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Research Article

Utilization of Pesantren Food Waste as an Alternative Poultry Feed Through Fermentation with *Rhizopus oligosporus* Using Different Carbon Sources

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Abstract | The underutilization of pesantren food waste, despite its abundance and rich organic composition, contributes to environmental pollution and potential pathogen spread. This study hypothesized that fermentation of pesantren food waste using *Rhizopus oligosporus*, supplemented with various carbon sources, could enhance its nutritional value and suitability as an alternative poultry feed. A solid-state fermentation process was conducted for five days at 30–37°C under aerobic conditions, using four treatments: A (90% pesantren food waste [PFW] + 10% expired noodles), B (90% PFW + 10% expired bread), C (90% PFW + 10% rice bran), and D (90% PFW + 10% cassava dreg), with five replications per treatment. Nutritional composition was analyzed through proximate and mineral content tests, while statistical analysis was performed using one-way ANOVA followed by Duncan's Multiple Range Test (DMRT) at P<0.05. The results showed that carbon source supplementation had a highly significant effect (P<0.05) on moisture, dry matter, crude fat, crude protein, crude fiber, and gross energy, though no significant changes were observed in ash, calcium, or phosphorus levels. Among all treatments, cassava dreg (Treatment D) produced the most nutritionally enhanced fermented product, indicating its potential as a sustainable and cost-effective poultry feed component.

Keywords | Carbon source, *Rhizopus oligosporus*, Pesantren food waste, Fermentation, Poultry feed, Nutrient content

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INTRODUCTION

Islamic boarding schools *(pesantren)* operate as dormitory-based educational institutions with a large number of students, leading to the generation of significant amounts of food waste. Pesantren food waste consists of leftover rice, bones, meat scraps, vegetables, and fruits. One of the major contributors to organic waste is pesantren, where kitchen activities generate organic waste in the form of vegetable and fruit peels, while dining areas produce leftover rice, bones, meat scraps, and uneaten fruits and vegetables (Hidayat *et al.*, 2024). Pesantren food waste can cause environmental problems, such as pollution due to the decomposition of organic matter. Therefore, innovative efforts are needed to utilize pesantren food waste effectively. Pesantren food waste can be used as an alternative poultry feed due to its nutritional content. The nutritional composition of pesantren kitchen waste includes 92.89% dry matter, 17.85% crude protein, 10.83% crude fat, 10.86% crude fiber, and 6.24% ash (Hidayat *et al*., 2024).

Pesantren food waste has several nutritional deficiencies that can limit its effectiveness as poultry feed. One of the main shortcomings is its low protein content and high crude fiber content, especially from leftover vegetables and rice bran. Excessive crude fiber can hinder poultry digestion, reduce feed efficiency, and limit the absorption of essential nutrients needed for growth and production. Another significant issue is the high moisture content, which accelerates the growth of pathogenic microorganisms and causes spoilage, thereby reducing the quality and shelf life of the feed. One approach to addressing the nutritional limitations of pesantren food waste-based feed is the application of fermentation technology using microorganisms such as *Rhizopus oligosporus*.

Rhizopus oligosporus is a non-pathogenic mold from the *Rhizopus* genus that can produce enzymes such as protease, amylase, lipase, and phytase. Phytase enzyme can reduce phytic acid levels in soybeans, thereby increasing the availability of minerals such as iron and zinc (Djulardi *et al*., 2023). Fermentation using *Rhizopus oligosporus* can enhance nutritional content, improve feed digestibility and palatability, eliminate spoilage microbes, reduce antinutritional factors that hinder poultry digestion, and extend the shelf life of feed ingredients, making them more stable and easier to store for a longer period (Pantaya *et al*., 2023).

The innovation of fermenting pesantren food waste using *Rhizopus oligosporus* is an effective method to enhance the nutritional quality of organic waste before being utilized as an alternative poultry feed. The use of fermented products can improve growth performance, organ development, immunity, and reduce the production of odorous compounds in the cecum (Zhu *et al*., 2023). Adli *et al*. (2024), Fermented feed products are superior to non-fermented ones in terms of intestinal morphology, growth performance, and breast meat quality. The utilization of food waste as poultry feed can be further optimized for layer chickens through fermentation (Adrizal *et al*., 2021).

An important factor in fermentation is the addition of a carbon source to the fermentation substrate, as it plays a crucial role in microbial growth and enzyme production needed to hydrolyze complex compounds during the fermentation process. Various carbon sources that can be used in fermentation include expired noodles, expired bread, rice bran, and cassava dreg. Different carbon sources will influence the fermentation rate, microbial growth, and the nutritional composition of the fermented feed product (Trisna *et al*., 2019).

This research is necessary because pesantren food waste is an abundant source of organic biomass that has not been optimally utilized. Pesantren food waste can cause various environmental problems, such as pollution due to organic decomposition, increased greenhouse gas emissions, and the potential spread of pathogens. However, with proper processing, this food waste can be converted into an environmentally friendly and economical alternative feed for the poultry industry. Currently, there are still research gaps regarding the utilization of pesantren food waste as poultry feed. Some studies have explored the fermentation of food waste, but there is no use of a specific microorganism such as *Rhizopus oligosporus*. Research on pesantren food waste fermented with different microorganisms, namely *Bacillus amyloliquefaciens*, *Neurospora crassa*, and *Saccharomyces cerevisiae* (Hidayat *et al*., 2024).

This research is also needed to address potential nutritional deficiencies in unfermented pesantren food waste. Typically, this waste still contains high crude fiber content and suboptimal protein levels for poultry feed. With proper fermentation, complex compounds in the waste can be broken down into forms that are more easily digested by poultry, thereby increasing feed utilization efficiency and livestock productivity. Based on the above explanation, this study aims to address these challenges by evaluating the effects of different carbon sources in the fermentation of pesantren food waste using *Rhizopus oligosporus* and assessing its potential as a more nutritious and sustainable alternative poultry feed.

MATERIALS AND METHODS

Materials

The collection of pesantren food waste began with a survey and gathering information on Islamic boarding schools (pesantren) in Tanah Laut Regency, South Kalimantan Province, Indonesia. Pesantren food waste consists of leftover rice, fish and chicken bones, fish and chicken meat scraps, vegetables, and fruits. The materials used in this study included pesantren food waste, *Rhizopus oligosporus* inoculum, expired noodles, expired bread, rice bran, and cassava dreg. Other materials included chemicals for proximate analysis. The equipment used in this study included an analytical balance, oven, autoclave, blender, laminar airflow cabinet, and various tools for proximate analysis.

Methods

The experimental method used in this study was a Completely Randomized Design (CRD) with four treatments and five replications. The treatment were as follows:

A= 90% PFW (Pesantren Food Waste) + 10% expired noodles
B= 90% PFW (Pesantren Food Waste) + 10% expired bread
C= 90% PFW (Pesantren Food Waste) + 10% rice bran
D= 90% PFW (Pesantren Food Waste) + 10% cassava dreg

Subculturing of *Rhizopus oligosporus* on PDA Medium

Preparation of PDA medium: The preparation of Potato Dextrose Agar (PDA) medium begins by weighing 39 grams of PDA powder per liter of distilled water. The PDA was dissolved in distilled water and heated until a homogeneous solution was formed. Next, the PDA medium was sterilized using an autoclave at 121°C for 15 minutes to ensure the absence of microbial contamination. After sterilization, the medium was cooled to approximately 50°C and then poured into petri dishes. The entire process was carried out inside a laminar airflow cabinet and near a Bunsen burner to maintain sterility. Once poured into petri dishes, the PDA medium was left to solidify before being used for the inoculation of microorganisms such as *Rhizopus oligosporus.*

Inoculation of *Rhizopus oligosporus*: The inoculation process was carried out in a laminar airflow cabinet with a Bunsen burner turned on to maintain aseptic conditions. A sterile inoculating needle was used to transfer a piece of *Rhizopus oligosporus* mycelium from an existing culture. After inoculation, the petri dish was tightly sealed with Parafilm to prevent contamination from the surrounding environment.

Incubation: After inoculation, the petri dishes containing *Rhizopus oligosporus* were incubated at a temperature of 25–30°C for 2–5 days until the mycelium fully grows and covers the surface of the medium. Proper ventilation in the container or incubator was essential, as *Rhizopus oligosporus* is an aerobic fungus that requires oxygen for growth.

Maintenance and subculturing: To maintain the sustainability and quality of *Rhizopus oligosporus* cultures, regular subculturing is necessary every 2–4 weeks onto fresh PDA medium. For short-term storage, cultures can be kept at 4°C. The subculturing process of *Rhizopus oligosporus* on PDA medium is illustrated in Figure 1.

Preparation of *Rhizopus oligosporus* Inoculant

Preparation of substrate as a growth medium for *Rhizopus oligosporus*: High-quality soybeans were selected to support the optimal growth of *Rhizopus oligosporus.* The soybeans were soaked for 6–12 hours, then boiled, and the seed coats were removed to accelerate fungal growth. Afterward, the soybeans were coarsely ground to increase the surface area, facilitating the growth of *Rhizopus oligosporus.*

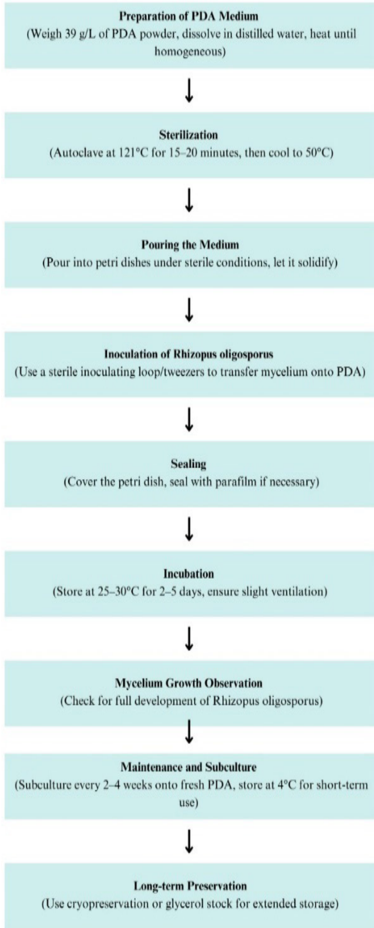

Figure 1: The subculturing process of *Rhizopus oligosporus* on PDA medium.

Sterilization of substrate: Sterilization was carried out using an autoclave at 15 psi pressure and 121°C for 15–30 minutes. After sterilization, the substrate was dried to reduce excess moisture, preventing the inhibition of *Rhizopus oligosporus* growth. Once the autoclaving process was complete, the sterile substrate was cooled to a temperature of 30–40°C before inoculation.

Inoculation of *Rhizopus oligosporus* into sterile substrate: A 10 ml test tube containing *Rhizopus oligosporus* at a concentration of 10^7–10^8 spores/ml was prepared. Inoculated the culture into 100 g of sterile substrate (soybeans). The inoculation process was conducted in a laminar airflow cabinet to maintain sterility and prevent contamination by other microbes.

Incubation of *Rhizopus oligosporus* substrate: After inoculation, the substrate was stored in a container with a thickness of approximately 1–2 cm at an optimal temperature of 30–37°C. Ensured proper air circulation during the incubation process to support the optimal growth of *Rhizopus oligosporus* mycelium. The substrate was incubated for 5 days (121 hours) to achieve optimal fungal growth.

Harvesting and storage of *Rhizopus oligosporus* inoculum: Once *Rhizopus oligosporus* has fully grown, the substrate was dried in an oven at a low temperature (≤40°C) to maintain the viability of the spores. The dried inoculum was then ground into a fine powder before being used for feed fermentation. The *Rhizopus oligosporus* inoculum was stored in a tightly sealed container at a cold temperature (4–10°C) to keep it active for an extended period. The Preparation of Rhizopus oligosporus Inoculant is illustrated in Figure 2.

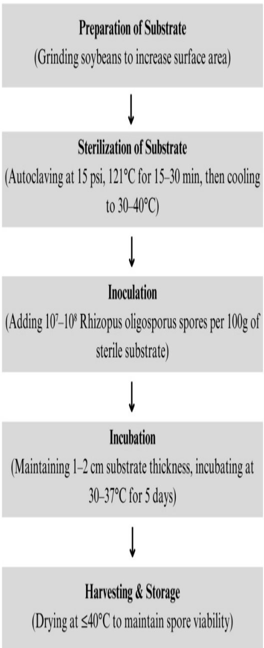

Figure 2: The Preparation of *Rhizopus oligosporus* inoculant.

Fermentation of Pesantren Food Waste with *Rhizopus oligosporus*

Preparation of pesantren food waste: A total of 500 g of pesantren food waste (PFW) was prepared, consisting of: 40% leftover rice, 30% fish and chicken bones, 5% chicken and fish meat, 25% vegetables and fruits.

Addition of carbon sources for fermentation with *Rhizopus oligosporus*: The pesantren food waste was weighed (500 g), then supplemented with different carbon sources according to the treatments. Next, 10% distilled water was added and mixed until homogeneous. The mixture is then placed in heat-resistant plastic bags.

Inoculation of *Rhizopus oligosporus* inoculum and incubation: Before inoculation, sterilization was carried out using an autoclave at 15 psi pressure and 121°C for 15–30 minutes. The sterile substrate was then cooled to 30–40°C before inoculation. A 3% *Rhizopus oligosporus* inoculum (based on the weight of the pesantren food waste substrate) was inoculated under aseptic conditions in a laminar airflow cabinet. The fermentation process was carried out for 5 days at an optimal temperature of 30–37°C with a substrate thickness of 1–2 cm in a fermentation container.

Harvesting and sample preparation for proximate analysis: After fermentation, the substrate was dried in an oven at a low temperature (≤40°C), ground into a fine powder, and then subjected to proximate analysis. The Fermentation of Pesantren Food Waste with *Rhizopus oligosporus* is illustrated in Figure 3.

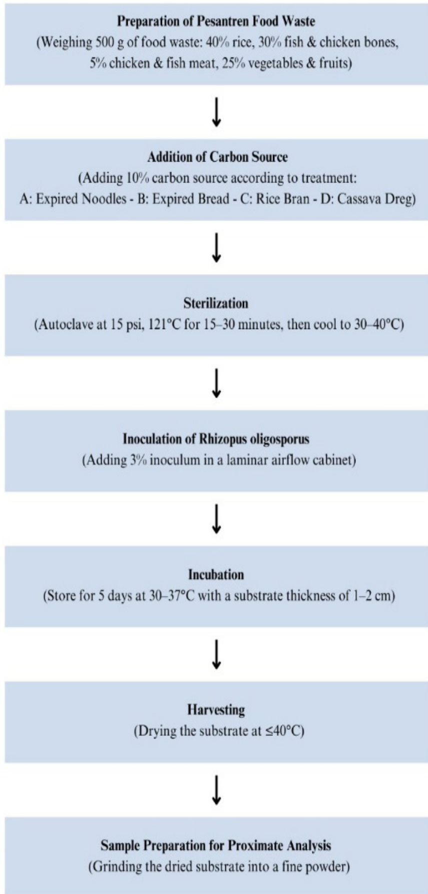

Figure 3: The Fermentation of Pesantren Food Waste with *Rhizopus oligosporus.*

Laboratory Analysis

The proximate analysis method (AOAC, 2016) was used to determine the following parameters: dry matter, total water content, crude fat, crude protein, crude fiber, gross energy, ash, calcium and phosphorus.

Data Analysis

All collected data were analyzed using analysis of variance (ANOVA). When significant differences among treatments were detected, Duncan's multiple range test was applied for further comparison at a significance level of $P < 0.05$ (Steel and Torrie, 1991).

RESULTS AND DISCUSSION

Table 1, shows that the addition of different carbon sources on the fermentation of pesantren food waste with *Rhizopus oligosporus* had a significant effect (P<0.05) on dry matter, total water content, and crude fat.

Table 1: Effect of different carbon sources on the fermentation of pesantren food waste with *Rhizopus oligosporus* on dry matter, total water content and crude fat.

Treatment	Dry Matter (%)	Total Water Content (%)	Crude Fat (%)
A (90% PFW + 10% expired noodles)	38.75 ± 1.32^{ab}	61.25 ± 1.32^{bc}	17.04 ± 1.16^{ab}
B (90% PFW + 10% expired bread)	37.73 ± 1.56^{b}	62.27 ± 1.56^{b}	17.10 ± 0.95^{ab}
C (90% PFW + 10% rice bran)	40.42 ± 1.16^{a}	59.72 ± 1.16^{c}	18.81 ± 1.11^{a}
D (90% PFW + 10% cassava dreg)	35.28 ± 1.01^{c}	64.72 ± 1.01^{a}	15.06 ± 1.42^{b}
SE	0.74	0.74	0.68

Description: $^{a-b}$Different superscripts in the same column are significantly different (P<0.05). **PFW:** Pesantren food Waste; **SE:** Standard error; **NS:** Non Significant.

The dry matter of pesantren food waste fermented with *Rhizopus oligosporus* ranged from 35.28 ± 1.01% to 40.42 ± 1.16%, indicating a decrease of approximately 7.35% to 19.24% compared to the pre-fermentation dry matter of 43.77%. The low dry matter in treatment D (35.28 ± 1.01%) was due to high microbial activity, which was stimulated by the addition of cassava dreg as a carbon source. This enhanced the growth and development of *Rhizopus oligosporus* mycelium, leading to optimal hydrolysis of complex compounds into simpler forms. As a result, the high metabolic activity increased water production, causing a decrease in dry matter. Muslim *et al.* (2018), the dry matter of fermented products can change due to substrate hydrolysis, which leads to the production of metabolic water. The better the microbial development, the higher the substrate hydrolysis activity, which ultimately affects the dry matter. During fermentation, complex compounds in the substrate are hydrolyzed into simpler forms, releasing water as a byproduct. This process contributes to the decrease in dry matter percentage, as more water is produced during microbial metabolism (Maulana *et al.*, 2021).

The lower dry matter of pesantren food waste after fermentation with *Rhizopus oligosporus* and the addition of cassava dreg indicates a positive outcome. This suggests that the hydrolysis of complex compounds into simpler forms was highly effective, making the feed easier to digest and absorb for poultry. The increased nutrient bioavailability enhances its potential as a sustainable alternative poultry feed. Abun *et al.* (2023), fermentation can enhance nutrient digestibility because the feed has already been hydrolyzed by microorganisms before entering the digestive tract, making it easier for poultry to absorb nutrients. Aktar *et al.* (2024), feed fermentation increases the nutritional value of feed due to beneficial chemical changes that are advantageous for poultry. The use of fermented products is better than non-fermented ones, as measured by chicken performance (Chachaj *et al.*, 2019).

The total water content of pesantren food waste fermented with *Rhizopus oligosporus* ranged from 59.72 ± 1.16% to 64.72 ± 1.01%, indicating an increase of approximately 3.03% to 7.03% compared to the total water content of pesantren food waste before fermentation, which was 57.69%. The high total water content in treatment D (64.72 ± 1.01%) was due to the low dry matter content, which led to an increase in water content. The water content value is obtained by subtracting the dry matter content, meaning that the higher the dry matter, the lower the water content and vice versa. Maulana *et al.* (2024), the dry matter content and water content are obtained through subtraction. Another factor contributing to the high water content is the addition of 5% aquades based on the amount of pesantren food waste substrate. This is intended to maintain moisture and water content in the material to be fermented. Dilaga *et al.* (2022), the addition of 10–40 ml of aquades during the mixing process of the inoculum with rice bran affects the total water content.

The crude fat of pesantren food waste fermented with *Rhizopus oligosporus* ranged from 15.06 ± 1.42% to 18.81 ± 1.11%, indicating a decrease of approximately 0.19% to 3.94% compared to the crude fat content before fermentation, which was 19%. The optimal reduction in crude fat was observed in treatment D (15.06 ± 1.42%), which was due to the lipase enzyme produced by *Rhizopus oligosporus* hydrolyzing crude fat into simpler components. These simplified products from hydrolysis were utilized as a nutrient source for the growth and development of *Rhizopus oligosporus*. Djulardi *et al.* (2023), *Rhizopus oligosporus* added to the fermentation substrate can produce lipase enzymes, which break down crude fat into triglycerides that are used as an energy source for growth and development during fermentation.

The lipase produced by *Rhizopus oligosporus* works by catalyzing the hydrolysis of ester bonds in fat molecules, breaking them down into free fatty acids and glycerol.

Table 2, shows that the addition of different carbon sources on the fermentation of pesantren food waste with *Rhizopus oligosporus* had a significant effect (P<0.05) on crude protein, crude fiber, and gross energy.

Table 2: The effect of different carbon sources on the fermentation of pesantren food waste with *Rhizopus oligosporus* on crude protein, crude fiber, and gross energy.

Treatment	Crude Protein (%)	Crude Fiber (%)	Gross Energy (kcal/kg)
A (90% PFW + 10% expired noodles)	16.98 ± 1.00[b]	9.58 ± 0.72[b]	4072.72 ± 106.71[b]
B (90% PFW + 10% expired bread)	17.85 ± 1.31[ab]	9.05 ± 0.95[bc]	4189,60 ± 92.31[b]
C (90% PFW + 10% rice bran)	13.50 ± 1.09[c]	11.50 ± 1.04[a]	3823.24 ± 96.50[c]
D (90% PFW + 10% cassava dreg)	19.48 ± 1.07[a]	7.68 ± 0.76[c]	4454.61± 88.05[a]
SE	0.65	0.51	55.51

Description: [a-b]Different superscripts in the same column are significantly different (P<0.05). **PFW:** Pesantren food Waste; **SE:** Standard error; **NS:** Non significant.

The highest crude protein was observed in treatment D, reaching 19.48 ± 1.07%. The crude protein content of pesantren food waste before fermentation was 14%, indicating an increase of approximately 5.48%. The increased crude protein content in fermented pesantren food waste was due to the addition of cassava dreg as a carbon source, which optimized the growth and development of *Rhizopus oligosporus* biomass, as evidenced by lipase enzyme activity of 3.16 U/ml. Suprabawati *et al.* (2018), the carbon content of cassava dreg is 59.31%. In this study, the carbon content was found to be 63% for cassava dreg, 49% for expired bread, 43% for expired noodles, and 35% for rice bran.

The optimal mycelium growth in treatment D (90% PFW + 10% Cassava Dreg) with a total fungal count of 23×10^{12} CFU/ml was influenced by the availability of carbon and nitrogen elements in the optimal ratio of 13.5:1. Maulana et al. (2021), the C:N ratio in the fungal category for feed fermentation ranges from 13:1 to 14:1. Fungi require carbon (C) and nitrogen (N) as a food or nutrient source for their metabolism (Trisna *et al.*, 2019).

The high crude protein content in treatment D, which is 19.48 ± 1.07%, is influenced by the optimal biomass of *Rhizopus oligosporus* and protease enzymes during the fermentation process of pesantren food waste. The biomass of *Rhizopus oligosporus* contributes to increasing the nutritional value of the fermented food waste product, while the protease enzymes produced can break down complex proteins in the fermentation substrate into amino acids that are easily absorbed and digested by poultry. Microbial biomass can increase the crude protein of the fermentation substrate (Andika *et al.*, 2025).

The microbial population in feed fermentation contributes to increasing protein content (Ciptaan *et al.*, 2022). The protease enzyme produced by *Rhizopus oligosporus* functions to break down crude protein in pesantren food waste through an enzymatic hydrolysis mechanism. This process works by breaking peptide bonds in complex proteins, converting them into smaller peptides and free amino acids. Consequently, this degradation enhances digestibility and nutrient availability in the material.

The low crude fiber content in treatment D was 7.68 ± 0.76%. The crude fiber content of pesantren food waste before fermentation was 15.88%, indicating a decrease of approximately 8.20%. This was influenced by the cellulase enzyme produced by *Rhizopus oligosporus* during the fermentation process, which reached 2.44 U/ml. A lower crude fiber content in the fermented substrate indicates a higher degradation process by the cellulase enzyme. Nuraini *et al.* (2019), the cellulase enzyme produced during the feed fermentation process has a significant impact on reducing crude fiber content. The reduction in crude fiber content in the fermented product is attributed to cellulase enzyme activity (Ciptaan *et al.*, 2024), the high or low activity of the cellulase enzyme is influenced by the biomass of *Rhizopus oligosporus* during the fermentation process. One of the key factors determining the success of fermentation is the availability of carbon in the substrate as a nutrient source throughout the fermentation process.

Rhizopus oligosporus is a mold capable of producing cellulase enzymes. The cellulase enzyme hydrolyzes β-1,4-glycosidic bonds in crude fiber, thereby improving the digestibility and nutritional value of waste. This degradation reduces the amount of indigestible crude fiber, making the waste a viable alternative feed source for livestock, especially poultry.

The high gross energy content in treatment D, which is 4454.61 ± 88.05 kcal/kg, is due to the fact that pesantren food waste is rich in starch. This starch is broken down by amylase enzymes produced by *Rhizopus oligosporus* into simpler compounds such as dextrin and maltose, increasing energy availability and consequently raising the gross energy content in the feed. The fermentation process of food waste with *Rhizopus oligosporus* produces protease and lipase enzymes, which degrade protein and fat, generating metabolites such as free fatty acids and other organic compounds that contribute to an increase in total energy in the fermented material.

Djulardi *et al.* (2023), the increase in the energy content of fermented feed is influenced by the degradation of crude fiber into glucose. The fermentation process involves the breakdown of complex compounds into glucose, thereby increasing the feed's energy content. This makes it a potential alternative local feed that can reduce the use of commercial feed (Febrina *et al.*, 2024).

Commercial feed is expensive, so alternative feed is needed to replace it in order to maximize profitability in livestock farming (Febrina *et al*., 2022). The phytase enzyme produced by *Rhizopus oligosporus* can reduce phytate content, which inhibits nutrient absorption and affects feed energy availability.

Table 3: The effect of different carbon sources on the fermentation of pesantren food waste with *Rhizopus oligosporus* on ash, calcium and phosphorus contents.

Treatment	Ash^{NS} (%)	Calcium^{NS} (%)	Phosphorus^{NS} (%)
A (90% PFW+ 10% expired noodles)	9.20 ± 0.95	3.38 ± 0.75	2.31 ± 0.85
B (90% PFW + 10% expired bread)	10.59 ± 1.21	3.03 ± 1.05	2.35 ± 0.86
C (90% PFW + 10% rice bran)	9.92 ± 0.98	2.63 ± 0.72	1.78 ± 0.49
D (90% PFW + 10% cassava dreg)	10.92 ± 1.08	3.84 ± 0.78	2.67 ± 0.77
SE	0.61	0.49	0.44

Description: The treatments gave results that were not significantly different (P>0.05). **PFW:** Pesantren food Waste; **SE:** Standard error; **NS:** Non significant.

Table 3, shows that the addition of different carbon sources on the fermentation of pesantren food waste with *Rhizopus oligosporus* did not have a significant effect (P>0.05) on ash, calcium, and phosphorus. The ash content of fermented pesantren food waste with different carbon sources ranged around 9.20 ± 0.95%. Calcium ranged between 2.63 ± 0.72% and 3.84 ± 0.78%, while phosphorus ranged between 1.78 ± 0.49% and 2.35 ± 0.86%. The results of this study indicate that the fermentation of pesantren food waste with *Rhizopus oligosporus* using different carbon sources does not affect ash, calcium, and phosphorus content. Wizna *et al.* (2023), phosphorus in the fermented product is not affected during the fermentation process. Microbial activity during fermentation does not influence inorganic compounds but primarily utilizes organic compounds as the main food source (Nuraini *et al*., 2019). The high ash, calcium and phosphorus content in pesantren food waste fermented with *Rhizopus oligosporus* using different substrate sources is due to the original materials before fermentation containing 30% fish and chicken bone waste, where the main components of bones are calcium and phosphorus.

CONCLUSIONS AND RECOMMENDATIONS

The results of this study indicate that incorporating 10% cassava dreg as a carbon source in the fermentation of pesantren food waste using *Rhizopus oligosporus* can significantly enhance the nutritional quality of the resulting product, making it a sustainable and viable alternative poultry feed. From a cost-effectiveness standpoint, the use of cassava dreg reduces reliance on expensive conventional feed ingredients such as corn and soybean, thereby lowering overall feed production costs and offering notable economic benefits to farmers. Additionally, the improved feed quality resulting from the fermentation process characterized by increased protein content and better digestibility can contribute to enhanced poultry growth and productivity. This improvement supports greater feed efficiency, as poultry are able to absorb essential nutrients more effectively, ultimately reducing feed waste and improving production outcomes.

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NOVELTY STATEMENT

There are no reported studies on the utilization of fermented pesantren food waste using *Rhizopus oligosporus* with different carbon sources to enhance nutritional quality for sustainable poultry feed. Moreover, the utilization of pesantren food waste can help mitigate its negative environmental impact, preventing waste accumulation and foul odors.

AUTHOR'S CONTRIBUTIONS

All authors made significant contributions to this research. Rusfidra was responsible for conceptualization and research supervision. Fajri Maulana as the writing - original draft and review and editing. Heppy Setya Prima played key roles in data collection and analysis. Malikil Kudus Susalam contributed to methodology development and results validation. Fadhli Fajri focused on interpreting findings and manuscript preparation. Satri Yusasra Agasi was responsible for literature review and final manuscript editing. All authors have reviewed and approved the final version of this manuscript.

Conflict of Interest

All authors have stated that they have no conflicts of interest.

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