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Postharvest evaluation, characteristics of yellow oyster mushroom (*Pleurotus citrinopileatus*): physicochemical properties and antioxidant activity

[Evaluasi pascapanen, karakteristik jamur tiram kuning (Pleurotus citrinopileatus): sifat fisikokimia dan aktifitas antioksidan]

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ABSTRACT

The level of physiological maturity of the plant, productivity at harvest, and content in the material were all determined by harvest age, which was a component strongly tied to the plant growth phase. Oyster mushrooms underwent biochemical changes as they matured. However, they also changed physically when they were harvested, especially regarding color, texture, size, form, and the sections that could be eaten. This study aimed to discover the optimal harvest age for yellow oyster mushrooms (Pleurotus citrinopileatus) based on their physical, chemical, and antioxidant activity. The design of the investigation was entirely random. This study used two harvest periods of yellow oyster mushrooms, namely 1 and 2, with harvest ages of 2, 3, 4, and 5 days after the pinheads appeared as the treatment. Each experimental unit was repeated three times. The findings demonstrated that the total phenol and antioxidant activity of yellow oyster mushrooms were significantly influenced by harvest age. Harvesting the yellow oyster mushroom on the third day after the appearance of pinheads is advised.

Keywords: Yellow oyster mushrooms; harvest age, antioxidant activity

ABSTRAK

Tingkat kematangan fisiologis tanaman, produktivitas saat panen, dan kandungan bahan semuanya ditentukan oleh umur panen, yang merupakan komponen yang sangat terkait dengan fase pertumbuhan tanaman. Jamur tiram akan mengalami perubahan biokimia saat dewasa, tetapi juga akan berubah secara fisik saat dipanen, terutama dalam hal warna, tekstur, ukuran, bentuk, dan bagian yang boleh dikonsumsi. Penelitian ini bertujuan untuk mengetahui umur panen optimal jamur tiram kuning (*Pleurotus citrinopileatus*) berdasarkan sifat fisik, kimia, dan aktivitas antioksidannya. Desain penelitian menggunakan rancang acak lengkap. Penelitian ini menggunakan dua periode panen jamur tiram kuning, yaitu periode panen 1 dan 2, dengan perlakuan umur panen 2, 3, 4, dan 5 hari setelah munculnya pinhead. Setiap satuan percobaan diulang sebanyak tiga kali. Hasil penelitian menunjukkan bahwa total fenol, dan aktivitas antioksidan jamur tiram kuning sangat dipengaruhi oleh umur panen. Disarankan untuk memanen jamur tiram kuning pada hari ketiga setelah munculnya pinhead.

Kata kunci: Jamur tiram kuning, umur panen, aktivitas antioksidan

Introduction

Yellow oyster mushrooms (*Pleurotus citrinopileatus*) are one of the potential agricultural products that continue to be developed in Indonesia. The oyster mushroom had a substantial nutritional content, making it suitable for use as a functional food that could offer health benefits beyond conventional supplements (Elattar et al., 2019; Djamila et al., 2020). Oyster mushrooms have been recognised as a valuable food source due to their rich nutritional components. Furthermore, their appealing taste and visual appeal have garnered considerable interest (dos Reis et al., 2022). Oyster mushrooms offer a remarkable nutritional profile, featuring significant amounts of protein, vitamins, minerals, fibre, trace elements, and minimal

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levels of calories and cholesterol. Apart from their role as a functional dietary component, mushrooms have also been used in traditional medicinal practices (Ahmed et al., 2023).

The yellow oyster mushroom presents a physically interesting hood color, characterized by an attractive golden yellow color, indicating its high vitamin C. The particular type of mushroom exhibits significant antioxidants and possesses therapeutic properties. The immunostimulatory beta-glucan found in oyster mushrooms are efficacious and valuable in treating various health disorders, including diabetes, cancer, and microbial infections. Various studies have provided research supporting the medicinal qualities of oyster mushrooms, including their potential as antihypercholesterolemic, antihypertensive, antidiabetic, antiobesity, antiaging, antibacterial, antioxidant, and anti-hepatoprotective agents. Oyster mushrooms have a unique nutritional composition defined by substantial protein, vitamins, minerals, dietary fiber, trace elements, and minimal calories and cholesterol levels. In addition to serving as a valuable nutritional component, mushrooms have also been used in traditional medical treatments (Bhambri et al., 2022; dos Reis et al., 2022). Yellow oyster mushrooms absorb selenium from the environment, significantly increasing endurance, regulating metabolism, and combating free radicals (Djamila et al., 2020).

The harvest age was closely linked to the plant growth phase, reflecting the physiological maturity level of plant parts and being connected to the production and content within the plant. Alongside biochemical transformations, harvest age also influenced the physical aspects, including alterations in color, texture, size, and shape of fruits or plant parts that were appropriate for consumption (Tafzi et al., 2021). Furthermore, a study focusing on the characteristics of yellow oyster mushrooms based on their harvest age has significance in determining the quality and nutritional value of the mushrooms. A suitable harvest age can optimize yellow oyster mushrooms' nutritional content, color, and texture while preserving the material's freshness, crispness, color, and vitamin content. Conversely, an inappropriate harvest age may result in wilting, softening, color alteration, and even a reduction in nutritional value. Conducting a study on the traits of yellow oyster mushrooms aids in identifying appropriate handling and preservation techniques and facilitates the transformation of the material into further processed products (Siregar et al., 2020; Stia et al., 2018).

This study aimed to determine the effect of the harvest age of yellow oyster mushrooms on their physical, chemical, and antioxidant properties and the best harvest age based on their physical, chemical, and antioxidant activities.

Material and method

The research was conducted at the oyster mushroom cultivation site, Bagan Pete, Kota Baru District, Jambi City, and the Chemistry Laboratory, Faculty of Agriculture, University of Jambi. The materials used were sangon sawdust (Paraserianthes falcataria), corn flour, and lime for the planting medium. Yellow oyster mushroom seedlings from mushroom farmers in Bagan Pete, Kota Baru District, and Jambi City

The study was completely randomized, and data analysis was performed using the SPSS software (ANOVA and the DMRT test). The treatment used the harvest age of yellow oyster mushrooms at various ages (2, 3, 4, and 5 days after the appearance of pinheads) during various harvesting periods: harvest period 1 and harvest period 2. The experiments were replicated three times.

The research consisted of several stages: the planting medium (baglog) preparation, inoculation, incubation, harvesting, drying, and parameters analysis. The material employed for the planting medium comprised a mixture of 67% sangon sawdust, 27% bran, 4% dolomite, and 2% corn flour. The inoculation procedure occurred in a specialized room disinfected with 70% alcohol for 24 hours and 1 hour before inoculation. The incubation phase was conducted until the entire medium was fully colonized by fungal mycelium within a dedicated room maintained at a temperature of 24–28 °C (with a relative humidity of 40–60%). After approximately 30–40 days, when the baglogs were enveloped by fully grown mycelium, they were transferred to the maintenance room (cultivation room). Harvesting was performed once the

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pinheads appeared on the exposed surface of the baglog. The mushroom harvesting process involved carefully detaching the fruit body from the mushroom base. For yellow oyster mushrooms, harvesting was carried out on the 2nd, 3rd, 4th, and 5th days after the pinheads appeared. After harvesting, the drying procedure followed, along with measuring the physical properties. The drying process involved placing the mushroom's cap and stalk in an oven set at 60°C for 4 hours (Tafzi et al., 2021).

Parameters

A. Physical and chemical analysis

The diameter of the yellow oyster mushroom hood that was measured was the diameter of the overall hood and the widest diameter of all the caps. The overall diameter of the hood was measured from the right end to the left end of the part that grows in one baglog. The overall height was measured from where the mushroom grows to the top. Physical properties were measured at each harvesting age on the 2nd, 3rd, 4th, and 5th days after the growth of the pinhead with two harvesting periods (Hasnah et al., 2022). Moisture content was measured at each age, namely on the 2nd, 3rd, 4th, and 5th days after the growth of pinheads. The oven-drying method measured moisture content (Setiawan et al., 2019). Vitamin C content was analyzed using titration (Tafzi et al., 2021).

B. Bioactives component analysis

The total phenol was measured using the Folin-Ciocalteu colorimetric (Lucas et al., 2022; Setiawan et al., 2019). A total of 200 µL of the sample solution was added to a reaction tube. Then, 1 mL of 10% Folin-Ciocalteu solution was added, and it was allowed to stand for 1 minute. After that, 3 mL of Na2CO3 was added, and the mixture was vortexed. It was then stored in a dark room at room temperature for 2 hours. The first hour of storage was followed by centrifuging the sample for 5 minutes, and the sample was stored in a dark room for another 1 hour. After the 2-hour storage period, the sample's absorbance was measured using a UV-Vis spectrophotometer at a wavelength of 760 nm. The antioxidant activity test was performed using the DPPH 2,2-diphenyl-1-picrylhydrazyl method. Using a micropipette, 1 mL of the sample was aspirated and placed in a reaction tube. Subsequently, 5 mL of the DPPH (2,2-diphenyl-1-picrylhydrazyl) solution was added to the reaction tube containing the sample. The solution mixture was homogenized with a vortex and allowed to react in a dark room for 30 minutes. At a wavelength of 517 nm, the absorbance of this mixture was measured with a UV-Vis spectrophotometer. The absorbance data from the spectrophotometer were used to calculate the percentage inhibition of antioxidant activity against the DPPH oxidation reaction produced by the sample. This percentage of inhibition was then used to determine the antioxidant content of the sample under analysis (Hu et al., 2019).

Result and discussion

Diameter of hood

The average diameter of the yellow oyster mushroom hood ranged from 10.33 cm to 14.50 cm (Table 1). The largest diameter was observed at a harvest age of 3 days during harvest period 2, while the minor diameter was found harvested at 5 days during harvest period 1. Based on ANOVA analysis, it was clear that the harvest age in harvest periods 1 and 2 had no noticeable effect on the diameter fruit hood, with significance values of 0.715 > 0.05 for harvest period 1 and 0.084 > 0.05 for harvest period 2. The development of various mushrooms impacted the total diameter. The absorption of various nutrients in each baglog also contributed to the variance in diameter. Each bag produced more stalks, some extending the hood as they grew (Hasnah et al., 2022). The decrease in cap diameter value at a harvest age of 5 days was because the longer the harvest age, the broader the cap diameter would shrink and become wrinkled, resulting in a reduction in diameter.

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Table 1. The diameter of the hood of the yellow oyster mushroom

Age of the harvest (day)	Diameter hood (cm)	
	Harvest period 1	Harvest period 2
2	12.11±2.71[a]	12.94±1.45[ab]
3	10.44±1.01[a]	14.50±1.01[b]
4	11.56±3,15[a]	11.56±0.50[ab]
5	10.33±1,01[a]	10.61±2.71[a]

Description: Numbers followed by the same lowercase letters in the same column did not differ markedly at the 5% level according to the DMRT test

Height

The average height ranged from 6.33 cm to 11.17 cm. The highest overall height produced yellow oyster mushrooms harvested at 2 days of age during harvest period 2. While this happened, harvest period 2 produced the most diminutive overall height at 5 days of age. The average of the overall height is presented in Table 2.

Table 2. Height of the yellow oyster mushroom

Age of the harvest (day)	Overall height (cm)	
	Harvest period 1	Harvest period 2
2	10.99±1.52[b]	11.17±1.48[b]
3	10.66±1.52[b]	11.06±0.58[b]
4	9.80±2.07[ab]	9.17±1.75[b]
5	7.33±1.20[a]	6.33±1.20[a]

Description: Numbers followed by the same lowercase letters in the same column did not differ markedly at the 5% level according to the DMRT test

ANOVA analysis showed that the harvest age in periods 1 and 2 did not significantly impact the overall height, with significance values of 0.086>0.05 for harvest period 1 and 0.084>0.05 for harvest period 2. This finding was supported by Rambey et al. (2020) on white oyster mushrooms, which reported a high range of 7.4 to 10.13 cm in various planting media. The white oyster mushrooms with the same planting media as this study (sengon wood sawdust) showed a high range (8.1 – 11.5 cm). The study demonstrated that the harvesting age did not affect the overall height variation produced. However, it was found that the availability of nutrients, oxygen, and various carbon compounds such as monosaccharides, polysaccharides, organic acids, amino acids, fats, and lignin significantly impacted energy requirements for the growth and development process. Furthermore, it was observed that there was a direct inverse correlation between the height and diameter of oyster mushrooms (Tafzi et al., 2021; Apriyani et al., 2019).

The amount of nutrients, oxygen, and carbon dioxide in the growing medium all impacted how tall oyster mushroom stalks grew. The quantity and diameter of the fruit bodies impacted the mushroom stalk's height; if there were many fruit bodies, the shadow would be short, and the diameter would be tiny (Apriyani et al., 2019).

Water content

The average water content ranged from 77,04% to 90,59%. ANOVA analysis showed that the harvest age treatment had no significant effect on the moisture content in harvest periods 1 and 2, with significance values of 0.307 > 0.05 in period 1 and 0.104 > 0.05 in harvest period 2. The average water content value can be seen in Table 3. Based on further tests, Table 3 showed that the moisture content of yellow oyster mushrooms at a harvest age of 2 days and period one did not differ markedly from all other yellow oyster mushroom harvest age treatments. While the moisture content of yellow oyster mushrooms

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at the mushroom harvest age of 4 days and period 2 significantly differed from the harvest age of 5 days, it did not differ markedly from the harvest age of 2 days and 3 days.

Table 3. The moisture content of the yellow oyster mushroom

Age of the harvest (day)	Water content (%)	
	Harvest period 1	Harvest period 2
2	90.59±4.74[a]	87.41±9.31[ab]
3	86.74±4.41[a]	88.15±1.28[b]
4	88.48±6.63[a]	88.52±1.28[b]
5	81.85±5.59[a]	77.04±6.11[a]

Description: Numbers followed by the same lowercase letters in the same column did not differ markedly at the 5% level according to the DMRT test

During its growth, the mycelium digested the medium into simpler components that were subsequently utilised as an energy source for metabolic processes. This metabolic activity produced water vapour, carbon dioxide, and organic acid metabolites. As a result of this metabolic process, the water content of the resulting biomass increased with the age of harvest (Gupta et al., 2019).

Vitamin C

The average vitamin C value ranged from 3.52 g/100gr – 5.85 g/100gr. The highest vitamin C was produced by yellow oyster mushrooms, with a harvest life of 2 days in the harvest period of 2. In comparison, a minor vitamin C was produced with a harvest age of 5 days in the harvest period of 2. The average vitamin C value can be seen in Table 6.

Table 4. Vitamin C of the yellow oyster mushroom

Age of the harvest (day)	Vitamin C (g/100 gr)	
	Harvest period 1	Harvest period 2
2	5.86 ± 1.01[a]	4.10 ± 1.01[a]
3	5.8 ± 1.01[a]	3.52 ± 0.00[a]
4	4.10 ± 1.01	4.10 ± 1.01[a]
5	5.28 ± 1.76[a]	3.52 ± 0.00[a]

Description: Numbers followed by the same lowercase letters in the same column did not differ markedly at the 5% level according to the DMRT test

The results of the variety analysis showed that the harvest age of yellow oyster mushrooms had no significant effect on the vitamin C produced in both harvest periods 1 and harvest period 2, with the significance of 0.330 > 0.05 in period 1 and 0,596 > 0,05 in period 2.

Based on Table 4, it was known that there was no correlation between the age of the harvest and the vitamin C content produced by the yellow oyster mushroom. It was known from the vitamin C content in the yellow oyster mushrooms that were produced that they were volatile. In the results of other studies, it was also observed that harvesting age had no significant effect on the vitamin C content of tomatoes. However, titratable acidity peaked in color intensity that subsequently decreased with longer harvesting ages. Furthermore, it was explained that the impact of harvesting age on vitamin C content could be influenced by various factors, including plant types, varieties, and growing conditions (Monday John et al., 2020; Priyankara et al., 2017).

Total phenol

The average total phenol value of yellow oyster mushrooms ranges from 0.19 to 0.61. The highest total phenol at 2 days of harvest in the first harvest period. In contrast, the smallest total phenol is produced at

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the harvest age of yellow oyster mushrooms (5 days in the harvest period of 2). The average total phenol of yellow oyster mushrooms can be seen in Table 5.

Table 5. Total phenol of the yellow oyster mushroom

Age of the harvest (day)	Total phenol (mg ag E/g)	
	Harvest Period 1	Harvest period 2
2	0.61 ± 0.05^{b}	0.48 ± 0.06^{b}
3	0.57 ± 0.10^{b}	0.32 ± 0.13^{a}
4	0.45 ± 0.05^{ab}	0.32 ± 0.02^{a}
5	0.36 ± 0.11^{a}	0.19 ± 0.07^{a}

Description: Numbers followed by the same lowercase letters in the same column did not differ markedly at the 5% level according to the DMRT test

The results of the ANOVA analysis showed that the harvest age of yellow oyster mushrooms in harvest period 1 and harvest period 2 had a significant effect on the total phenol of yellow mushrooms, with significance values of 0.023 < 0.05 for period 1 and 0,015 < 0.05 for period 2.

Based on the results of further tests in Table 5, it can be known that the total phenol at the harvest age of 2 days in the harvest period of 1 is significantly different from the harvest age of yellow oyster mushrooms of 5 days. The total phenol at the harvest age of 2 days in period 2 significantly differs from the harvest ages of yellow oyster mushrooms of 3, 4, and 5 days. From the measurement results in Table 5, it was observed that the total phenol content decreased with the duration of harvest. The same results were also reported by Setiawan et al. (2019). In the study, the total phenol content of bean seeds decreased with the extended harvest age. It occurs due to changes in the phenolic concentration during the growth process, which are correlated with a decrease in water content, which may contribute to a decrease in total phenol content.

During growth, physical and chemical changes such as water content, proteins, fatty acids, minerals, and carbohydrates will occur. Changing starch carbohydrates to glucose or vice versa will affect the antioxidant activity in the ingredients. In addition, changes in color pigments will also affect antioxidant activity because some color pigments can act as antioxidants (Assemie & Abaya, 2022). Table 5 shows that the longer the yellow oyster mushrooms are harvested, the lower the total phenol produced.

Antioxidant activity

The average value of the oxidant activity ranges from 78.25% to 86.58%. Yellow oyster mushrooms produce the highest oxidant activity at a harvest age of 3 days in the harvest period 1. At the same time, the lowest oxidant activity at the age of 3 days of harvest in the harvest period of 2. The average of oxidant activity can be seen in Table 6.

Table 6. Antioxidant activity of the yellow oyster mushroom

Age of the harvest (day)	inhibition (%)	
	Harvest period 1	Harvest period 2
2	85.82 ± 0.30^{ab}	85.33 ± 0.98^{b}
3	86.58 ± 0.30^{b}	78.25 ± 5.68^{a}
4	86.37 ± 0.09^{b}	83.16 ± 0.93^{ab}
5	85.15 ± 0.78^{a}	81.51 ± 3.74^{ab}

Description: Numbers followed by the same lowercase letters in the same column did not differ markedly at the 5% level according to the DMRT test

The ANOVA analysis showed that the harvest age in harvest period 1 significantly affected the antioxidant activity of yellow mushrooms, with a significance value of 0.017 < 0.05. However, the harvest

age treatment in period 2 did not significantly affect the antioxidant activity, with a significance value of 0.163 > 0.05. Table 8 showed that the antioxidant activity at the harvest age of 3 days in harvest period 1 significantly differed from the harvest age of 5 days.

Yellow oyster mushrooms have the potential for antioxidant activity, so they can be used as an alternative food that positively affects body health. The benefit is indicated by the change of the test solution from purple to yellow after being reacted with DPPH during incubation. Antioxidants found in pagan materials are enzymes or organic compounds that can significantly reduce the harmful effects of reactive oxygen and nitrogen species in the body, reduce free radical levels, and contribute to preventing various chronic diseases.

Based on Table 6, it can be observed that there is a negative correlation between the total phenol content and antioxidant activity in yellow oyster mushrooms. As the harvest age increases, the total phenol content decreases, leading to decreased antioxidant activity. It is important to note that antioxidant activity is influenced by various natural compounds present in the mushrooms, not just phenolic compounds. Therefore, the increased antioxidant activity may be attributed to other natural components, such as vitamins, found in the mushrooms, in addition to phenolic compounds. Antioxidants are essential for the body as they act as a defense against oxidation caused by free radicals, which can lead to various diseases. The presence of pigments in materials with antioxidant activity is influenced by several factors, including exposure to sunlight, temperature, and relative humidity (RH).

Conclusion

Based on the results of the ANOVA test, it was concluded that the harvest age of yellow oyster mushrooms had a significant effect on the total phenol content and antioxidant activity of the produced yellow oyster mushrooms. Yellow oyster mushrooms are recommended to be harvested on the third day after the appearance of pinheads.

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