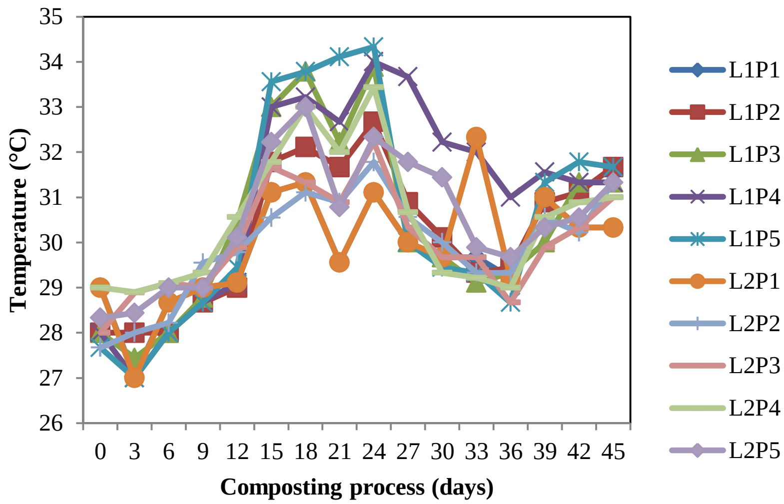

Figure 2. Temperature change of compost substrates during the composting process

The initial temperature of the composting process was ranged in 27.67 – 29.00 ℃, meanwhile in the final was ranged in 30.33 – 31.67 ℃. The produced compost was odorless, dark grey in color and has a constant temperature.

Water content

The water content of produced compost was in the range of 55.05 – 69.39. This was out of range of the standard quality of compost (Table 2).

Organic C content

The highest organic C content of produced compost was 50.67% obtained from L1P5 (sawdust alone). However, the lowest (16.67%) was obtained from cow manure alone (L1P1 and L2P1). The organic C of the compost substrate was directly proportional to C/N ratio, therefore the high organic C of the substrate will result in the high C/N ratio of compost. It seemed that the decrease of organic C depends on the substrate types and the increase of cow manure ratio in the compost substrate (Table 2).

Total N content

The highest (0.85%) and the lowest (0.29%) N content of the compost substrate in the initial composting process was obtained from cow manure alone and sawdust alone respectively. The highest N content of the produced compost (0.92%) was obtained from L2P3, while the lowest was 0.45% was obtained from L1P5 (sawdust alone). N content was inversely proportional to organic C and C/N ratio, therefore, low N content at the final composting process due to low activity of decomposer microorganisms in sawdust.

Table 2. Physical properties and nutrient content of compost from different organic substrate used after 45 days of composting process

Substrates ratio [/1]	pH	Water content (%)	Organic C (%)	Total N (%)	P (P_2O_5) (%)	K (K_2O_5) (%)	C/N ratio
L1P1	7.48 [e]	55.05 [e]	16.67 [d]	0.83 [abc]	0.14 [a]	0.20 [a]	20.90 [c]
L1P2	7.83 [d]	63.25 [bc]	17.33 [d]	0.71 [abc]	0.11 [b]	0.16 [ab]	25.22 [c]
L1P3	7.94 [bcd]	65.87 [b]	36.00 [b]	0.63 [cd]	0.08 [c]	0.15 [abc]	58.58 [b]
L1P4	8.04 [abc]	66.26 [ab]	40.33 [b]	0.67 [c]	0.09 [bc]	0.11 [c]	61.54 [b]
L1P5	7.97 [bcd]	69.39 [a]	50.67 [a]	0.45 [d]	0.05 [d]	0.12 [bc]	114.41[a]
L2P1	7.30 [f]	55.05 [e]	16. 67 [d]	0.83 [abc]	0.14 [a]	0.20 [a]	20.90 [c]
L2P2	7.87 [cd]	62.00 [cd]	21.33 [cd]	0.89 [ab]	0.13 [a]	0.18 [a]	24.65 [c]
L2P3	7.92 [bcd]	59.68 [d]	26.33 [c]	0.92 [a]	0.13 [a]	0.18 [a]	31.07 [c]
L2P4	8.08 [ab]	64.26 [bc]	21.00 [cd]	0.68 [bc]	0.13 [a]	0.19 [a]	31.35 [c]
L2P5	8.15 [a]	64.22 [bc]	36.00 [b]	0.76 [abc]	0.13 [a]	0.16 [ab]	48.85 [b]
Permentan[2/]	4 - 9	15 - 25	>15 %	$N+P_2O_5+K_2O$ >4 %			15 - 25
SNI[3/]	6.80 -7.49	50	9.8-32	≥ 0.40	≥ 0.10	≥ 0.20	10 – 20

[1]/L1P1=0% sawdust + 100% cow manure; L1P2=25% sawdust + 75% cow manure; L1P3=50% sawdust + 50% cow manure; L1P4=75% sawdust + 25% cow manure; L1P5=100% sawdust + 0% cow manure; L2P1=0% spent oyster mushroom substrate + 100% cow manure; L2P2=25% spent oyster mushroom substrate + 75% cow manure; L2P3=50% spent oyster mushroom substrate + 50% cow manure; L2P4=75% spent oyster mushroom substrate + 25% cow manure; L2P5=100% spent oyster mushroom substrate + 0% cow manure

[2]/Minister of Agriculture Regulation No.70/Permentan/SR.140/10/2011.

[3]/Indonesian National Standard (BSN) 19-7030-2004

Total P Content

The total P content of the produced compost from the spent oyster mushroom substrate and cow manure was significantly higher than those from sawdust and cow manure and it was not significantly different among the compost from the spent oyster mushroom substrate and cow manure.

Total K Content

The total K content of 0.20% has met the Indonesian National Standard (SNI) for organic fertilizer which was obtained by the produced compost from cow manure alone. However, it was not significantly different with the other compost produced from spent oyster mushroom substrate and cow manure.

C/N ratio

C/N ratio was decreased with the time of the composting process (Sulaeman, 2011).The highest C/N ratio of the substrate at the initial composting process (192.00) was obtained from L1P5, and it was significantly decreased to 114.41 at the final composting process (day 45). The lowest C/N ratio (33.97) was obtained from L2P2, which was higher than the substrates C/N of cow manure alone (L1P1 or L2P1). The lowest C/N ratio (20.90) of produced compost in the final composting process was obtained from L1P1. High C/N ratio at the initial composting process of L1P1 and L2P1 was caused by slower decomposition of the substrate. In this study, the C/N ratio of 24.65 has met the quality standard of compost according to Minister of Agriculture Regulation No. 70/ Permentan/SR.140/10/2011 was obtained from L2P2. Results of nutrient analysis of the produced compost showed that the C/N ratio of L2P2 was height (114.41). It means that decomposition process was slower and the compost should be not applied yet.

Effect of the compost on the growth of Indian mustard

Plant height

The highest plant of Indian mustard (23.74 cm) was obtained from cow manure alone (L2P1) and it was not significantly different with L1P1, L1P2, L2P1, L2P2, and L2P4. The lowest plant height (10.64 cm) was obtained from the compost from 100% sawdust (L1P5) (Table 3).

Total leaves

The best total leaves (8.8) at days-7 after transplanting was obtained by L2P2. However, L1P5 resulted in the lowest total leaves (4.97). The compost from sawdust or spent oyster mushroom supplemented with cow manure has lower nitrogen content than cow manure alone, therefore, leaf production was lower. Similar to the plant height observation, the highest and lowest weight per plant was obtained from L2P1 and L1P5 respectively. In harvesting time, the best total leaves of the substrate combination were obtained from L2P2. The spent oyster mushroom substrate resulted in a better result (8.8) compared with the sawdust in the same ratio (Table 3).

Table 3. Plant height, total leaves, and wet weight per plant of Indian mustard (*Brassica juncea*) fertilized with compost from different organic substrates in harvesting time

Substrates ratio [/1]	**Plant height (cm)**	**Total leaves**	**Wet weight per plant (g)**
L1P1	21.66 [abc]	8.17 [ab]	16.22 [abc]
L1P2	18.70 [abcd]	7.19 [bc]	11.25 [bcd]
L1P3	15.57 [de]	6.30 [cd]	8.30 [cd]
L1P4	14.44 [de]	6.39 [cd]	7.24 [d]
L1P5	10.64 [e]	4.97 [d]	3.51 [d]
L2P1	23.74 [a]	7.94 [abc]	19.83 [a]
L2P2	23.35 [ab]	8.80 [a]	19.31 [ab]
L2P3	17.72 [cd]	6.89 [bc]	10.92 [cd]
L2P4	19.83 [abcd]	7.28 [abc]	11.50 [bcd]
L2P5	18.00 [bcd]	7.06 [bc]	11.22 [bcd]

Means followed by different letter(s) within columns are significantly different ($p<0.05$) by Duncan's multiple range test (DMRT)

[1]/L1P1=0% sawdust + 100% cow manure; L1P2=25% sawdust + 75% cow manure; L1P3=50% sawdust + 50% cow manure; L1P4=75% sawdust + 25% cow manure; L1P5=100% sawdust + 0% cow manure; L2P1=0% spent oyster mushroom substrate + 100% cow manure; L2P2=25% spent oyster mushroom substrate + 75% cow manure; L2P3=50% spent oyster mushroom substrate + 50% cow manure; L2P4=75% spent oyster mushroom substrate + 25% cow manure; L2P5=100% spent oyster mushroom substrate + 0% cow manure

Discussion

Physical and chemical properties and C/N ratio of the substrates affected the quality of produced compost. A study conducted by Ashrafi *et al.* (2015) showed that SMS can be effectively used to produce good quality compost. SMS is a low priced organic ingredient for horticultural substrates and it is also its use can constitute a suitable way to protect the environment and to conserve natural resources such as peat (Medina *et al.*, 2009). Ludfia (2012) found that cow manure contains 18.6% hemicellulose, 25.2% cellulose, 20.2% lignin, 1.67% nitrogen, 1.11% phosphate, and 0.56% potassium with the C/N ratio of 16.6-25. These can enhance the decomposition process of organic matter.

Initial C/N ratio greater than 40 is recommended to minimize nitrogen loss during dairy manure composting with sawdust or straw amendments (Mitchel *et al.,* 2004). Increased pH in the initial composting process was caused by the addition of cow manure to the sawdust or spent oyster mushroom substrate so therefore has more base properties. In contrast, the decreased pH in the final of composting process was caused by the conversion of organic matter into humic acid (Irshad *et al.*, 2013).

According to Van *et al.* (2016), the change of temperature during the composting process indicated the change of microbes in the composts. A study conducted by Raviv *et al.* (2002), found that lack of an adequate amount of carbonaceous material in plain poultry manure and plain mushroom compost may have prevented them from reaching higher temperatures.

In this study, the produced compost needs to be dried at least to 50% of water content prior to being applied. There are many environmental variables affected the presence of pathogenic microbes in the produced compost such as animal contamination or stormwater runoff from source materials (Gichon, 2006).

According to Isroi (2008) and Day and Shaw (2001) organic C is the energy source in the composting process. Meanwhile, nitrogen is essential for microbial growth. N content fluctuated during the composting process in accordance with the study conducted by Widarti *et al.* (2015). The increase of cow manure ratio in the substrate resulted in the increase of N which produced by decomposer microorganism during the composting process (Sulaeman, 2011; Sevindrajuta, 2012). A study conducted by Meng *et al.* (2018) using spent mushroom substrate and rice husk with the addition of pig manure showed that total P and total K of the compost from spent mushroom and pig manure was significantly increased than those from spent mushroom alone.

The low substrate C/N caused lack of C as the energy source for the decomposer microorganism, which was also resulted in a slower decomposition (Pandebesie, 2012). A study conducted by Michel *et al*. (2004) showed that a significant negative correlation between C/N ratio and nitrogen and carbon loss during composting. According to Eiland (2001), a high C/N ratio resulted in slower decomposition because of N limitation. This in line with the opinion of Febriansyah (2009) that higher C/N ratio of the sawdust means lower N content, thus causing N deficiency in the plant which will cause slow plant growth.

In general, that spent oyster mushroom substrate compost resulted in good-quality compost based on Minister of Agriculture Regulation No.70/Permentan/SR.140/10/2011 and or Indonesian National Standard (BSN) 19-7030-2004 (Table 1).

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