International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Utilization of Durian Husk as Substrates for White Oyster Mushroom Cultivation

Audrey Dannica O. Perez[1], Mary Michael C. Belviz[2], Isaiah Zenrich Y. Kho[3], Aiken Neil T. Soquita[4], Janel Brian S. Abangan[5]

[1,2,3,4,5]High School Department, Mapua Malayan Colleges Mindanao, Davao City, Philippines

ABSTRACT
This study examines the performance of White Oyster mushrooms grown on three types of organic substrates which are: fresh durian husks, decomposed durian husks, and dried banana leaves. The goal of this experiment is to determine the effectiveness of the agricultural waste in mushroom production and thus aid in solving food waste management. The mean growth rate as well as the variance were amongst the metrics which were measured. The findings showed that decomposed durian husk stimulated growth at a maximum level, whereas the statistical tools indicated no significant differences in growth performance across the three treatments. This means that all the technologies tested in this research are suitable for mushroom cultivation. The results of the study call attention to the possibilities of using cheap and easily accessible sources of agricultural waste for effective and environmentally friendly farming technologies, thus augmenting waste management and environmental protection.

Keywords: White Oyster Mushroom, Food Waste Management, Mushroom Cultivation, Agricultural Waste, Alternative Substrates, Waste Utilization
SGD's: Responsible Consumption and Production (SGD12), Climate Action (SGD13), Life on Land (SGD15)

Introduction

Overview and Problem of the Study

Durian (Durio zibethinus), often hailed as the "King of Fruit" in Southeast Asia, is highly valued for its distinct flavor. However, it has a short shelf life due to rapid postharvest changes (Ketsa, 2018). With the growing popularity of durian in both local and export markets, there has been a corresponding increase in durian husks, a substantial by-product of consumption that significantly contributes to agricultural waste. Consequently, improper disposal methods, whether through incineration or natural decomposition, pose environmental challenges, such as air pollution and waste accumulation (Payus et al., 2021). As food waste becomes a more pressing issue, finding sustainable solutions to repurpose durian husk waste is crucial to mitigating its environmental impact. One potential solution, therefore, is to utilize durian husks as a substrate for mushroom cultivation. This approach not only aids in waste management but also transforms waste into a valuable resource, supporting both environmental sustainability and food security. On a global scale, agricultural waste management remains a critical issue. For instance, Indonesia alone generates approximately 556,360 tons of durian waste annually. Given the high resistance of durian husks to degradation, their disposal is particularly challenging (Kusumaningtyas & Syah, 2020). Thus, converting these husks into valuable products becomes essential to reducing environmental impact and promoting sustainability. In the Philippines, around 22,000 metric tons of durian waste are generated each year, much of which ends up in landfills or is left to decompose along roadways. Improper disposal, whether through landfilling or burning, further exacerbates environmental issues by contributing to pollution and waste accumulation (Abegail et al., 2024). Moreover, in Mindanao's Region XI, durian waste reaches about 31,100 metric tons annually, with much of it similarly discarded in landfills or incinerated, compounding local environmental problems. Therefore, implementing sustainable management practices for durian husks is vital in addressing these challenges (Carlo & Lawagon, 2022).This study aims to explore the potential of utilizing durian husks and banana leaves, two common agricultural by-products, as substrates for mushroom cultivation. Both materials represent a significant portion of agricultural waste in tropical regions and finding sustainable uses for them is critical for improving waste management. By investigating the effectiveness of these substrates, this research addresses the dual challenges of reducing food waste and promoting sustainable agricultural practices. While banana leaves have been studied extensively as a substrate for mushroom cultivation, there remains a notable gap in research regarding using durian husks for the same purpose. This study seeks to bridge that gap by conducting a comparative analysis of banana leaves and durian husks, thereby providing insights into their viability as mushroom substrates. Ultimately, this research aspires to contribute to more efficient waste repurpose and offer sustainable solutions for managing agricultural byproducts.

Theories and Related Literature

Theories:

Circular Economy Theory

The Circular Economy Theory by David W. Pearce and R. Kerry Turner in 1989, is based on the rationale that now is the time to rethink the traditional economic model in such a way that the least amount of waste is produced, and resources will be utilized as efficiently as possible. Contrary to the linear approach of "take, make, dispose," this circular economy looks forward to the use of products, materials, and resources as long as possible through the processes of reuse, recycling, and regeneration. This theory calls for the complete closure of production processes to ensure that waste is recycled into resources that may be reintroduced into the economy in order to reduce harm to the environment.

The relevance of this theory to this study relates to the durian husk waste created in the food processing industry. By applying the approach to the circular economy, this enormous amount of durian husks could be transformed into a resource, for example, by serving as a substrate for mushroom cultures. In other words, instead of being waste that is disposed of, those husks became an input with sustainability and helped lessen environmental degradation. Thus, these provided a circular use of resources. This approach has its application in waste management, offering value by reconversion of by-product into an economically feasible and environment-friendly solution according to the core tenets of the Circular Economy Theory.

Sustainable Agriculture Theory

Sustainable Agriculture Theory by Christopher Chapman and Spencer Cheshire in the 1950s emphasizes farming practices that maintain ecological balance, reduce environmental harm, and ensure the long-term viability of agricultural resources. It focuses on methods that promote food security, resource efficiency, and biodiversity while minimizing the use of synthetic inputs and non-renewable resources (MacRae, 1990). This theory integrates environmental stewardship, economic viability, and social responsibility to create resilient and self-sustaining agricultural systems.

This theory is relevant to this study as it focuses on the use of agricultural by- products to promote eco-friendly farming practices. By utilizing durian husks and banana leaves, which are commonly discarded as waste, the research supports the efficient use of resources and reduces environmental impact. This approach not only minimizes waste but also offers a sustainable method for mushroom cultivation, contributing to food security and resource conservation. The study aligns with the principles of sustainable agriculture by transforming waste into valuable resources, thereby supporting both environmental and economic sustainability in farming.

Related Literature

Exploring Agricultural Waste as Sustainable Substrates

The agricultural sector is one of the leading generators of massive amounts of waste, which has raised public concern and threatened the sustainability of agricultural practices. Agricultural waste includes organic by-products from farming activities, such as crop residues, fruit peels, husks, leaves, and other plant materials (Adetunji, 2021). In the Philippines, approximately 42% of the vegetable harvest is lost to spoilage, which significantly contributes to the country's solid waste management challenges (Sanchez et al., 2019). When not properly managed, agricultural waste leads to environmental issues such as pollution, land degradation, and greenhouse gas emissions (Abubakar et al., 2022). These by-products release methane (CH4) and carbon dioxide (CO2), which negatively affect air and water quality, degrade soil health, and produce unpleasant odors (Pawar et al., 2024). In addition, improper disposal of agricultural residues, often through open burning or landfilling, exacerbates environmental degradation. Therefore, finding sustainable uses for this waste is critical to reducing its environmental impact.

One promising solution to this growing issue is mushroom cultivation, which repurposes agricultural waste into productive substrates (Dey et al., 2024). Mushrooms, particularly species like Pleurotus (oyster mushrooms), have the ability to decompose lignocellulosic materials, converting agricultural by-products into a valuable resource (Adebdayo, 2015). Agricultural by-products such as wheat straw, paddy straw, rice bran, molasses, coffee husks, banana leaves, tea leaves, cotton straw, and sawdust can effectively support mushroom growth (Kmathan, 2017). These materials are often rich in cellulose, hemicellulose, and lignin, which are ideal components for mushroom substrates as they provide the necessary nutrients for fungal growth. For instance, Thuc et al. (2024) demonstrated that rice straw, a prevalent by-product in rice-producing regions, is an ideal substrate for mushroom cultivation. Rice straw is abundant in cellulose, which makes it a suitable medium for mushrooms to decompose and absorb nutrients. Similarly, Dubey et al. (2019) conducted a comparative analysis of different substrates—rice straw (T1), wheat straw (T2), banana leaves (T3), and sugarcane bagasse (T4)—and found that banana leaves and rice straw yielded promising results in terms of both productivity and sustainability.

Rice husk is a by-product of rice milling and contains a high lignin content, making it suitable for mushroom cultivation, especially for species like Pleurotus (Oyster mushroom) (Costa et al., 2023). It is lightweight and provides a favorable aeration environment for mushroom mycelium development. Corn cobs, often discarded after harvesting, are rich in carbohydrates, which can support mycelial growth. Research has shown that Pleurotus ostreatus (Oyster mushrooms) and Ganoderma lucidum (Reishi mushrooms) thrive on corn cob-based substrates (Itelima, 2012). Banana leaves, stems, and pseudostems are abundant waste materials in banana- producing regions. Studies suggest that banana substrates are effective for growing mushrooms like Volvariella volvacea (straw mushrooms) due to their water-holding capacity and high cellulose content (Carvalho, 2012). Spent coffee grounds are another waste product with growing potential in mushroom farming. They are rich in nutrients and are ideal for cultivating mushrooms like Pleurotus species. This approach also aids in reducing coffee waste in urban areas (Chai et al., 2021). Sawdust is one of the most commonly used agricultural and forestry by-products for mushroom cultivation, particularly for growing species like Lentinula edodes (Shiitake mushrooms) and Pleurotus (Oyster mushrooms). Sawdust is rich in lignin and cellulose, providing essential nutrients for mushroom mycelium (Bhattacharjya et al., 2014).

The agricultural sector generates a significant amount of waste, such as crop residues and husks, leading to concerns about sustainability and environmental degradation. In the Philippines, around 42% of vegetable harvests are lost due to spoilage, adding to solid waste management issues. Improper disposal of agricultural waste contributes to pollution and greenhouse gas emissions, harming soil health and air quality. To tackle these problems, mushroom cultivation has emerged as a promising solution by repurposing agricultural waste into effective substrates. Mushrooms, particularly Pleurotus (Oyster mushrooms), can break down lignocellulosic materials, converting by-products like rice straw, banana leaves, and sawdust into valuable resources for growth. Research shows that substrates rich in cellulose and lignin, such as rice straw and corn cobs, support strong mushroom production. Additionally, the use of spent coffee grounds and banana substrates helps promote sustainability in mushroom farming by reducing waste. Overall, employing agricultural waste for mushroom cultivation encourages a circular economy and addresses environmental challenges in agriculture.

Analyzing the Role of Substrates in Mushroom Cultivation

Growing interests of farmers, entrepreneurs, and scientists in mushroom cultivation toward increasing potential profitability and good nutrition have been noticed at a global level. There have been several studies carried out by researchers on the use of various substrates for the increased yield and quality of mushrooms, but the main focus is nutritional sources for the mushroom mycelium (Fasehah & Shah, 2017). The other common substrates that have reported success variably included wheat straw, cottonseed straw, cereal straw, corncob, sugar cane straw, and sawdust (Besufekad et al., 2019). However, there has been no clear and precise information on the usage of wood chips as compared to other substrates used for mushroom cultivation (Masevheet al., 2016). This does not contest the point that proper substrates are usually important in influencing bioefficiency, yield, and nutritional content factors of mushrooms (Honsbein, 2016). The multiplicity of substrate types suggests that more research is required for the optimization of mushroom cultivation practices.

The general cultivation process involves the inoculation of logs with mushroom spawn, after which they are incubated under optimal environmental conditions (Levine, 2020). Hardwood substrates, used as a growing medium for mushrooms, not only act as a substrate for mushroom growth but also help in the production of medicinal bioactive compounds in mushrooms. The tradition and medicine attached to wood substrate-grown mushrooms find their relevance to modern life. Straws are one of the most commonly used and easily available substrates for mushroom cultivation, especially in species such as the Oyster mushrooms and Volvariella volvacea. Straw is the substrate that is popularly used due to its abundant availability, ease of handling, and being at a low-cost factor for mushroom farmers (Sharma et al., 2014). Preparation of the straw for mushrooms requires soaking, sterilizing, and even supplementation with nutrients like wheat bran for growth (Ahlawat, 2016). Straw substrates have the disadvantage of being prone to contamination, which would negatively impact mushroom yield (Owaid et al., 2015). Whether or not mushroom cultivation on straw is successful depends on how well these challenges can be managed. Hence, there is an ever-present need for continuous improvement in the preparation and processing of straw substrates.

Since, such agricultural by-products as straw and sawdust are at hand and relatively inexpensive, most traditional methods of mushroom farming are based on these materials. In many cases, such substrates are supplemented with wheat bran, gypsum, or other organic additives to make it better in its nutritional value (Royse et al., 2017). These enrichments are particularly important for adjusting pH with necessary nutrients, such as nitrogen, carbon, and minerals, for fungi in enhanced growth (Sardar & Haque, 2017). Proper substrate preparation for sterilization or pasteurization will ensure that microorganisms have been removed, allowing effective fungal colonization (Zied et al., 2016). According to Beyer (2017), the preparation should be enhanced properly.According to Masevhe et al. (2016), mushrooms can be grown on different substrates. Agro-industrial wastes, such as coffee grounds and sugarcane bagasse, are being used as substrates to produce a very good alternative to traditional materials in a very environmentally friendly way (Sardar & Haque, 2017). It will not only contribute to reducing environmental wastes but also lower production costs with respect to the circular economy (Zhang & Wang, 2017). Besides this, simplification in mushroom cultivation comes with the development of synthetic formulation and pre-treated substrate blocks, which reduce several labor-intensive preparation steps (Beyer, 2017; Royse et al., 2017).

Substrates play an important role in mushroom cultivation since they serve as a medium of nutrients for mycelium growth and greatly affect yield, bioefficiency, and mushroom quality. The substrates that have been widely used are the traditional ones, namely wheat straw, sawdust, and cottonseed straw, which are very accessible and affordable, though they pose risks such as contamination. Among the innovations in their use of agro-industrial wastes like coffee grounds and sugarcane bagasse is that they are renewable resources, which could help cut down on environmental waste, while the cost of production will be reduced as well if it is prepared perfectly. The most important preparations, especially sterilization and supplementation with nutrients such as wheat bran, are for ensuring optimal substrate performance. Coupled with breakthroughs in substrate processing, the continuous discovery of new substrates forms an arena with whose challenges mushroom cultivation will face with, and thus, will require endless research into making it more efficient and sustainable. This paper sets its center on how substrates from conventional agricultural by-products to innovative alternatives affect mushroom yield, bio-efficiency, and the sustainability of mushroom yields directly. It further explains that the choice of substrate and preparation methods play a critical role in the overall success and impact that mushroom culture will have.

Assessing the Feasibility of Durian Husk as a Mushroom Substrate

Durian husk is a type of lignocellulosic biomass that consists of cellulose, hemicellulose, and lignin. It comprises about 55-66% of the durian fruit by weight (Gamayet, al., 2024). Disposing of agricultural waste poses environmental challenges, often ending up in landfills or contributing to pollution when burned (Payus, et al.,2020). However, it is readily available in regions where durian is produced and can be used as a mushroom substrate. Research has shown that durian husk contains significant amounts of glucan, xylan, and lignin, which are beneficial for supporting fungal growth (Wen et al., 2023). Its high cellulose content suggests it could effectively serve as a substrate for various mushrooms, potentially rivaling more traditional substrates like straw and wood chips (Sayner, 2024). Durian husk's nutritional profile indicates it could sustain mushroom species that thrive on lignocellulosic materials (Woo et al., 2023).

Several studies have demonstrated the potential effectiveness of durian husk as a substrate for mushroom cultivation. According to Jayasinghe et al. (2022), species such as oyster mushrooms, shiitake, and button mushrooms have been successfully cultivated on durian husk, achieving notable growth rates. The results indicate that mushrooms cultivated on durian husk substrates can yield competitive results when compared to more traditional substrates. Utilizing durian husk as a mushroom substrate contributes to sustainability by transforming agricultural waste into a valuable resource. This practice not only mitigates environmental issues related to waste disposal but also reduces reliance on non-renewable resources, aligning with broader sustainability goals (Woo et al., 2023). Economic studies indicate that using durian husk as an alternative substrate can be a cost-effective solution for mushroom cultivation, particularly in regions where durian is produced in large quantities (Jia Ying Chua et al., 2023). The accessibility and low-cost nature of durian husk could benefit small-scale farmers, enabling them to increase their profitability while reducing waste. For durian husk to be effectively used as a substrate, it requires some processing, which may include drying, shredding, and potentially composting to improve nutrient content and reduce contamination risks (Hamzah et al., 2023). Additional enrichment may be necessary to enhance its performance for specific mushroom species (Mahathaninwong et al., 20220.

Research comparing the nutritional value and biological efficacy of mushrooms grown on durian husk versus other agricultural waste substrates indicates that while durian husk holds potential, it may not consistently match the performance of conventional options (Carrasco et al., 2018). Variations in yield and nutritional composition can lead to differing outcomes in mushroom viability depending on the substrate used (Hoa et al., 2015). Oyster mushrooms, particularly Pleurotus ostreatus and Pleurotus pulmonarius, have demonstrated good growth on durian husk, yielding competitive results when compared to traditional substrates like sawdust (Zamakshshari et al., 2023). Studies show that these species can effectively utilize the lignocellulosic components in durian husk, suggesting that they are well-suited for this substrate (Suwannarach et al., 2022). This comparative analysis emphasizes the need for detailed evaluations to fully determine the strengths and weaknesses of durian husk in comparison to other substrates.

The husk of durian, a byproduct from durian production, is being considered as a potential substrate for mushroom cultivation due to its high cellulose, hemicellulose, and lignin content (Gamayet et al., 2024). Research indicates that various mushroom species, including oysters, shiitake, and button mushrooms, can grow well on durian husk (Jayasinghe et al., 2022). This makes it a cost-effective alternative to traditional substrates like straw and sawdust, especially for small-scale farmers in durian- producing regions (Jia Ying Chua et al., 2023). Its use not only helps in addressing agricultural waste disposal issues, and reducing landfill use and pollution (Payus et al., 2020) but also aligns with sustainability goals by repurposing waste into a valuable resource (Woo et al., 2023). However, durian husk requires processing—such as drying, shredding, and composting—to reduce contamination risks and optimize its nutrient profile, with potential enrichment needed for certain mushroom species (Hamzah et al., 2023). While its performance may vary (Carrasco et al., 2018), species like Pleurotus ostreatus and Pleurotus pulmonarius have shown strong growth on durian husk, indicating its viability (Zamakshshari et al., 2023). Overall, integrating durian husk into mushroom cultivation offers a sustainable and economically beneficial approach, though further optimization is necessary to fully realize its potential.

Evaluating Banana Leaves as a Viable Substrate Option

Being rich in sugars, lignocellulosic materials such as banana leaves are potential resources for recovery. The lignin, cellulose, and hemicellulose they contain are responsible for low biodegradability, thus pre-treatment methods are needed (Akpinar and Urek, 2017; Kucharska et al., 2018). In tropical countries like Tanzania, banana leaves, which are a common by-product, are generated in substantial quantities every day because of its versatile utility (Padam et al., 2014). Such leaves need an effective pre-treatment to break down the lignin structure, which would enhance substrate digestibility if such waste is utilized for energy recovery, for example, in biogas production (Kennedy, 2014). So being able to convert such wastes to energy is a very strong focus of the present research endeavor. (Sharma et al., 2020)

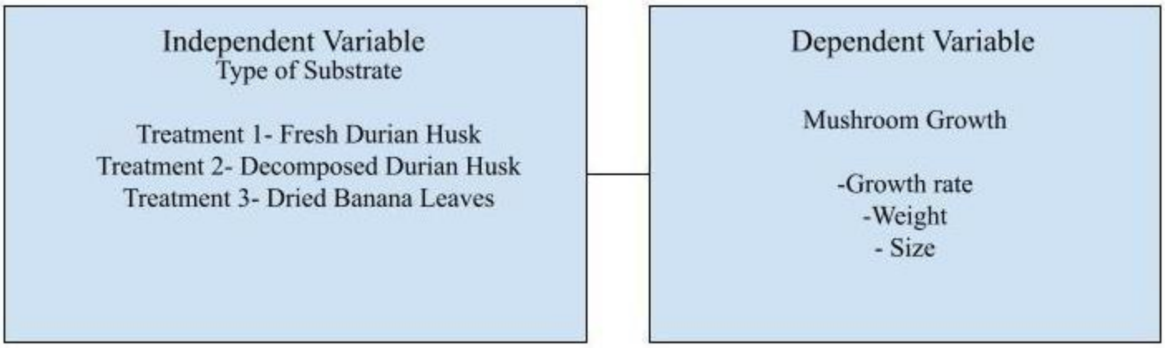
Pre-treatment techniques have been developed to increase the digestibility of lignocellulosic materials, and generally, they include chemical, physical, and biological approaches. Chemical treatments, although effective, mainly tend to be costly and unfriendly to the environment because of the formation of inhibitory by-products such as phenolic compounds and furans (Ariunbaatar et al., 2014; Kumar and Sharma, 2017). Chemical pre-treatments often create additional challenges, as they require intensive waste management processes to address toxic by-products, further increasing environmental impact (Alvira et al. 2010; Lu et al. 2022). The biological methodologies based on fungal pretreatment are considered more environmentally friendly since they operate under milder conditions and safely avoid residues of hazardous chemicals (Chaturvedi and Verma, 2014; Sari and Budiyono, 2014). In return, biological treatments have a host of disadvantages themselves, with slow processes and the loss of precious carbohydrate resources during their processing (Mishra et al., 2018).

Fungal pre-treatment, especially of species such as Pleurotus ostreatus that have been proven to degrade lignin from lignocellulosic substrates and thus make them more easily digestible for biogas production, has been quite promising (Abdel-Hamid et al., 2015). Research has indicated that *P. ostreatus* fungi produce enzymes capable of breaking down the lignin structure effectively, thus making the cellulose more accessible (Munir et al., 2021). Fungal treatment has been able to show better anaerobic digestion in various material wastes, including wheat straw and sugarcane bagasse. Works reported by Albornoz et al., (2018) and Amirta et al., (2016) showed that this could increase anaerobic digestion. Hence, similar results would be assumed for banana leaves for those types of works which have not been tested much. For example, fungi like P. ostreatus remove lignin by depolymerization, thus increasing the access of cellulose and subsequently increasing the effectiveness of the biogas production process (Pérez-Chávez et al., 2019).

These pre-treatment methods with the aid of fungi are effective, but their efficacy is dependent on the species of fungi involved and the pre-treatment time (Wobiwo et al., 2018). For example, longer pre-treatment times may lead to higher lignin degradation but could also cause loss of available carbohydrates, reducing biogas yield (Zhou et al., 2020). Although fungi like P. ostreatus increased biogas yield on some occasions, in other studies, fungal pre-treatment caused removal of carbohydrates to even reduce biogas yield (Tuyen et al., 2014). Such variability brings to mind just how complex a process it is and how important it would be to conduct more studies aimed at further optimizing the conditions for such specific substrates as banana leaves. (López et al., 2020; Wei et al., 2023).

This work is, therefore, an effort to fill the identified knowledge gap by looking into the decomposition of banana leaf waste with P. ostreatus and further biogas production. In this work, treatment of banana leaves with P. ostreatus studied mushroom production and biogas yield. The interesting areas of research included changes in trace elements, changes in composition of biomass, and some alterations contributing to the formation of biogas in general (Vieira and de Andrade, 2016). Conditions were very controlled in terms of humidity and temperature to enable the spawn to have great growth of its fungi. In fact, Tesfaw et al., (2015), present data which could explain how waste banana leaves, after pretreatment by fungi, could be made to become promising feedstock for energy production.

Conceptual Framework



(Fig. 1. Conceptual Framework of the Study)

The conceptual framework illustrates the relationship between the independent variable and the dependent variable. The framework intends to trace how the variation of substrate type impacts the cultivation process, specifically the growth rate, weight, and size of mushrooms. The independent variable will be varied to study its direct effect on the dependent variable and comprehend which substrate is more effective for mushroom cultivation.

Objectives and Hypothesis

This study aims to assess the effectiveness of Durian Husk and Banana Leaves as a substrate for white oyster mushroom cultivation. By examining the material, the researchers seek to evaluate the effectiveness and potential in supporting mushroom growth and quality. The insights gathered will help us understand if the substrate is effective and cost-efficient for mushroom cultivation.

1. Determine the growth rate of White Oysters using Durian Husk and Dried Banana Leaves
2. Determine the weight of Oyster Mushrooms utilizing the different treatments of Durian Husk and Dried Banana Leaves as substrate
3. Determine the size of Oyster Mushrooms utilizing the different treatments of Durian Husk and Dried Banana Leaves as substrate

Hypothesis:

There is no significant difference in the growth rate, size and weight of the Oyster Mushroom utilizing the different treatments of Durian Hush as Substrate

Significance of the Study

This research explores the potential of durian husk and dried banana leaves as sustainable substrates in white oyster mushroom cultivation. It aims to assess the effectiveness of the durian husk and dried banana leaves as it will provide the findings that will serve as a reference for the various beneficiaries, including:

Mushroom Cultivators: This study will directly benefit mushroom cultivators as the study will provide insights about the potential and yield growth of durian husk and dried banana leaves as substrates for white oyster mushrooms that would promote sustainable cultivation.

Agriculture Advocates: The study will benefit agriculture advocates by demonstrating the potential and cost-effectiveness of durian husk and dried banana leaves as a substrate in sustainable mushroom farming.
Environmentalist: Environmentalists will benefit from the study by gaining insights how agricultural waste like durian husk and dried banana leaves can be repurpose into cost effective white oyster mushrooms.
Students: Future researchers will benefit from this study by gaining valuable insights and knowledge from the potential of white oyster mushroom cultivation as a sustainable agriculture practices.

Limitations of the Study

The study covers the growth rate of White Oyster Mushrooms on a Durian husk substrate and dried Banana leaves that compares relative to the growth rate. The data will be derived from the comparison the researchers make with the help of an expert to thoroughly explore the results of the experiment. The study may also run into a lack of exploration in between variables and may not be thoroughly explored due to either prior knowledge or lack of depth in the past studies that surround them. This places the study on a theoretical standpoint as there is a lack of abundant data on our study topic. Though the data may be limited, the data acquired in this research may help improve further iterations or versions of the topic. There may also be gaps in the lack of knowledge on each variable's practicality as many variables play into a plant's growth. Though minimal in scale, cases such as time of year, quality of materials, and general knowledge may play factors into experiments that may be conducted in the future.

Methods

Research Design

The research design that will be used in this study will be experimental, as proposed by Sir Ronald A. Fisher (Montgomery et al., 2022). This design will allow the researchers to test hypotheses and systematically study causal relationships among variables. By manipulating the independent variable; the type of substrate that will be used for mushroom cultivation. The researchers will observe its effects on the dependent variables, such as mushroom growth rate and shell life while controlling for external factors like temperature, humidity, and light. This design will be highly relevant to the study as it will enable a direct comparison between durian husk and other substrates (Banana leaves), ensuring that any differences in mushroom growth can be attributed to the substrate itself. The findings will provide insights into the feasibility of using durian husk as a sustainable, cost-effective substrate, potentially contributing to both agricultural innovation and environmental sustainability by repurposing agricultural waste.

Sampling Design, Respondents, and Locale

This study will be conducted in Calinan, Davao City, a region known for its agricultural activities, particularly the cultivation of tropical fruits such as durian and bananas. Calinan's agricultural environment provides an ideal setting for the experiment, as the availability of durian husks and banana leaves offers readily accessible raw materials for substrate preparation. A completely randomized design (CRD) is a straightforward experimental approach where subjects or experimental units are randomly assigned to different treatment groups, ensuring that each group has an equal chance of receiving any specific treatment (Forthofer et al., 2007). This randomization minimizes bias and helps control for potential external factors, such as environmental conditions, that could otherwise influence the results. It is especially useful when external factors are expected to be consistent across the experiment.

This study aims to convert three types of agricultural waste into mushroom substrates: banana leaves, fresh and decomposed durian husks, and rice bran (used as a control). These treatments will be distributed into five separate bags for each substrate type. This random assignment ensures that any variations in mushroom growth can be attributed to the different substrate types, rather than uncontrolled external influences. By using a CRD, the study enhances the reliability and validity of its findings, providing a clearer understanding of how each substrate performs under the same conditions. This design not only simplifies the experimental process but also ensures more accurate comparisons among the treatments.

Instrument and Procedures

A comparison of the ability of durian husk and banana leaves to support white oyster mushroom growth will be carried out by an experiment. The tools for finding how fast the mushrooms grew, how much they produced, and their size were simple survey tools that had to be tested first for correctness in giving results. The collection procedure for the data is as follows: (1) Substrate preparation: The sawdust sieves out the larger particles. A mixture is prepared by making use of 78% of sawdust, 20% rice bran, 1% sugar, 1% lime, and 60-65% water, by using palm test method. Mix the substrate and pile it in a cone shape for composting or fermentation with plastic sheets. It is turned every 2-3 days for 15-21 days. This is step 1 of the process. (2) 1 kg of the fermented substrate is packed into 6 x 12inch polypropylene bags. The bags are compressed, and ready for steaming, which will sterilize the bags for 6-8 hours at 15- 20 psi. Later, mushroom spawn is introduced into each bag in a clean and sterile room.

(3) The bags inoculated are kept in an incubation room with controlled temperature at 25°C for 30-45 days so that the mushrooms grow. (4) In this period, the conditions inside the bags are watched so that ideal conditions exist from 20-28°C with relative humidity of 80-85%.3 Growth observations and size with a general health condition are recorded. (5) Once the fruiting stage is accomplished, the mushroom is picked, weighed, and yield recorded on a basis of "Poor" to "Excellent" standards developed and chosen. Growth and yield rated from "Poor" to "Excellent" based on standard set criteria. As can be derived from the tables below.

Table 1

Fresh Durian Husk	Replica 1	Replica 2	Replica 3	Replica 4	Replica 5
Growth Rate					
Weight					
Size					
Overall					

Table 2

Dried Banana Leaves	Replica 1	Replica 2	Replica 3	Replica 4	Replica 5
Growth Rate					
Weight					
Size					
Overall					

Data Analysis

In this study, mixed descriptive and inferential statistical analysis of data will be applied to review the effectiveness of durian husk and banana leaves as substrates for mushroom culture. This would summarize the growth rates, quality, and yield of the white oyster mushrooms. The four treatments that will be used are pure decomposed durian husk, fresh durian husk, dried banana leaves, and sawdust with rice bran as a control treatment. A completely randomized design will enable all treatments to be fair. In the form of "Analysis of Variance", inference statistics would be used in testing the hypothesis towards the comparison of growth rates means of mushrooms on substrates so as to be able to settle whether or not there is a difference in terms of growth between such substrates and consequently, which of them should be appropriate for mushroom cultivation.

RESULTS AND DISCUSSION

Objective 1

Table 1 illustrates the growth performance of White Oyster mushrooms grown in fresh durian husk and dried banana leaves substrates.

Table 1

Growth Rate (Days) of White Oyster Mushrooms on Different Substrates

Treatment	R1	R2	R3	R4	R5	Mean
Fresh Durian Husk			2			2.07
Decomposed Durian Husk			2.67	1.66 2.33 2.67	4 2.67	
Banana Leaves	2	2.33 6	2.6	2.33	2.66 0	2.4

ANOVA - Value

Cases	Sum of Squares	df	Mean Square	F	p
Column 2	1.736	4	0.434	1.116	0.402
Residuals	3.887	10	0.389		

Note. Type III Sum of Squares

This table illustrates the growth rate performance of the White Oyster mushroom cultivated in the three different substrates fresh durian husk, decomposed durian husk and banana leaves. The value which was the highest mean growth of 2.67 days as documented for the decomposed durian husk the best among the treatments. Indicating that there was more variability in the growth performance between replicates. However, mean growth values of 2.07 days and 2.40 days were obtained for fresh durian husks and banana leaves. These results are indicative of consistent and stable growth performance in these two substrates. The sum of squares for the factor in "Column 2" is 1.736, with a corresponding F-statistic of 1.116. This indicates that the variability between the groups is relatively small compared to the residuals. Since the p-value is greater than 0.05, we fail to reject the null hypothesis. This means there is no statistically significant difference between the groups in "Column 2." Any differences observed are likely due to random variation rather than the factor being tested.

Studies on mushroom cultivation with the utilization of agricultural waste encourage supporting fungi with lignocellulosic materials. According to Kumla et al. (2020), banana leaves have moderate content of cellulose and hemicelluloses but still contain enough nutrients for the mycelium and fruiting bodies to grow. Similar findings by Rizal et al. (2020) distinguished the potential of the tropical agricultural residues including banana leaves and fresh durian husk to be used as effective substrates for mushroom production. This study is also consistent with the previous experiments in that fresh durian husk, which is porous in structure, is able to create a more conducive environment for better yields.

The results of objective 1 indicates that there is no need for extra resources to invest in already existing materials as fresh durian husk can be utilized as a substrate for mushroom cultivation. These crops are also particularly promising for small and large mushroom farmers because of their relatively higher yield as compared to dried banana leaves. In addition, the use of these agricultural waste substrates is in line with sustainability measures by utilizing waste products and supporting circular agriculture systems. The fact that the growth rates as well as the yields associated with these substrates are similar indicates that they can both be used in a wide range of farming systems with little loss in output levels.

The minor yield advantage offered by the dry durian husk and banana leaves has been attributed to the presence of greater nutrients, which may have drained away during the drying process, in comparison to the dry banana leaves. Furthermore, the fresh durian husk facilitates greater mycelial attachment and growth as it has a lower density constructional factor. On the contrary, the dried banana leaves have a much less advanced structure and as a result, the yields are likely to be non-uniform. These types of differences also highlight the optimum variety of substrate for mushroom farming so that the optimization of availability, nutrition, structural characteristics and quality is achieved.

Objective 2

Table 2

The weight (g) of Oyster Mushrooms utilizing the different treatments of Durian Husk and Dried Banana Leaves as substrate

Treatment	R1	R2	R3	R4	R5	Mean
Fresh Durian Husk			72.67			65.27
Decomposed Durian Husk	65.67	71.67	46.33	45.67	44	54.67
Banana Leaves	64	75.33	68.33	56	53	63.33

ANOVA - Column 2 ▼

Cases	Sum of Squares	df	Mean Square	F	p
Column 3	219.833	4	54.958	0.745	0.583
Residuals	737.673	10	73.767		

Note. Type III Sum of Squares

The objective of this research was to study the weight of white oyster mushrooms produced using various treatments of durian husk as a substrate. The two primary treatments are Durian Husk (decomposed and fresh) and a control substrate, Dried Banana Leaves. The main parameter for assessing substrate efficiency was mushroom weight, recorded after harvest across several growth cycles and replicates.

Yield of white oyster mushrooms cultivated on three different substrates, fresh durian husk, decomposed durian husk, and banana leaves (control). Fresh durian husk has a mean yield of 65.27 g, this indicates a consistent growth across replicates. Decomposed durian husk had the lowest mean yield of 54.67 g, with the highest standard deviation of 11.61 and highest variance of 134.88, indicating greater variability in mushroom growth. The mean yield of the control substrate, banana leaves, is competitive at 63.33 g. The factor in "Column 3" has a sum of squares of 219.833, with an F-statistic of 0.745. This suggests that the factor accounts for a relatively small portion of the total variability compared to the residuals (737.673). Again, the p-value is greater than 0.05. This indicates no significant effect of the factor on the outcomes in "Column 3." The results suggest that the factor being tested does not cause meaningful differences between groups.

These results confirm the potential of durian husk as a viable substrate for cultivating the white oyster mushroom, complementing the recent findings by Jayasinghe et al. 2022, and Zamakshshari et al. 2023 related to equal growth and yield from Pleurotus species based on substrates developed from durian husk. This must be due to the existence of lignocellulosic constituents such as cellulose and lignin according to Wen et al. (2023) and Woo et al. (2023). In general, the lignocellulosic agro-industrial residues such as rice straw (Thuc et al., 2024) and banana leaves (Carvalho, 2012) provide a good nutrient foundation for the growth of fungi.

Even though durian husk has competitive results, there were some variations that occurred, which agrees with Carrasco et al. (2018), who stated that the performance of the substrate might vary depending on the species of mushroom and preparation of the substrate. This research, as found by Hamzah et al. (2023), focuses on the importance of pre-treatment processes such as drying and shredding in order to reduce contamination and optimize the substrate for fungal colonization. Other contamination risks, as mentioned with other substrates, such as banana leaves (Owaid et al., 2015), were also seen, and more processing or additives may enhance the performance of the substrate.

The performance of other substrates, rice straw, and sawdust, is achieved with durian husk, suggesting its viability as an affordable, sustainable substitute where durians are primarily grown. This further supports the findings of Jia Ying Chua et al. (2023), which emphasized its accessibility and low cost for small-scale farmers. Further optimization, as suggested by Mahathaninwong et al. (2022), is needed to fully match the consistency of traditional substrates like sawdust in terms of yield and bio- efficiency. These results reiterate the potential of Durian Husk for commercial mushroom cultivation. Its reliability is highlighted by the lower variance than Banana Leaves. Although less efficient and consistent, Banana Leaves are cheaper and more readily available. Access to durian husk is, therefore, variable. The expected outcome is the improvement of preparation processes for Durian Husk to enhance its optimal benefits, thus further improving its commercial viability.

Its high nutrient bioavailability and greater capacity to retain water are the reasons for the good performance of Durian Husk in supporting growth. Lower variability in the weight results can be attributed to stable support for fungal growth. Conversely, Banana Leaves underperformed probably due to their low nutrient content and poor retention of water leading to higher variability. These findings therefore highlight how differences in the substrate composition and preparation can critically influence mushroom yields.

Objective 3

Table 3 illustrates the volume size (approximated as ellipsoids) of White Oyster mushrooms, grown in fresh durian husk, decomposed durian husk, and dried banana leaves substrates.

Table 3 ***Volume size*** **(approximated as ellipsoids)** ***of White Oyster Mushrooms on Different Substrates***

Treatment	R1 (cm^3)	R2 (cm^3)	R3 (cm^3)	R4 (cm^3)	R5 (cm^3)	Mean (cm^3)
Fresh Durian Husk	896.57	805.29	851.72	1004.79	1018.92	915.46
Decomposed Durian Husk	702.15	554.84	481.37	512.08	551.87	560.46
Banana Leaves	987.86	1003.91	811.58	733.04	998.33	906.94

ANOVA - Column 3

Cases	Sum of Squares	df	Mean Square	F	p
Column 2	184094.745	4	46023.686	0.640	0.646
Residuals	718840.179	10	71884.018		

Note. Type III Sum of Squares

The data from this objective show significant differences in the growth of Oyster Mushrooms cultivated on three different substrates: Fresh Durian Husk, Decomposed Durian Husk, and Dried Banana Leaves. The mushrooms grown on fresh durian husk exhibited the largest mean volume of 915.46 cm^3, indicating

moderate variability in growth. In contrast, the decomposed durian husk produced mushrooms with a mean volume of 560.46 cm^3, which was substantially lower, indicating more consistent growth. The dried banana leaves yielded mushrooms with a mean volume of
906.94 cm^3, similar to that of fresh durian husk, signifying greater variability in mushroom size. These results suggest that while fresh durian husk is the most effective substrate for larger yields, dried banana leaves are a comparable alternative with more variable outcomes. For "Column 2" in this table, the sum of squares for the factor is 184,094.745, with an F-statistic of 0.640. Despite the large sum of squares, the residuals (718,840.179) dominate the total variability, and the F-statistic is low. The p-value is much greater than 0.05, indicating no statistically significant differences among the groups. The factor being tested does not seem to meaningfully affect the variability in this column.
This study shows that durian husk is a good material for growing Pleurotus ostreatus mushrooms. The results highlight how durian husk performs better than dried banana leaves for growing oyster mushrooms. Because it is rich in cellulose and lignin, durian husk supports mushroom growth, leading to larger mushrooms and higher yields. Research by Zamakshshari et al. (2023) also suggests that fresh durian husk creates the best conditions for mushroom development. This agrees with the high yield we saw in this study. Additionally, Woo et al. (2023) showed that choosing the right substrate affects the growth rate and final yield of mushrooms, durian husk usually promotes faster growth. Pre-treating the substrate, such as drying and shredding, enhances the availability of nutrients in durian husk. Carrasco et al. (2018) emphasized this point, which explains the strong results observed in the group using fresh durian husk. The findings also demonstrated that banana leaves are indeed effective as a substrate for mushroom cultivation. Sharma et al. (2020) discovered that properly pre- treated banana leaves can yield results comparable to those of traditional materials. Although this study showed slightly lower yields with dried banana leaves, they can still serve as an effective alternative substrate when optimized.
The implications of these results are significant for sustainable mushroom farming practices. The use of durian husk, particularly fresh durian husk, provides an effective and high-yielding substrate that is rich in nutrients, thereby reducing the need for synthetic substrates or additional fertilizers in mushroom cultivation. Moreover, the moisture retention capacity of durian husk, as highlighted by Woo et al. (2023), plays a key role in promoting optimal growing conditions, and ensuring steady mushroom development. However, the sustainability of using durian husk is dependent on the availability of this agricultural waste, and in regions where it is not readily accessible, banana leaves offer a highly promising alternative. The variability in results observed with banana leaves indicates that with further refinement in pre-treatment processes, such as enhancing the degradation of lignocellulosic material, banana leaves could be optimized for more consistent and predictable yields. This could offer a sustainable option for mushroom farming in areas where durian husk is scarce, while also contributing to waste management by repurposing agricultural byproducts.
While the study highlights the advantages of fresh durian husk and banana leaves, several factors could explain the variability observed in the results, particularly with banana leaves. The higher standard deviation and variance in banana leaves may be attributed to the less intensive pre-treatment they require compared to durian husk. While durian husk benefits from a more thorough drying and shredding process, which may standardize nutrient availability, banana leaves might require more specialized methods such as fungal inoculation or controlled degradation to reach their full potential as a substrate. This variability may also be influenced by environmental factors, such as temperature, humidity, and cultivation practices, which can affect the consistency of fungal colonization on banana leaves. Furthermore, the slightly lower

yields observed on decomposed durian husk could be due to the breakdown of its cellular structure, which reduces its ability to provide sufficient nutrients for the mushrooms. This suggests that while decomposed durian husk is more consistent, it may not offer the same nutritional advantages as fresh durian husk for optimal mushroom growth.

CONCLUSION AND RECOMMENDATIONS

Conclusions

The research problem addressed in this study focuses on the environmental challenges posed by the improper disposal of agricultural waste, specifically durian husks, and banana leaves, which contribute to pollution and waste accumulation. The study's purpose is to investigate the potential of these by-products as sustainable substrates for mushroom cultivation, providing dual benefits of waste management and food production. The objectives included assessing the growth rate, yield, and volume size of mushrooms cultivated on fresh and decomposed durian husks and dried banana leaves. Results revealed that decomposed durian husks supported the fastest growth (2.67 days) with higher variability, while fresh durian husks exhibited the highest yield consistency (65.27 g) and produced the largest mushroom volumes (915.46 cm^3). Although banana leaves performed comparably in some metrics, they demonstrated greater variability, suggesting the need for further optimization. Overall, the study underscores the viability of durian husks, especially in their fresh form, as effective, high-yielding substrates for sustainable mushroom farming, while banana leaves remain a promising alternative when properly pre-treated.

Limitations

The study acknowledges several limitations that may impact the interpretation of its findings. Time constraints restricted the scope of the research, limiting the duration of substrate observation and mushroom cultivation trials. Extraneous variables, such as fluctuations in weather and humidity, which are critical to mushroom growth, were beyond the researchers' control and may have influenced the outcomes. Additionally, the study did not explore the long-term effects of repeated cultivation cycles on the substrates, nor did it consider variations in substrate preparation methods, such as additional pre-treatment or nutrient supplementation. Finally, while the focus was on durian husks, other potential substrates and their comparative efficacy remain unexplored, suggesting avenues for further research to validate and expand upon these findings.

Writing the Recommendations

For future reference this study proposes recommendations to be implemented on improving data collection. Firstly, would be to ensure that each row contains a valid substrate type for a clear and concise growth outcome. Expanding substrate comparisons may also prove a worthy endeavor to further analyze the effects of other substrates on mushroom growth and quality. Taking into account environmental factors may also help gather more consistent data and through the use of controlled greenhouses and monitored surrounding may yield to more data-oriented results. Tracking the growth of trends over time may also increase the consistency of data and even improve the strategy used in growing mushrooms with certain substrates when compared to previous data collected in previous iterations of the experiment.

Statement of Author Contribution

All authors contributed to the study's conception and design. Methodology: All authors developed the research methodology, while Mary Michael Belviz, Isaiah Zenrich Kho, Audrey Dannica Perez, and Aiken Neil Soquita conducted the data collection and analysis. Writing - Original Draft: All authors wrote the initial draft of the manuscript. Writing - Review & Editing: All authors actively participated in reviewing and revising the manuscript

Declaration of AI Use

In this study, AI tools (ChatGPT -4.0, Elicit, Quillbot) were employed to assist in (literature review, data analysis, language editing). The AI's role was strictly supportive, with all outputs rigorously reviewed and validated by the research group, together with the adviser. The authors retain full responsibility for the content and conclusions presented in this paper.

REFERENCES

1. Abegail, R., May, P., Donald, P., & Alvarado, M. (2024, April 5). *Durian (Durio zibenthinus) waste: a promising resource for food and diverse applications—a comprehensive...* ResearchGate; Springer Nature. https://www.researchgate.net/publication/379575781_Durian_Durio_zibenthinus_waste_a_promising_resource_for_food_and_diverse_applic ations-a_comprehensive_review
2. Abubakar, I. R., Maniruzzaman, K. M., Dano, U. L., AlShihri, F. S., AlShammari, M. S., Ahmed, S. M. S., Al-Gehlani, W. A. G., & Alrawaf,
3. T. I. (2022). Environmental Sustainability Impacts of Solid Waste Management Practices in the Global South. *International Journal of Environmental Research and Public Health*, *19*(19), 12717. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9566108/
4. Adam Sayner. (2024). *A Complete Guide to Mushroom Substrates | GroCycle*.
5. GroCycle. https://grocycle.com/mushroom-substrate/
6. Adebayo, E. A., & D., M.-C. (2015). Oyster mushrooms (Pleurotus) are useful for utilizing lignocellulosic biomass. *African Journal of Biotechnology*, *14*(1), 52–67. https://doi.org/10.5897/ajb2014.14249 Adegoke Isiaka Adetunj, & . Mariana Erasmus. (2021). Synthesis of silica nanoparticles from agricultural waste. *Elsevier EBooks*, 121–138. https://doi.org/10.1016/b978-0-12-823575-1.00028-7
7. Akpati, C. F. (2019). A multimodal discourse study of some online campaign cartoons of nigeria's 2015 presidential election. *IAFOR Journal of Arts & Humanities*, *6*(2), 69–80. https://doi.org/10.22492/ijah.6.2.07 Bhattacharjya, D. K., Paul, R. K., Miah, Md. N., & Ahmed, K. U. (2014). Effect of Different Saw Dust Substrates on the Growth and Yield of Oyster Mushroom (Pleurotus ostreatus). *IOSR Journal of Agriculture and Veterinary Science*, *7*(2), 38–46. https://doi.org/10.9790/2380-
8. 07233846
9. Carlo, J., & Lawagon, C. P. (2022, December 15). *Optimization of Durio zibethinus (Durian) Fiber-Reinforced Composite as Automotive Skin Material*. ResearchGate; Trans Tech Publications, Ltd. https://www.researchgate.net/publication/366341999_Optimization_of

10. _Durio_zibethinus_Durian_Fiber- Reinforced_Composite_as_Automotive_Skin_Material
11. Carrasco, J., Zied, D. C., Pardo, J. E., Preston, G. M., & Pardo-Giménez, A. (2018). Supplementation in mushroom crops and its impact on yield and quality. *AMB Express*. https://doi.org/10.1186/s13568-018-0678-0 Carvalho, C. S. M. de, Aguiar, L. V. B. de, Sales-Campos, C., Minhoni,
12. M. T. de A., & Andrade, M. C. N. de. (2012). Applicability of the use of waste from different banana cultivars for the cultivation of the oyster mushroom. *Brazilian Journal of Microbiology*, *43*(2), 819–826. https://doi.org/10.1590/s1517-83822012000200048
13. Chai, W. Y., Krishnan, U. G., Sabaratnam, V., & Tan, J. B. L. (2021). Assessment of coffee waste in formulation of substrate for oyster mushrooms Pleurotus pulmonarius and Pleurotus floridanus. *Future Foods*, *4*, 100075. https://doi.org/10.1016/j.fufo.2021.100075
14. Costa, F., Pauli, G., Ricardo Bemfica Steffen, Valéria Ortaça Portela, Natielo Almeida Santana, Pereira, S., & Josemar, R. (2023). The use of rice husk in the substrate composition increases Pleurotus ostreatus mushroom production and quality. *Scientia Horticulturae*, *321*, 112372–112372. https://doi.org/10.1016/j.scienta.2023.112372
15. Dey, B., Ador, M. A. H., Haque, M. M. U., Ferdous, J., Halim, M. A., Uddin,
16. M. B., & Ahmed, R. (2024). Strategic insights for sustainable growth of mushroom farming industry in Bangladesh: A comprehensive evaluation using SWOT-AHP and TOPSIS frameworks. Heliyon. https://doi.org/10.1016/j.heliyon.2024.e36956
17. Dubey, D., Dhakal, B., Dhami, K., Sapkota, P., Rana, M., Poudel, N. S., & Aryal, L. (2019). Comparative study on effect of different substrates on yield performance of oyster mushroom. Global Journal of Biology, Agriculture, Health Sciences, 7.
18. Forthofer, R. N., Lee, E. S., & Hernandez, M. (2007). Study Designs. *Biostatistics*, 135–167. https://doi.org/10.1016/b978-0-12-369492- 8.50011-x
19. Gamay, R. A. J., Botecario, P. M. N., Sanchez, P. D. C., & Alvarado, M. C. (2024). Durian (Durio zibenthinus) waste: a promising resource for food and diverse applications—a comprehensive review. *Food Production, Processing and Nutrition*. https://doi.org/10.1186/s43014-023-00206-4
20. Go, J. R. (2018). Tulong: An articulation of politics in the Christian Philippines. *Philippine Political Science Journal*, *69-71*.
21. Hamzah, M. H., Amran, A. S., Aili Hamzah, A. F., Mohd Nor, M. Z., Shamsudin, R., Che Man, H., & Wan Razali, W. A. (2023). Durian Waste Husks as an Adsorbent in Improving Soaking Water during the Retting Process of Piper nigrum L. (Pepper Berries). *Separations*, *10*(2),
22. 96. https://doi.org/10.3390/separations10020096
23. Hoa, H. T., Wang, C.-L., & Wang, C.-H. (2015). The Effects of Different Substrates on the Growth, Yield, and Nutritional Composition of Two Oyster Mushrooms (Pleurotus ostreatus and Pleurotus cystidiosus). *Mycobiology*, *43*(4), 423–434. https://doi.org/10.5941/myco.2015.43.4.423
24. Itelima, J. (2012). Cultivation of mushroom (*Pleurotus ostreatus*) using corn cobs and saw dust as the major substrate. *Global Journal of Agricultural Sciences*, *11*(1). https://doi.org/10.4314/gjass.v11i1.9 Jayasinghe, I., Kariyawasam, H., & Thilakarathne, K. (2022). Feasibility Study on Growing Abalone and Oyster (Pleurotus sp) Mushrooms on Agricultural Residue. *ATIKAS*, *2022*, 52. http://kegalle.sliate.ac.lk/uploads/ATIKAS/18.%20AGRI_01_IH%20J ayasinghe.pdf
25. Jia Ying Chua, Kien Ming Pen, Jin Voon Poi, Khim May Ooi, & Kian Fei Yee. (2023). *Upcycling of*

biomass waste from durian industry for green and sustainable applications: An analysis review in the Malaysia context. 100203–100203. https://doi.org/10.1016/j.nexus.2023.100203 Kamthan, R., & Tiwari, I. (2017). Agricultural Wastes- Potential Substrates For Mushroom Cultivation. *European Journal of Experimental Biology*, *7*(5). https://doi.org/10.21767/2248- 9215.100031
26. Ketsa, S. (2018, January 1). *Durian—Durio zibethinus* (S. Rodrigues, E. de Oliveira Silva, & E. S. de Brito, Eds.). ScienceDirect; Academic Press.
27. https://www.sciencedirect.com/science/article/abs/pii/B978012803138 4000228
28. Kusumaningtyas, R. D., & Faiz, A. (2020). *CONVERSION OF DURIAN SHELL AGROINDUSTRIAL WASTE INTO VARIOUS VALUABLE PRODUCTS TO SUPPORT THE FOOD SECURITY DURING THE*
29. *COVID-19 NEW NORMAL ERA: REVIEW*. Semanticscholar.com. https://www.semanticscholar.org/paper/CONVERSION-OF-DURIAN- SHELL-AGROINDUSTRIAL-WASTE-TO-Kusumaningtyas-
30. Syah/eead56fb40ef3c3001aa6c8173fc958251bbb3ae?p2df
31. Lacy, P., & Jakob Rutqvist. (2015). The Roots of the Circular Economy. *Palgrave Macmillan UK EBooks*, 19–23. https://doi.org/10.1057/9781137530707_2
32. Lacy, P., & Rutqvist, J. (2015). The roots of the circular economy. In *Palgrave Macmillan UK eBooks* (pp. 19–23). https://doi.org/10.1057/9781137530707_2
33. MacRae, R. (1999). Not just what, but how: Creating agricultural sustainability and food security by changing Canada's agricultural policy making process. *Agriculture and Human Values*, *16*(2), 187–202. https://doi.org/10.1023/a:1007528823700
34. Mahathaninwong, N., Wandee, S., Totwaree, N., and Romyen, P. (2022). "Aerobic composting and vermicomposting of durian shell and citrus peel wastes," *BioResources* 17(1), 1144-1160.
35. Malimas, M.A.P., Carreon, J.A.D. & Peña, N.W. (2018). Critical discourse analysis of Filipino women politicians' campaign speeches. *Asian EFL Journal, 20,* p386-403.
36. Montgomery, D., Rigdon, S., Pan, R., & Freeman, L. (2022). Fundamentals of Experimental Design. *Wiley Series in Probability and Statistics*, 89–155. https://doi.org/10.1002/9781119237754.ch4
37. Otieno, O. D., Mulaa, F. J., Obiero, G., & Midiwo, J. (2021). Utilization of fruit waste substrates in mushroom production and manipulation of chemical composition. *Biocatalysis and Agricultural Biotechnology*, *39*, 102250. https://doi.org/10.1016/j.bcab.2021.102250
38. Pawar, S., Ikram, M., & Khan, S. (2024). Chapter–6 Health and Environmental Impacts of Agricultural Pollution. A Comprehensive Exploration of Soil, Water, and Air Pollution in Agriculture, 103.
39. Payus, C., Mohd Asyraf Refdin, N.Z. Zahari, & Alvin Oliver Payus. (2020, November). *Durian husk wastes as low-cost adsorbent for physical pollutants removal: groundwater supply*. ResearchGate; Elsevier BV.
40. https://www.researchgate.net/publication/346858583_Durian_husk_wa stes_as_low-cost_adsorbent_for_physical_pollutants_removal_groundwater_supply Pearce, D. W., & R Kerry Turner. (1990). *Economics of natural resources and the environment. David W. Pearce and R. Kerry Turner*. Harvester Wheatsheaf.
41. Sanchez, P. A., Cruz, M. L., Manansala, J. V., Espaldon, M. V., Seroje, K. K., Calora, Jr, J. F., Malamug, J., & Molintas, E. (2019). Solid Waste Management and Reduction of Agricultural Post-harvest Losses Using Cold-storage: Perceptions of Farmers in Benguet, Philippines. *Journal of Environmental Science and Management*, *22*(1), 99–108. https://doi.org/10.47125/jesam/2019_1/09

42. Sani, I., Hayati Abdullah, M., Abdullah, F. S., & Ali, A. M. (2012). Political cartoons as a vehicle of setting social agenda: The newspaper example. *Asian Social Science*, *8*(6), 156–164. https://doi.org/10.5539/ass.v8n6p156
43. Suwannarach, N., Kumla, J., Zhao, Y., & Kakumyan, P. (2022). Impact of Cultivation Substrate and Microbial Community on Improving Mushroom Productivity: A Review. *Biology*, *11*(4), 569. https://doi.org/10.3390/biology11040569
44. Tjiurutue, Muvari & Haukongo, Kristine & Horn, Lydia. (2022). Effects of different substrates as medium for mushrooms cultivation. 10.15413/ajfr.2021.0104.
45. Thuc, L. V., Corales, R. G., Sajor, J. T., Truc, N. T. T., Hien, P. H.,
46. Ramos, R. E., Bautista, E., Tado, C. J. M., Ompad, V., Son, D. T., & Van Hung, N. (2019). Rice-Straw Mushroom Production. *Sustainable Rice Straw Management*, 93–109. https://doi.org/10.1007/978-3-030- 32373-8_6
47. Wen, Xuan, Woo., Nur, Zahidah, Nasoha., Abdullah, Amru, Indera, Luthfi., Swee, Keong, Yeap., Yew, Woh, Hui., Nurul, Adela, Bukhari., Shareena, Fairuz, Abdul, Manaf., Jian, Ping, Tan. (2023). Bio-based succinic acid production from durian husk: A rising Southeast Asia agricultural waste. doi: 10.1016/j.indcrop.2023.117624
48. Wen Xuan Woo, Nur Zahidah Nasoha, Swee Keong Yeap, Yew Woh Hui, Yew Woh Hui, Nurul Adela Bukhari, Jian Ping Tan, & Abdullah,

A. I. L. (2023). Bio-based succinic acid production from durian husk: A rising Southeast Asia agricultural waste. *Industrial Crops and Products*, *206*, 117624–117624. https://doi.org/10.1016/j.indcrop.2023.117624

49. Woo, W. X., Nasoha, N. Z. binti, Luthfi, A. A. I., Yeap, S. K., Hui, Y. W., Bukhari, N. A., Manaf, S. F. A., & Tan, J. P. (2023). Bio-based succinic acid production from durian husk: A rising Southeast Asia agricultural waste. *Industrial Crops and Products*. https://doi.org/10.1016/j.indcrop.2023.117624
50. Zamakshshari, N. H., Ahmed, I. A., Nasharuddin, M. N. A., Zaharudin,
51. N. S., Mohd Hashim, N., & Othman, R. (2023). Comparative Study on Biological Activities and Chemical Profiling of Mushroom (Pleurotus pulmonarius (Fr.) Quel.) Cultured on Lignocellulosic Agro Wastes. *Chemistry & Biodiversity*, e202300111. https://doi.org/10.1002/cbdv.202300111