Comparison of sawdust and kenaf core fibre as cultivation substrates for grey oyster (*Pleurotus sajor-caju*) and black jelly (*Auricularia auricular-judae*) mushrooms

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Abstract. Unlike plants, mushrooms are heterotrophic organisms which require external nutrients to grow the hypha network which supplies nutrients for the growth of reproductive stage. In this study, rubber tree sawdust, kenaf core fibre and mixture of sawdust-kenaf (50:50) were used as the cultivation substrates for grey oyster (*Pleurotus sajor-caju*) and black jelly (*Auricularia auricular-judae*) mushrooms. Kenaf (*Hibiscus cannabinus* L.) composed of fibre-rich substances which consist of an internal woody core and a superficial fibrous bark. This study was conducted to compare between sawdust and kenaf core fibre as the cultivation substrates in terms of growth performance, yield and postharvest quality of grey oyster and black jelly mushrooms. There was no significant difference (P≥0.05) observed in the mycelium growth rate among the substrates used. However, grey oyster mushroom showed higher growth rate (0.74-0.77 cm/day) compared to black jelly mushroom (0.44-0.55 cm/day). Sawdust substrate showed the highest yield (415.5 g) for both mushroom species followed by mixture of sawdust-kenaf and lastly kenaf. There was also no significant different (P≥0.05) found in the postharvest quality of both mushrooms species among different substrates used. In conclusion, in terms of yield, sawdust was the best mushroom cultivation substrate for both grey oyster and black jelly mushrooms.

1. Introduction

In Malaysia, mushroom can be cultivated throughout the year due to the local agro-climatic conditions. There are seven mushroom varieties that can be cultivated commercially where, grey oyster is the most cultivated follow by black jelly, ganoderma and shitake [1]. Under Malaysia's National Agro-Food Policy (2011-2020) government had classified mushrooms as one of high-value commodities. Grey oyster mushroom (*Pleurotus sajor-caju*) has a physical appearance which resembled an oyster shell. It can be cultivated on almost all agricultural waste medium such as sawdust, cereal straws, coffee waste, lemongrass leaves, groundnut shells, sugarcane bagasse, sunflower husks and others. Meanwhile, black jelly mushroom grows on woody based medium. This mushroom has a gelatinous ear-shaped, that firm when fresh and hard when dry [2].

Rubber tree sawdust has been used traditionally as the main substrate for mushroom cultivation in Malaysia. Malaysia is one of the largest rubber producers in the world and this makes the sawdust
resource available and not an issue. However, nowadays, the total area of rubber plantation declining and affecting the availability and sustainability of rubber tree sawdust [3]. The scarcity of rubber tree sawdust enhances this research to find an alternative cultivation substrate from other available agricultural wastes.

One of the abundance agricultural wastes which might have potential as mushroom substrate is kenaf wastes. Kenaf (Hibiscus cannabinus L.) is one of natural fibre resource that is cultivated commercially in Malaysia [4]. Kenaf can be used as a form of biomass that consist of non-woody lignocellulosic material composed mainly by cellulose, hemicelluloses and lignin which is suitable to be used as mushroom cultivation medium [5]. Kenaf stem is composed of fibre-rich structure which is an internal woody core and a superficial fibrous bark binding around the core [6].

Kenaf core fibre with woody structure possess high absorbency which benefit for multi field which is automotive industry, sewage sludge composting as a bulking agent, particleboard in dashboards, acting absorbent, as animal bedding and poultry litter, as a potting soil amendment, and effectively used for toxic discarded waste removal such as oil spills [7]. Kenaf fibre are known to have high tensile and bust strength that make it a long lasting, strong and suitable for paper base manufactories [6].

In this study, kenaf core fibre was used as a medium to cultivate two different mushroom species. Its potential as mushroom cultivation substrate was then compared to the existing commercial substrate from rubber tree sawdust.

2. Methodology

Three different type of the substrates were prepared for grey oyster and black jelly mushrooms cultivation using 100% rubber tree sawdust, 100% kenaf core fibre and a mixture of sawdust and kenaf core fibre (50:50). The mushroom substrate consists of a mixture of calcium carbonate, rice bran, and rubber tree sawdust and/or kenaf core fibre with the ratio of 1:10:100 respectively. The substrate mixture was filled into polyethylene bags and were closed with a cotton stuffed cap. The bags were then sterilized in autoclave at 121°C for 30 minutes. The sterilized bags were left overnight in laminar flow to cool down before inoculation process with mushroom spawns.

Five bags were prepared for each type of cultivation substrate and for each mushroom species with a total of 30 bags. The inoculated bag were arranged vertically on the racks in spawning chamber with optimum controls condition (temperature of 25-28°C; 75-80% relative humidity; light exposure of about 10%) for the spawn-running process [8]. Once the mycelium had fully grown over the cultivation bags, the cultivation bags were transferred to the mushroom house for production stage.

For grey oyster mushroom, the caps of the cultivation bags were open and the cultivation bags were placed horizontally on the racks for pinhead emergence and fruiting bodies formation. However, for black jelly mushroom, the cap of the cultivation bags were kept closed as few slits were made vertically to allow for the formation of the pinhead and fruiting bodies.

2.1. Experimental design and statistical analysis

The experiment had been designed based on Complete Randomized Design (CRD) involving two different mushroom species, grey oyster (Pleurotus sajur-caju) and black jelly (Auricularia auricula-judae) mushroom and three different substrates which are rubber tree sawdust, kenaf core fibre and the mixture of sawdust and kenaf core fibre (50:50). Each treatment was represented by five replicates. Statistical software SAS version 16.0 had been used to analyze all the data obtained. The differences among the treatments were determined using two-way Analysis of Variances (ANOVA), considering significant at P < 0.05 using Post-hoc Tukey test.

2.2 Analyses of growth performance

Growth performance of two mushroom species cultivated on three different substrate formulations were analyzed in terms of the rate of mycelium growth during spawn-running stage and the number of days taken to reach the different growing stages.
2.2.1 **Mycelium growth rate.** The growth rate (cm/day) of mycelium for each mushroom bag was measured by using a ruler in term of length (cm) at every 5 days interval. The measurement was done from the neck of the bag until the bag was fully covered with mycelium at the bottom.

2.2.2 **Mushroom growth performance.** The number of days taken for mycelium to fill up the cultivation bags, pinhead emergence and fruiting bodies formation were counted and recorded.

2.3 **Analyses of yield**

The yield of oyster mushroom was analyzed in terms of total fresh weight of fruiting bodies, the number of fruiting bodies and percentage of biological efficiency.

2.3.1 **Total fresh weight of fruiting bodies.** The total fresh weight of all harvested mushroom fruiting bodies were weighed by a weighing balance and was recorded for each bag.

2.3.2 **Total number of fruiting bodies.** The number of mushrooms fruiting bodies for every harvesting were counted and recorded. The counted mushroom must have pileus diameter greater than 1 cm.

2.3.3 **Percentage of biological efficiency.** The percentage of biological efficiency was calculated based on Equation 1.

\[
\text{Biological efficiency} \% = \frac{\text{Total fresh weight of mushroom (g)}}{\text{Dry weight of substrate (g)}} \times 100 \quad (1)
\]

2.4 **Postharvest quality of mushroom**

The harvested mushroom from each bag was analyzed for postharvest quality of pileus diameter, color, texture (firmness) and percentage moisture content.

2.4.1 **Pileus diameter.** The diameter of the largest and smallest size of the pileus was measured by using a ruler (in cm) and recorded.

2.4.2 **Pileus color.** The harvested mushroom sample was analyzed using Minolta Chromameter with CIELAB Color parameter of L*, a*, b*. Three different points were taken from one harvested mushroom pileus. L* value means that monochrome scale expressing the amount of reflected light (lightness). L* value of 100 is pure white and L* value of 0 is matt black. While for a* value, it is a measurement of greenness (-) to redness (+) and b* value is blueness (-) to yellowness (+).

2.4.3 **Pileus texture.** Texture analyzer TA.XT plus (Stable Micro Systems) was used to determine the firmness of the harvested mushroom by using P/2 stainless steel probe. The pileus of the harvested mushroom was placed on the stage of the texture analyser and penetration test was carried out using 2 mm diameter cylinder probe at a set distance of 5 mm. Pre-test speed, test speed and post-test speed of 1.0, 0.5 and 5 mms\(^{-1}\) were set for the analysis. The maximum positive force which indicates the firmness value was then recorded.

2.4.4 **Percentage moisture content.** The freshly harvested mushroom was weighed and placed on a pan in a moisture analyzer MX-50 at 105°C. According to [8], the moisture content of mushroom had been determined directly by the moisture analyzer which works based on Equation 2.

\[
\text{Moisture content} \% = \frac{\text{Fresh weight of mushroom (g)} - \text{Dry weight of mushroom (g)}}{\text{Fresh weight of mushroom (g)}} \times 100 \quad (2)
\]

3. **Results and Discussion**
3.1 Growth performance

Different cultivation substrates provided different chemical and nutrient composition like the total C, total N, C/N ratio, pH, EC, and mineral content, which were the essential factor that gives impact on mycelium growth rate and development of fruiting bodies [9]. According to [10], the sign of mycelium growth is seen right after 2 or 3 days of inoculation, which is because mushrooms degrade the cultivation substrate through enzyme production.

3.1.1. Mycelium growth rate. Mycelium growth rate is a measurement of mycelium growth in cm for every 5 day intervals. The average value of mycelium growth rate for grey oyster and black jelly mushrooms that cultivated on different cultivation substrates are presented in Table 1. In addition, Figure 1 illustrates the mycelium growth pattern based on total length of mycelium growth subjected to different cultivation substrates used for grey oyster and black jelly mushrooms until it fully colonized the bag of about 23.5 cm.

Table 1. The mycelium growth rate (cm/day) of grey oyster (Pleurotus sajur-caju) and black jelly (Auricularia auricula-judae) mushrooms subjected to different cultivation substrates used.

| Mushroom species       | Mycelium growth rate (cm/day) |
|------------------------|--------------------------------|
|                        | Sawdust | Kenaf          | Mixture SD:K (50:50) |
| Grey oyster            | 0.741±0.041\text{Aa} | 0.774±0.037\text{Aa} | 0.735±0.016\text{Aa} |
| Black jelly            | 0.441±0.016\text{Ba} | 0.553±0.165\text{Ba} | 0.475±0.030\text{Ba} |

Note: Value are mean of 5 replicates. Means (n=5) ± standard deviation.

A-B : Value bearing the different superscript within the same column are significantly different at 5% level (P<0.05).

a-b : Value bearing the different superscript within the same row are significantly different at 5% level (P<0.05).

Figure 1 also showed that the mycelium of grey oyster mushroom generally grew much faster compared to black jelly mushroom in all types of cultivation substrates used. As reported by [11], *Pleurotus* species require shorter growth time compared to other mushroom species. From the data presented in Table 1, it can be seen that there were significant differences (P<0.05) in term of mycelium growth rate between these two mushroom species. [12] stated that different species of mushrooms have different types of enzymes systems based on endoglucanase, laccase and phenoloxidases where the mycelium also produce extracellular enzymes that responsible for lignin degradation.

Table 1 shows that there is no significant different (P>0.05) in mycelium growth rate among all substrates for grey oyster mushroom which ranged from 0.735 to 0.774 cm/day. During spawning process, the mycelium growth rate were also influenced by environmental factor such as light intensity, temperature, O2 and CO2 concentrations, relative humidity and pH of the cultivation substrate [13]. The mycelium growth rate for black jelly mushroom was lower than grey oyster and the rate had no significant different (P>0.05) among all the cultivation substrates which ranged from 0.441cm/day for Sawdust (SD) to 0.553cm/day for Kenaf (K). According to [14], mycelium growth rate over substrate used were variance on deference substrate type.
3.1.2. Mushroom growth performance. The growth stages of grey oyster and black jelly mushrooms cultivated on different substrates were measured at 3 stages which were the number of days taken for mycelium to fill-up the bag, pinhead emergence and fruiting bodies formation (Table 2). Meanwhile, Figure 2(a) shows that grey oyster mushroom require less time to complete all the stages compared to black jelly mushroom in figure 2(b) for all type of cultivation substrates. The figures also indicated a constant time require for fruiting bodies formation among different cultivation substrates used for both mushrooms species.

Grey oyster mushroom took shorter time for mycelium to fill-up the cultivation bag compared to black jelly mushrooms for all the three cultivation substrates. However, no significant different (P>0.05) in the time taken for mycelium to fill-up the bag was observed among different substrates used for both species. For black jelly mushroom, number of days taken to fill-up the mushroom bag was from 45.0 to 53.4 days. Whereas for grey oyster mushroom was in the range of 30.4 to 32.0 days. Mycelium growth in this study was far slower than the finding of [15] where the spawning period of Pleurotus sp. took about three weeks and fruiting bodies appeared after 2 to 3 days.

Table 2 also showed that there were significant differences (P<0.05) in number of days taken for pinhead emergence in mushroom bag cultivated in sawdust (SD) substrate for both mushroom species, whilst no significant different (P>0.05) observed for the other two substrates. Grey oyster mushroom showed faster time (3.6 days) for pinhead emergence in sawdust (SD) than for black jelly mushroom (8.6 days).

Grey oyster mushroom only took 1 day to form fruiting bodies and ready for harvest while more days were required for black jelly mushroom (16.8 to 21.4 days). For both grey oyster and black jelly mushrooms, there was no significant different (P>0.05) in the number of days required for fruiting bodies formation among different substrates. The results presented in table 2 were different with finding of [16] who found that the first fruiting bodies of oyster mushroom occurred on different days depending on substrates.
Table 2. The number of days for mycelium to fill-up the bag, pinhead emergence and fruiting body formation of grey oyster (*Pleurotus sajur-caju*) and black jelly (*Auricularia auricula-judae*) mushroom cultivation subject to different substrates used.

| Mushroom species | Sawdust (SD) | Kenaf (K) | Mixture SD:K (50:50) |
|------------------|--------------|-----------|---------------------|
| Mycelium fill-up the bag | | | |
| Grey oyster | 31.800±1.643<sup>Ba</sup> | 30.400±1.517<sup>Ba</sup> | 32.000±0.707<sup>Ba</sup> |
| Black jelly | 53.400±2.074<sup>AAa</sup> | 45.000±10.536<sup>AAa</sup> | 49.600±3.050<sup>AAa</sup> |
| Pinhead emergence | | | |
| Grey oyster | 3.600±0.245<sup>Ba</sup> | 8.000±2.510<sup>Aa</sup> | 7.400±1.720<sup>Aa</sup> |
| Black jelly | 8.600±0.245<sup>AAa</sup> | 8.000±0.316<sup>AAa</sup> | 8.400±0.400<sup>AAa</sup> |
| Fruiting bodies formation | | | |
| Grey oyster | 1.000±0.000<sup>Ba</sup> | 1.000±0.000<sup>Ba</sup> | 1.000±0.000<sup>Ba</sup> |
| Black jelly | 19.800±3.114<sup>AAa</sup> | 16.800±1.095<sup>AAa</sup> | 21.400±4.506<sup>AAa</sup> |

Note: Value are mean of 5 replicates. Means (n=5) ± standard deviation.
A-B : Value bearing the different superscript within the same column are significantly different at 5% level (P<0.05).
a-b : Value bearing the different superscript within the same row are significantly different at 5% level (P<0.05).

Figure 2. The growth performance of (a) grey oyster mushroom (*Pleurotus sajur-caju*); (b) black jelly mushroom (*Auricularia auricula-judae*) subjected to different substrate used. Vertical bars represent standard errors.

3.2. Yield
The yield of mushroom in terms of total fresh weight, number of fruiting bodies harvested and the percentages of biological efficiency were analysed to determine the effect of different type of cultivation substrates used for both mushrooms species. Table 3 showed that sawdust (SD) substrate produced the highest weight of fruiting bodies for both mushroom species. Grey oyster mushroom produced higher
(P<0.05) weight of fruiting bodies for all different cultivation substrates compared to black jelly mushroom.

For grey oyster mushroom, the total fresh weight of fruiting bodies in kenaf (K) and mixture SD:K (50:50) cultivation substrates showed no significant different (P>0.05) between each other but significantly lower value than in sawdust (SD). There were also significant differences (P<0.05) in total fresh weight of black jelly mushroom among different substrates, where kenaf (K) produced the lowest weight of fruiting bodies (174.9 g) followed by mixture SD:K (50:50) with 230 g fruiting bodies and sawdust (SD) had the highest weight of 297.5 g.

**Table 3.** The yield of grey oyster (*Pleurotus sajur-caju*) and black jelly (*Auricularia auricula-judae*) mushrooms subjected to different substrate used.

| Mushroom species       | Yield                  |        |
|------------------------|------------------------|--------|
|                        | Sawdust (SD)           | Kenaf (K) | Mixture SD:K (50:50) |
| Total fresh weight of fruiting bodies (g) | 415.50±8.178<sup>Aa</sup> | 293.00±69.246<sup>Ab</sup> | 315.50±23.809<sup>Ab</sup> |
| Grey oyster            | 297.50±37.500<sup>Ba</sup> | 174.90±13.813<sup>Bc</sup> | 230.00±37.921<sup>Bb</sup> |
| Black jelly            | 47.00±13.509<sup>Ba</sup> | 20.00±7.289<sup>Bb</sup> | 28.00±7.374<sup>Bb</sup> |
| Number of fruiting bodies | 79.00±13.987<sup>Ba</sup> | 42.30±8.175<sup>Bb</sup> | 48.00±10.677<sup>Bb</sup> |
| Biological efficiency (%) | 83.10±1.636<sup>Aa</sup> | 77.82±18.392<sup>Aa</sup> | 71.99±5.433<sup>Aa</sup> |
| Grey oyster            | 59.50±7.500<sup>Ba</sup> | 46.45±3.669<sup>Bb</sup> | 52.48±8.653<sup>Bb</sup> |
| Black jelly            | 42.30±8.175<sup>Ba</sup> | 48.00±10.677<sup>Bb</sup> | 52.48±8.653<sup>Bb</sup> |

Note: Value are mean of 5 replicates. Means (n=5) ± standard deviation.

A-B : Value bearing the different superscript within the same column are significantly different at 5% level (P<0.05).
a-b : Value bearing the different superscript within the same row are significantly different at 5% level (P<0.05).

Table 3 also showed the number of fruiting bodies of grey oyster and black jelly mushrooms were recorded for different substrates. Higher number of fruiting bodies were obtained from black jelly mushroom than from grey oyster mushroom for all the different substrates used. Compliment with the results of total fresh weight, sawdust (SD) produced higher number of fruiting bodies compared to the other two cultivation substrates for both mushroom species.

The percentage of biological efficiency of different cultivation substrates were compared for both grey oyster and black jelly mushrooms. Higher percentage of biological efficiency was obtained for grey oyster mushroom than black jelly mushroom for all the substrates used. Sawdust (SD) showed higher percentage of biological efficiency (59.5%) for black jelly mushroom than the other two substrates. Whereas for grey oyster mushroom, there was no significant different (P>0.05) in percentage biological efficiency among different substrates which ranged from 71.991 to 83.1%.

### 3.3. Postharvest quality
Freshly harvested fruiting bodies of grey oyster and black jelly mushrooms cultivated on different substrates were analysed in terms of pileus diameter, color, texture and percentage moisture content.

#### 3.3.1. Pileus diameter
The largest and smallest sizes of fruiting bodies from each bag were taken for diameter measurement. Results shown in table 4, indicates that there are significant differences (P<0.05) of the largest pileus diameter between grey oyster and black jelly mushrooms. The largest pileus of black jelly mushroom fruiting bodies is larger in diameter compare to the largest pileus of grey oyster mushroom. Table 4 also shows that there is no significant different (P>0.05) among cultivation substrate used in the aspect of largest pileus diameter for both mushroom species. Meanwhile, there is significant
differences (P<0.05) of the smallest pileus diameter between both mushroom species. However, there is no significant different (P>0.05) of smallest pileus diameter among different cultivation substrates for grey oyster and black jelly mushrooms.

**Table 4.** The largest and smallest pileus diameter (cm) of grey oyster (*Pleurotus sajur-caju*) and black jelly (*Auricularia auricula-judae*) mushrooms subjected to different cultivation substrates used

| Mushroom species           | Pileus diameter (cm) | Sawdust (SD) | Kenaf (K) | Mixture SD:K (50:50) |
|---------------------------|----------------------|--------------|-----------|----------------------|
| **Largest pileus**        |                      |              |           |                      |
| Grey oyster               | 11.660±1.558<sup>Ba</sup> | 10.800±1.605<sup>Ba</sup> | 9.960±1.197<sup>Ba</sup> |
| Black jelly               | 13.560±0.619<sup>Aa</sup> | 13.000±0.612<sup>Aa</sup> | 12.780±0.130<sup>Aa</sup> |
| **Smallest pileus**       |                      |              |           |                      |
| Grey oyster               | 4.580±2.124<sup>Aa</sup> | 6.100±3.896<sup>Aa</sup> | 4.740±2.003<sup>Aa</sup> |
| Black jelly               | 1.740±0.623<sup>Ba</sup> | 1.580±0.512<sup>Ba</sup> | 1.440±0.428<sup>Ba</sup> |

Note: Value are mean of 5 replicates. Means (n=5) ± standard deviation.

A-B : Value bearing the different superscript within the same column are significantly different at 5% level (P<0.05).
a-b : Value bearing the different superscript within the same row are significantly different at 5% level (P<0.05).

3.3.2. **Pileus color.** The color parameters measured were the L* value which represents the lightness properties of the mushroom pileus, the a* value which indicates the redness to greenness color and the b* value which measures the yellowness to blueness. Table 5 showed that there were significant differences (P<0.05) in L* values between grey oyster and black jelly mushroom pileus for all different substrates used where grey oyster mushroom had lighter color compared to black jelly mushroom. Black jelly mushroom is a popular black food in China where the dark-colored fruiting bodies contains abundant melanin pigment that regarded as major bioactive substance [17, 18] had described melamins as a complex, amorphous and incompletely understood polymeric pigments. Among different cultivation substrates grey oyster mushroom cultivated on mixture SD:K (50:50) and kenaf (K) showed lighter pileus compared to the one on sawdust (SD). The same trend was also observed for black jelly mushroom. According to [19] black jelly mushroom produces melanin pigments by utilizing the cultivation substrate.

For a* values, all the values obtained were positive indicated the redness in color. However there were significant differences (P<0.05) in the a* values between grey oyster and black jelly mushrooms where black jelly had higher values compared to grey oyster mushroom for all the different substrates used. Black jelly mushroom also showed significant differences (P<0.05) in the a* values among different substrates where mushroom cultivated on kenaf (K) substrate showed the highest a* value, 10.564 followed by mixture SD:K (50:50) which was 7.642 and the least value was sawdust (SD) with 6.124. Meanwhile for grey oyster mushroom pileus, sawdust (SD) had higher (P<0.05) a* value compared to kenaf (K) and mixture SD:K (50:50) substrates.

Table 5 also showed that all the values for b* were positive which indicated the color was in the ranged of yellowness. There were significantly higher (P<0.05) b* values in grey oyster mushroom than in black jelly mushroom regardless the substrates used. The b* value in black jelly mushroom cultivated on kenaf (K) had the highest value followed by mixture SD:K (50:50) whereas sawdust (SD) had the lowest value. However for grey oyster mushroom, no significant different (P>0.05) was observed in b* values among different cultivation substrates used.
Table 5. The pileus color properties (L*, a* and b* values) of grey oyster (*Pleurotus sajur-caju*) and black jelly (*Auricularia auricula-judae*) mushrooms subjected to different cultivation substrates used.

| Mushroom species | Color properties | Sawdust (SD) | Kenaf (K) | Mixture SD:K (50:50) |
|------------------|------------------|-------------|-----------|---------------------|
| L* value         |                  |             |           |                     |
| Grey oyster      | 57.99±1.235      | 65.02±4.245 | 65.34±1.363 |
| Black jelly      | 36.29±0.657      | 41.19±0.575 | 41.22±1.232 |
| a* value         |                  |             |           |                     |
| Grey oyster      | 5.55±0.295       | 4.74±0.517  | 4.64±0.407 |
| Black jelly      | 6.12±0.563       | 10.56±0.229 | 7.64±1.244 |
| b* value         |                  |             |           |                     |
| Grey oyster      | 15.10±0.923      | 14.44±0.823 | 14.75±0.643 |
| Black jelly      | 8.71±0.676       | 16.99±1.217 | 10.18±1.631 |

Note: Value are mean of 9 replicates. Means (n=9) ± standard deviation.
A-B : Value bearing the different superscript within the same column are significantly different at 5% level (P<0.05).
a-b : Value bearing the different superscript within the same row are significantly different at 5% level (P<0.05).

3.3.3. Pileus texture. The pileus texture of grey oyster and black jelly mushroom cultivated on different substrates are presented table 6. There were significantly firmer (P<0.05) texture of black jelly mushroom compared to grey oyster mushroom for all the three different substrates used. For grey oyster mushroom fruiting bodies, softer texture was observed in mixture SD:K (50:50) than in the other two substrates. However, no significant different (P>0.05) of firmness between kenaf (K) and sawdust (SD) substrates. The firmness values of fruiting bodies of black jelly mushroom showed the highest value in sawdust (SD) substrate, followed by mixture SD:K (50:50) and the least firmness was kenaf (K).

Table 6. The texture (firmness) of grey oyster (*Pleurotus sajur-caju*) and black jelly (*Auricularia auricula-judae*) mushrooms subjected to different cultivation substrates used.

| Mushroom species | Firmness (gF) | Sawdust (SD) | Kenaf (K) | Mixture SD:K (50:50) |
|------------------|--------------|-------------|-----------|---------------------|
| Grey oyster      | 61.52±4.456  | 63.51±11.151| 50.34±3.281 |
| Black jelly      | 338.17±11.84 | 166.26±23.506| 214.96±11.020 |

Note: Value are mean of 9 replicates. Means (n=9) ± standard deviation.
A-B : Value bearing the different superscript within the same column are significantly different at 5% level (P<0.05).
a-b : Value bearing the different superscript within the same row are significantly different at 5% level (P<0.05).

3.3.4. Percentage moisture content. One of the most influence factor of mushroom growth is water where nutrients were transported from mycelium to fruiting bodies by steady moisture flow [20]. Percentage of moisture content for grey oyster mushroom were analysed on pileus and stem. Meanwhile, for black jelly mushroom, only moisture content on pileus was measured due to the morphology of its fruiting bodies which was stemless. Table 7 shows the percentage of moisture contents for both mushroom species subjected to different cultivation substrates used. There were significantly higher (P<0.05) moisture content in pileus of grey oyster mushroom than in black jelly mushroom cultivated in sawdust (SD) and mixture SD:K (50:50), where no different was observed on both species for kenaf (K) substrate.

For grey oyster mushroom, the percentage moisture content of pileus cultivated on kenaf (K) showed lower moisture content compared to sawdust (SD) and mixture SD:K (50:50) substrates. Meanwhile for
stem part, the moisture content was higher in sawdust (SD) than in the other two substrates, where, there was no significant different (P>0.05) between kenaf (K) and mixture SD:K (50:50) substrates. [21] stated that not only the type of cultivation substrate, moisture content of fruiting bodies was also influence by the mushroom age, mushroom strains, growing environment and post-harvest condition.

Table 7. The percentage moisture content of grey oyster (Pleurotus sajur-caju) and black jelly (Auricularia auricula-judae) mushrooms subjected to different cultivation substrates used.

| Mushroom species | Moisture content (%)       |
|------------------|---------------------------|
|                  | Sawdust (SD) | Kenaf (K) | Mixture SD:K (50:50) |
| Pileus           |              |           |                      |
| Grey oyster      | 90.493±0.140<sup>Aa</sup> | 87.590±1.117<sup>Ab</sup> | 89.377±0.276<sup>Aa</sup> |
| Black jelly      | 75.327±1.614<sup>Bc</sup> | 87.020±1.119<sup>Aa</sup> | 80.167±0.536<sup>Bb</sup> |
| Stem             |              |           |                      |
| Grey oyster      | 75.480±1.882<sup>a</sup> | 68.547±0.167<sup>b</sup> | 71.347±0.743<sup>b</sup> |

Note: Value are mean of 3 replicates. Means (n=3) ± standard deviation.
A-B : Value bearing the different superscript within the same column are significantly different at 5% level (P<0.05).
a-b : Value bearing the different superscript within the same row are significantly different at 5% level (P<0.05).

4. Conclusion
In term of growth performance, grey oyster mushroom had higher mycelium growth rate than black jelly mushroom. However, no significant different (P>0.05) was observed in the growth rate among different substrates used. The number of days for mycelium to fill-up the bag, pinhead emergence and fruiting bodies formation were shorter in grey oyster mushroom compared to black jelly mushroom and no significant different showed in the number of days for each growth stage among different substrates for both mushroom species.

In term of yield, grey oyster mushroom produced higher total fresh weight of fruiting bodies and percentage biological efficiency compared to black jelly mushroom. Grey oyster and black jelly mushrooms cultivated on sawdust (SD) had significantly higher (P<0.05) total fresh weight of fruiting bodies and percentage biological efficiency than those cultivated on mixture SD:K (50:50) and kenaf (K). However, black jelly mushroom had significantly higher (P<0.05) number of fruiting bodies than grey oyster mushroom. The highest number of fruiting bodies of black jelly mushroom was obtained from sawdust (SD) substrate followed by mixture SD:K (50:50) and the least was from kenaf (K) substrate.

Black jelly mushroom also produced larger pileus size compared to grey oyster mushroom, however there was no significant different (P>0.05) observed in the pileus size among different substrates for both mushroom species. In term of pileus color, grey oyster mushroom had lighter color (higher L* values), lower a* values and higher b* values compared to black jelly mushroom. Grey oyster mushroom cultivated on sawdust (SD) showed lower L* value and higher a* value compared to the other two substrates. However, no significant different (P>0.05) showed for b* values among different substrates used. Black jelly mushroom cultivated on sawdust also showed lower L* value compared to the other two substrates. However, there were significant differences (P<0.05) in the a* and b* values of black jelly mushroom cultivated on differences substrates. Kenaf (K) substrate showed the highest a* and b* values, followed by mixture SD:K (50:50) and the least values for a* and b* were sawdust (SD).

Black jelly mushroom showed firmer texture compared to grey oyster mushrooms. Regardless different species, mushroom which were cultivated on sawdust (SD) had firmer texture than the other two substrates. For percentage moisture content, grey oyster mushroom had significantly higher (P<0.05) moisture content than black jelly mushroom. Grey oyster mushroom cultivated on sawdust
(SD) had higher moisture content in both pileus and stem compared to the other substrates. However for black jelly mushroom, the highest moisture content was observed in kenaf (K) substrate followed by mixture SD:K (50:50) and the lowest was the one on sawdust (SD).

From the results obtained, the best substrate to be used in the cultivation of grey oyster and black jelly mushrooms which have faster growth, higher yield and good postharvest quality was sawdust (SD). However, kenaf core fibre waste could also be a potential cultivation substrate and can be fully utilized by mushroom grower due to its relatively good performance showed in this study.

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