

The Potential of Palm Oil Waste Biomass as a Mushroom Growing Medium: A Preliminary Study of Nutrient Content

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Article History: Received: 01 December 25, Final Revision: 09 January 26, Accepted: 19 January 26, Online Publication: 30 January 26

ABSTRACT

The expansion of oil palm plantations has resulted in large amounts of biomass waste that has the potential to be used as a substrate for mushroom cultivation. However, information on the nutrient content of various types of oil palm waste is still limited. This study aims to analyze the macro nutrient content (organic C, N, P, K, Ca, Mg) and C/N ratio of three types of palm oil waste, namely empty fruit bunches, fronds, and leaves. Laboratory analysis was performed using the Walkley & Black method for organic C, Kjeldahl for total N, and Atomic Absorption Spectroscopy (AAS) for P, K, Ca, and Mg. The results showed that empty fruit bunches had the highest organic C content (57.24%) and relatively high K and Mg, making them a potential carbon source. Leaves have a higher N content (0.26%) with the lowest C/N ratio (114.58), making them decompose more quickly. Fronds have the highest Ca content (0.61%) but a very high C/N ratio (332.40), requiring a longer decomposition time. Overall, each type of palm oil waste has specific nutrient advantages that can complement each other when used in combination. These results provide a scientific basis for utilizing palm oil waste as a more efficient and environmentally friendly alternative growing medium in mushroom cultivation.

Keywords: palm oil waste, nutrient content, growing medium, mushrooms

INTRODUCTION

Increased oil palm cultivation areas will result in increasing amounts of waste. This is because unused oil palm biomass must be disposed of. One ton of oil palm can produce oil palm waste consisting of empty fruit bunches, fronds, leaves, shells, etc. Waste in the form of empty palm fruit bunches accounts for 23% or 230 kg, shell waste accounts for 6.5% or 65 kg, wet decanter solid

(palm sludge) accounts for 4% or 40 kg, and fiber accounts for 13% or 130 kg [1]. The large amount of palm oil biomass waste provides opportunities for utilization into products with added value.

Waste generated from the palm oil processing process will have a negative impact on the environment, both in terms of the quantity of natural resources, the quality of natural resources,

and the environment. The control of palm oil mill waste processing needs to be carried out in accordance with Law No. 32 of 2009 concerning Environmental Protection and Management and Government Regulation No. 27 of 2012 concerning Environmental Permits. Waste control in factories can be done through utilization, volume reduction, and quality control [2]. One example of the utilization of organic palm oil waste is turning it into Liquid Organic Fertilizer (POC) that can be applied to plants. Research indicates that the application of POC provides a good response in the early stages of plant growth [3]. In addition, palm oil organic waste can also be utilized as a mushroom growing medium. Palm oil trunks and empty bunches used as a mushroom growing medium produce slightly higher yields but have a shorter cultivation time [4].

Mushrooms are a nutritious food source rich in natural antioxidants and have economic value as agents and producers of biocontrol for the agricultural and other industries [5]. Currently, mushrooms with high prospects are oyster mushrooms, lingzhi mushrooms, and straw mushrooms. In their cultivation, these three mushrooms require a growing medium rich in lignocellulose, which is the main component of palm oil waste [6]. The crude fiber and nutrient content in palm oil biomass makes it a potential candidate as an alternative growing medium in the form of baglog, which is cheaper and more environmentally friendly than conventional growing media such as sawdust or rice straw.

Various types of solid oil palm waste, such as empty fruit bunches, mesocarp fiber, and shells, have been widely utilized as fuel, mulch, or compost. However, the utilization of oil palm waste as a growing medium for cultivated mushrooms has not been extensively developed, despite its considerable potential to support

mushroom growth. Previous research by Dibisono et al. [7] reported the use of empty fruit bunches combined with sawdust as a substrate for oyster mushroom cultivation.

Nevertheless, the utilization of other oil palm biomass components, particularly leaves and fronds, as mushroom growing media has received limited scientific attention. To determine whether these biomass residues can be effectively used as mushroom substrates, it is essential to first evaluate their nutrient availability. The presence of macro-nutrients, including organic carbon (C-organic), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), as well as the balance of the C/N ratio, plays a crucial role in determining the quality and suitability of mushroom growing media.

The limited availability of data and scientific studies concerning the nutrient characteristics of oil palm waste has restricted its application as an alternative substrate for mushroom cultivation and resulted in a largely empirical and unstructured utilization approach. Existing studies on nutrient content of mushroom substrates are also scarce and predominantly focus on non-oil palm materials, such as coffee husk-sawdust mixtures (Ulandari et al., 2025)[8]. Therefore, specific information regarding the nutrient characteristics of oil palm biomass waste as mushroom growing media remains insufficient and requires further investigation.

Accordingly, this study aims to analyze the macro-nutrient content (C-organic, N, P, K, Ca, and Mg) and C/N ratio of three types of oil palm waste. The results are expected to provide a scientific basis for evaluating the potential of each waste material as a mushroom growing medium and for developing more effective and sustainable strategies for utilizing oil palm biomass in mushroom cultivation.

MATERIALS AND METHODS

The materials used in this study were palm oil waste in the form of empty fruit bunches, fronds, and palm oil leaves (Figure 1). These three materials were obtained from palm oil plants located on the AKPY Papringan and KP2 Ungaran

campuses. Material preparation, such as separating the fronds and palm oil leaves and shredding them, was carried out to reduce their size.

Nutrient content parameters were tested on each material, including Organic C, Total N, P, K,

Ca, Mg, and C/N Ratio. Organic C content was analyzed using the Walkley & Black method. Total N was tested using the Kjeldahl method. The parameters of P, K, Ca, and Mg content were analyzed using the Atomic Absorption Spectroscopy (AAS) method. For these parameters, wet extraction was carried out by

dissolving the sample in HNO_3 and HClO_4 . Each nutrient content parameter was repeated three times. The data obtained was then analyzed using One-Way ANOVA to see the differences in nutrient content in each type of material and further tested using Tukey's HSD at a level of 5% ($p\text{-value} \leq 0.05$).

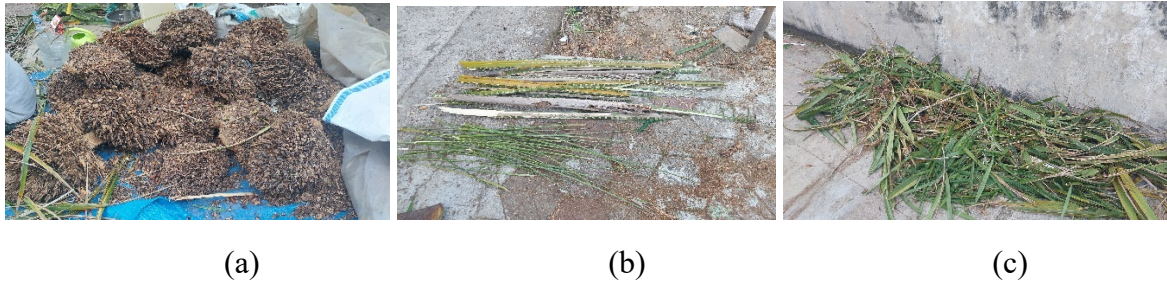


Figure 1. Research materials consist of empty fruit bunches (a), leaf stalks (b), and leaves (c) of oil palm trees.



Figure 2. The process of collecting raw materials (a) and separating the leaves and fronds of oil palm trees (b).



Figure 3. The process of shredding palm oil waste into raw material for mushroom growing media.

RESULTS AND DISCUSSION

These results show clear variations between waste types and between replicates. The organic C content in empty stalks ranged from 52.94 to 63.61%, which was much higher than that in fronds

(31.32–35.41%) and leaves (29.45–30.69%). This indicates that empty stalks have greater potential as a carbon source due to their high lignocellulose content.

Conversely, total nitrogen was highest in leaves (0.25–0.28%), followed by empty stalks (0.27–0.31%), and lowest in fronds (0.08–0.12%). The high nitrogen content in leaves is related to their higher protein content because leaves are active photosynthetic organs.

Meanwhile, other nutrients such as potassium (K) were relatively high in empty fruit bunches (0.87–0.95%) and fronds (0.87–0.92%) compared to leaves (0.38–0.42%), while calcium (Ca) tended to be higher in fronds (0.57–0.68%). These replicate data show consistency between replicates, so that laboratory results can be used as a basis for analyzing nutrient content differences between types of palm oil waste.

For other macro elements, the phosphorus (P) content per replicate in fronds and leaves is relatively stable at a low level of 0.12% in all replicates, while empty bunches contain 0.15–0.17%. K (potassium) was high in empty fruit bunches (0.86–0.95%) and fronds (0.87–0.90%) compared to leaves (0.36–0.42%). The calcium (Ca) content in the sheath was slightly higher (0.57–0.68%) compared to calcium in the leaves (0.43–

0.47%) and empty bunches (0.51–0.53%). Magnesium (Mg) in the fronds is relatively low (0.05–0.06) compared to the leaves (0.10–0.11%) and is quite high in the empty bunches (0.31–0.32%). Based on these elements, it can be concluded that empty fruit bunches are superior as a source of K and Mg, fronds are superior in Ca content, and leaves are superior in nitrogen content. These three types of waste can complement each other when mixed proportionally.

The results of the One-Way ANOVA analysis as presented in Table 2 show that there are significant differences ($p \leq 0.05$) in nutrient content among the three types of oil palm waste, namely leaves, fronds, and empty fruit bunches. The highest organic C content was found in empty fruit bunches (57.24%), which was significantly different from fronds (33.04%) and leaves (30.10%). This indicates that empty fruit bunches have greater potential as a carbon source for decomposing microorganisms and as a base material for growing media. Generally, the organic carbon content for oyster mushroom growing media ranges from 20-30% [9].

Table 1. Nutrient content analysis in palm oil waste

Sample	Sample No.	C-organik (%)	P (%)	K (%)	Ca (%)	Mg (%)	N-Total (%)
Leaf Stalks	1	31,32	0,12	0,88	0,57	0,05	0,11
	2	32,38	0,12	0,87	0,59	0,05	0,12
	3	35,41	0,12	0,9	0,68	0,06	0,08
Leaves	1	30,16	0,12	0,36	0,44	0,1	0,28
	2	30,69	0,12	0,42	0,43	0,1	0,25
	3	29,45	0,12	0,38	0,47	0,11	0,26
Empty Fruit Bunch	1	55,16	0,17	0,86	0,51	0,32	0,31
	2	52,94	0,15	0,93	0,52	0,32	0,31
	3	63,61	0,15	0,95	0,53	0,31	0,27

The P content in empty fruit bunches (0.16%) was higher than in leaves and fronds (both 0.12%), although the difference was relatively small. The K, Ca, and Mg contents also showed variations among palm oil waste. The highest potassium (K) content was found in empty fruit bunches (0.91%), while fronds (0.88%) and leaves (0.39%) had lower content. High potassium concentration in mushroom substrates can contribute to fruiting body formation, thereby

resulting in higher mushroom production [10]. The highest Ca content was found in leaves (0.45%), which was significantly different from fronds (0.61%) and empty fruit bunches (0.52%). Meanwhile, Mg in empty fruit bunches (0.32%) and fronds (0.50%) was higher than in leaves (0.10%). Total N content was relatively higher in leaves (0.26%) than in fronds (0.12%) and empty fruit bunches (0.31%).

These differences in nutrient composition

have implications for the C/N ratio. The leaf sheath showed the highest C/N value (332.40), indicating a large dominance of carbon over nitrogen, so it decomposes more slowly. Conversely, the leaves had the lowest C/N ratio (114.58), so they decompose more quickly and can provide nitrogen more quickly to microorganisms. Empty fruit bunches have a medium C/N ratio (194.77), which is still quite high, but they are more potentially usable as a planting medium after undergoing composting or additional treatment. The results of the C/N ratio analysis in the initial stage are still very high. Generally, the ideal C/N ratio for maximum mushroom growth and yield is 25 [11]. Thus, the three types of palm oil waste need to be

processed first through composting or mixing with other nitrogen sources to reduce the C/N ratio.

Overall, these results show that each type of palm oil waste has different characteristics. Leaves decompose more quickly due to their low C/N ratio, fronds have high carbon content but take longer to decompose, while empty fruit bunches have the potential to be a major source of carbon with relatively complete macro nutrient content. The highest concentrations of macronutrients, including N, P, K, Ca, and Mg, were found in empty fruit bunch waste. These differences are important in determining strategies for utilizing palm oil waste, particularly in its use as a mushroom growing medium or compost material.

Table 1. Results of One-Way ANOVA analysis of nutrient content in palm oil waste.

Nutrient Content Parameters	Palm Oil Waste		
	Leaves	Leaf Stalks	Empty Fruit Bunch
C-organik (%)	30,10 ^b	33,04 ^b	57,24 ^a
P (%)	0,12 ^b	0,12 ^b	0,16 ^a
K (%)	0,39 ^b	0,88 ^a	0,91 ^a
Ca (%)	0,45 ^b	0,61 ^a	0,52 ^b
Mg (%)	0,10 ^b	0,05 ^c	0,32 ^a
N (%)	0,26 ^a	0,10 ^b	0,30 ^a
C/N Ratio	114,58 ^b	332,40 ^a	194,77 ^{ab}

* The means followed by different superscript letters in the same column indicate significant differences at the $p \leq 0.05$ significance level based on Tukey's Honest Significance Test.

CONCLUSION

The results showed that palm oil waste in the form of leaves, fronds, and empty fruit bunches had different nutrient contents. Empty fruit bunches had the highest organic carbon (57.24%) and were rich in potassium (0.91%) and magnesium (0.32%), making them a great potential source of carbon and macro nutrients. Leaves have higher total nitrogen (0.26%) with the lowest C/N ratio (114.58), indicating faster decomposition. The fronds contain relatively high calcium (0.61%) with fairly high organic carbon (33.04%), but a very high C/N ratio (332.40), resulting in slower decomposition. These compositional differences

indicate that all three types of waste can be used as mushroom growing media, each with its own advantages and limitations, although the high C/N ratio requires further processing. It is recommended that the waste be processed through composting or mixing with nitrogen-rich materials to reduce the C/N ratio, and that a combination of wastes be formulated to achieve a more balanced nutrient content. Further research is needed to directly test mycelium growth and mushroom production yields, so that the utilization of palm oil waste can be more optimal ecologically and economically.

ACKNOWLEDGEMENTS

The author would like to thank AKPY and KP2 Ungaran for their support in providing facilities and research materials. Thanks are also

extended to the Hibah Penelitian Dosen Pemula Kemdiktisaintek, which provided funding to enable this research to be carried out successfully.

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