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Potential Food Waste Products to Substitute Corn and Rice Bran for Poultry

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Abstract | Waste leads to land, water, and air pollution when left untreated. Turning food waste into feed answers two problems at once: It offers an approach to control waste and resolves the problem of feed efficiency. The potential of "aking rice" as a substitute for corn and rice bran was analyzed based on its purposes. "Aking rice" produced by PT. Zakiyah Jaya Mandiri, Lumajang, East Java, Indonesia, was prepared for five treatments: T0 (control of mélange-free unrinsed rice), T1 (oily rice, rinsed before drying), T2 (non-oily rice, rinsed before drying), T3 (unrinsed oily rice), and T4 (unrinsed non-oily rice). Proximate analysis was conducted in the University of Muhammadiyah Malang, Indonesia's nutrition laboratory, to determine water, ash, crude protein, crude fat, and crude fiber contents. The water contents in all samples (< 14 %) were insignificantly different, while ash (3.72 %) and crude protein (12.02 %) contents in T4 were the highest and significantly different. The crude fiber in T3 (1.44 %) and T4 (1.23 %) was the highest and significantly different. With a total crude protein content of 7 % to 9 % – similar to corn and rice bran – yet lower crude fat content (< 5 %), "aking rice" is qualified to substitute the materials mentioned above in poultry feed.

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Introduction

Currently a major environmental problem, waste causes land, water, and air pollution when left untreated (Adinurani *et al.*, 2015; Hendroko *et al.*, 2013; Hoornweg *et al.*, 2013). While numerous endeavors on waste management have been operative, SISPN (2022) points out that as much as 37 % of it remains untouched. Several mass media have reported on food loss and waste (FLW), especially in Indonesia. Tempo Magazine (2021) reported that the Indonesian Ministry of National Development Planning (Bappenas) stated that food waste in Indonesia reaches 112 × 10^6 t yr^{-1}, or 344 kg $capita^{-1}$ yr^{-1}. Kertha (2024) stated that Indonesians throw away 23 × 10^6 t to 48 × 10^6 t of food yearly, equivalent to 115 kg to 184 kg per person. FLW has a significant impact on the environment and economy. FLW contributes 7.29 % of Indonesia's annual greenhouse gas emissions, exacerbating climate change. Economically, FLW results in losses of between IDR 214 $\times 10^9$ and IDR 551 $\times 10^9$ yr^{-1}, or around 4 % to 5 % of the national Gross Domestic Product (GDP).

Rajendra, FAO Representative in Indonesia and Timor Leste, stated that Indonesia ranks first in food waste production in Southeast Asia, which is 20.9$\times 10^6$ yr^{-1}, followed by the Philippines at 9.33$\times 10^6$ yr^{-1}. In contrast, Wulandari, Universitas Syiah Kuala (USK) stated that Indonesia is the second largest in the world in food waste production, 300 kg $capita^{-1}$ yr^{-1}, after Saudi Arabia, which is in first rank (Tiofani and Prodjo. 2025; Yocerizal, 2024). The Minister of Environment/Environmental Control Agency of the Republic of Indonesia stated that a total of (7 to 8) $\times 10^3$ t of daily waste ends up at the Bantar Gebang Integrated Waste Management Site (TPST), Bekasi, Indonesia, half of which is food waste (Tempo, 2024).

Approximately 50 % of which is organic (Syahrial, 2024; USK, 2024) in the form of food remains from households, restaurants, and other food vendors that is feasible for further processing into beneficial products (Kertha, 2024; Mondello *et al*., 2017; Roy *et al*., 2014; Tempo 2021, 2024). Several researchers underline the importance of the attempt as mentioned earlier (Adinurani *et al*., 2014; Anam *et al*., 2023a, b; Fitasari and Mushollaeni, 2020; Mushollaeni and Fitasari, 2021; Setyobudi *et al*., 2023, 2024a; Susanto *et al*. 2020).

Turning rice leftovers into aking rice is a realistic answer for areas where rice is the staple food (Tonda *et al*., 2024b). To make "aking rice," rice is cleaned and rinsed under running water, then sundried or oven-dried until the water content is 14 % or less (Roboth, 2015; Tonda *et al*., 2022, 2023a).

Household or restaurant waste typically contains 20 % crude protein suitable for animals (Achardri *et al*., 2018). Furthermore, between 20 % and 25 % of crude fat is noted in addition to crude fiber and low minerals (Alqaisi *et al*., 2019; Truong *et al*., 2019).

"Aking rice" for feed answers two problems at once. First, it offers an approach to control waste and resolves feed expenses due to imported materials costing as much as 65 % of its total cost (Patience *et al*., 2015; Pinotti *et al*., 2021). Feed is economically crucial in poultry farming because it is where the commodity growth relies on (Hassan *et al*., 2021; Mandey *et al*., 2017) and where the most production spending goes (Mallick *et al*., 2020; Rusli, 2012). The high import charge is therefore influential towards farmers' welfare.

A low-calorie carbohydrate source compared to other base feeds such as corn (Ariyadi and Anggraini, 2010; Tonda *et al*., 2022). Aking rice is easier to digest than corn and rice bran due to lower crude fiber content (Isharyudono *et al*., 2019; Tonda *et al*., 2023a). In addition, its being inexpensive and highly palatable adds to the advantages of "aking rice" for alternative poultry feed (Tonda *et al*., 2023b, 2024a, b; Zulfikar *et al*., 2014).

Compared to other energy sources, aking rice contains a higher level of nitrogen-free extract (86.63 %) and lower crude fiber (0.59 %), which enhances its digestibility for poultry, particularly monogastric animals such as chickens. Its crude protein content (8.96 %) supports maintenance requirements when used as a partial feed ingredient. While its crude fat is relatively low (0.43 %), it can be complemented with other fat sources in formulated rations. Furthermore, the ash content (0.83 %) suggests low mineral presence, reducing the risk of imbalance when combined with mineral-fortified feed. These characteristics suggest that aking rice can be used up to certain levels (10 % to 40 %) without negatively impacting poultry performance, especially when integrated with other balanced ingredients.

Unlike fresh rice bran and corn, aking rice originates from leftover cooked rice, raising potential concerns regarding microbial contamination or spoilage. However, proper handling including repeated rinsing and drying to reduce moisture content below 14 % is known to minimize microbial activity and prolong shelf life (Roboth, 2015; Tonda *et al*., 2022). Studies by Tonda *et al*. (2023a) and Isharyudono *et al*. (2019) reported that microbial counts of adequately dried aking rice remained within the safe threshold for feed use. Additionally, no aflatoxins or mycotoxins were detected in sun-dried samples, especially when drying was performed under hygienic conditions and storage was properly managed. Thus, when processed correctly, "aking rice" presents a safe and viable alternative feed ingredient. Referring to the nutrients in "aking rice," the shallow crude fiber content essential in the avian digestive system should qualify it as poultry feed. Therefore, this study aims to find the proper method to process "aking rice" while analyzing its potential for consistent quality.

Materials and Methods

Aking rice

Aking rice was produced by PT. Zakiyah Jaya Mandiri, Lumajang, East Java, Indonesia (112° 53' 113° 23' E and 7° 54' 8° 23' S). Proximate analysis of the products was conducted in the nutrition laboratory of the University of Muhammadiyah Malang, Indonesia (S 7°55'4 .9944" and E 112°35'37.1724").

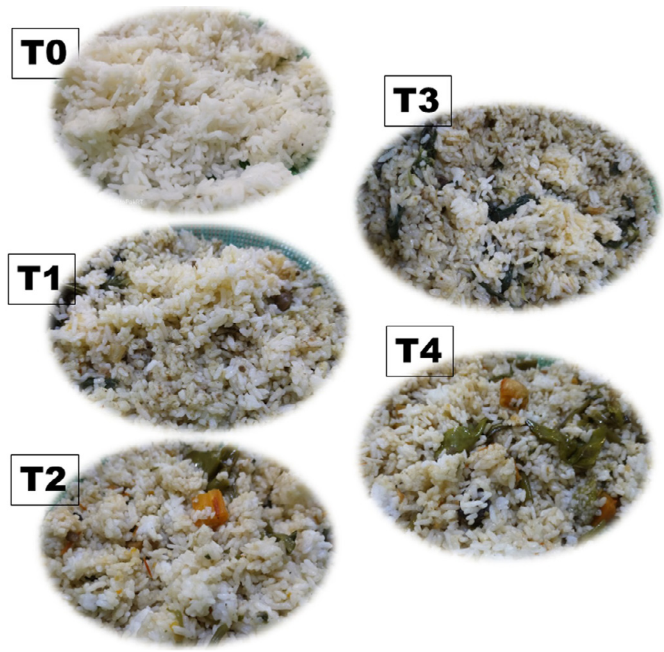

Figure 1: *Rice waste.*

Rice waste samples are shown in Figure 1. T0 served as a control and was made of mélange-free unrinsed rice. T1 was of oily rice and rinsed before drying. T2 was of non-oily rice and rinsed before drying. T3 was of unrinsed oily rice. T4 was of unrinsed non-oily rice. Once sorted out, samples were rested for 24 h at room temperature and then observed on the odors and forms. After that, all treatments except the control were separated from their mélange, rinsed under running water, and drained for 30 min. Finally, all samples were sundried or oven-dried until 14 % water content or lower was attained (Tonda *et al.*, 2022, 2023a). Previous research suggests that the temperature in the oven should be below 50 °C. A drying mat made of non-plastic material should be used to avoid microplastic contamination (Setyobudi *et al.*, 2024b, 2024c) because observations show that chickens are one of the livestock exposed to microplastics that come mainly from factory-made feed (Garfansa *et al.*, 2024; Hermayanti *et al.*, 2024).

Proximate analysis

Water content: Water content was tested per thermogravimetry method using an oven at 105 °C (Asmariani and Sari, 2019; Wróblewski and Ceran, 2016). First, weigh 1 g to 2 g of each sample (HWH digital scale, Osuka, Taiwan) was put into a 75 mL porcelain evaporating dish dried and measured before use and dried in a furnace (Elba EG8021S-B, Italy) at 105 °C for 3 h, cooled in a desiccator (Duran DN 300, Germany), and scaled for its fix weight. The values were then run by Equation 1 (Damat *et al.*, 2021a):

$$\text{Water content (\%)} = \frac{\text{W (W1-W2)}}{\text{W}} \times 100\ \% \quad (1)$$

Where
W = sample weight before drying
W1 = dish and sample weight after drying
W2 = empty dish weight

Ash content

Gravimetric analysis according to the Indonesia National Standard (SNI) and the fourth chapter of Official Methods of Analysis specified for feed test established by the Association of Official Analytical Chemists (AOAC) was performed to determine ash content. Ash is the result of burning a specific sample at 500 °C or beyond (Bouqbis *et al.*, 2018; Charan *et al.*, 2017; Nazirov *et al.*, 2019); when all organic materials are completely oxidized into carbon dioxide (CO_2) and water vapor (H_2O), only inorganic ones like minerals are left. Therefore, porcelain dishes were oven-dried (Elba EG8021S-B, Italy) at 105 ℃ for 1 h, cooled in a desiccator (Duran DN 300, Germany) for 15 min, and measured. Containing 1.5 g to 2 g of each sample, they were heated in a muffle furnace (Thermolyne™ Benchtop 1 100 °C, China) at 600 ℃. After 120 min, the dishes were taken out of the stove and left to reach the temperature of 120 ℃ before being sent into a desiccator. Once cooled, they were scaled for their fixed weights. The values were then computed in line with Equation 2 (Mushollaeni and Tantalu, 2022).

$$\text{Ash content (\%)} = \frac{\text{Ash weight (g)}}{\text{Sample weight (g)}} \times 100\ \% \quad (2)$$

Links Researchers

Crude protein

The Kjeldahl method was arranged to test the protein content (Damat *et al*., 2023; Mushollaeni and Tantalu, 2022; Pilyukshina *et al*., 2020). A total of 1 g of each sample was put in a 100 mL Kjeldahl flask (Pyrex, Iwaki-Indonesia), mixed with catalysts of 2 g selenium and 25 mL concentrated H_2SO_4, and heated on an induction stove (Kirin kic-1000, Indonesia) for 2 h. Once digested, the emulsion was cooled before diluted and then transferred to a 100 mL Pyrex volumetric flask up to the mark. In the distilling tube, 5 mL NaOH 40 % and a few drops of phenolphthalein indicator were added. The distillation process ran for approximately 10 min, and the distillate was collected in a flask containing 10 mL 2 % boric acid and phenolphthalein mix. The titration process involved HCl 0.01 N, followed by the blank establishment (Damat *et al*., 2020; Li *et al*., 2018). Crude protein content was calculated by Equation 3 (Setyobudi *et al*., 2023, 2024a).

$$\sum \text{Nitrogen } \% = \frac{(V1 - V2) \times N \times 14.008 \times f}{W \times 100} \times 100\ \% \quad \ldots(3)$$

Where; V1= titrate volume for sample (mL), V2 = titrate volume for blank (mL), N=normal titrate volume (N), f = solvent, W= sample weight (g), 14.008 = relative atomic mass of nitrogen ($gmol^{-1}$).

Crude fat

Soxhlet method was employed to check fat content (Alam *et al*., 2014; Andrianova and Egorov, 2021). A total of 1 g to 2 g of each sample was put in a rolled filter paper bag (Whatman No. 1/1001-090, England), of which ends were secured with cotton (Paramitha Husada, Indonesia) and then oven-dried (Elba EG8021S-B, Italy) at < 80 °C for 1 h. The samples were then transferred in a Soxhlet extractor apparatus set 250 mL (Pyrex class A)–connected to a Pyrex lipid flask containing dried, measured hot stone – and extracted with hexane or other fat solvents for ± 6 h. Once hexane was distilled, the fat extracts were oven-dried at 105 °C before being cooled and measured. The drying process was repeated to reach a fixed weight. Finally, Equation 4 was used to calculate fat content (Widiyastuti *et al*., 2015).

$$\text{Fat content } (\%) = \frac{w - w1}{w2} \times 100\ \% \qquad (4)$$

Where; w = sample weight (g), w1 = fat weight before extraction (g), w2 = fat and flask weight after extraction (g).

Crude fiber

The Weende method determined crude fiber content (Pujiawati *et al*., 2021; Widjaja and Utomo, 2021). Weigh 2 g of each sample was placed in a 250 mL Erlenmeyer flask and mixed with 200 mL boiling H_2SO_4 (0.255 N) before being secured with a back cooler, then boiled for 30 min on an induction stove (Kirin type kic-1000, Indonesia). Its suspense was filtered (Whatman no. 1/1001-090, England), and the residue in the flask was rinsed with boiling aqua dest while one on the filter paper was washed to eliminate acidity. The filtrate on the paper was transferred in a clean Erlenmeyer flask using a stainless steel spatula (JSE, Indonesia), washed with 200 mL NaOH (0.313 N), and boiled for 30 min before run against another filter sheet (already scaled) while passed with 10 % K_2SO_4–the residue was rinsed with boiling aquadest and 15 mL 95 % alcohol. The filter sheet was then oven-dried (Micra SDL093739334, Indonesia) at 110 °C before being charred in a muffle furnace (Thermolyne™ Benchtop 1100 °C, China) at 500 °C, cooled in a desiccator (Duran DN 300, Germany), and measured. The procedure was repeated three times to reach a fixed weight, and the values were processed according to Equation 5 (Mushollaeni *et al*., 2017).

$$\text{Crude fiber } (\%) = \frac{\text{Fiber weight}}{\text{Sample weight}} \times 100\ \% \quad (5)$$

Each variable studied was repeated three times. All chemicals and reagents used in these experiments were of technical grade and purchased from CV. Dunia Kimia Lestari–a chemical supply store in Malang, East Java, Indonesia (S 7°57’37.3752” and E 112°38’10.554”).

Data analysis

Obtained data were of average and deviation standards, which were then run through the analysis of variance to detect any distinctions between studied variables (Damat *et al*., 2021). Once found, the Least significant difference test was performed (Adinurani *et al*., 2016; Mgbeahuruike *et al*., 2021; Ripon *et al*., 2019).

Results and Discussion

Aking rice physical forms

Physical forms shows on Figure 2.

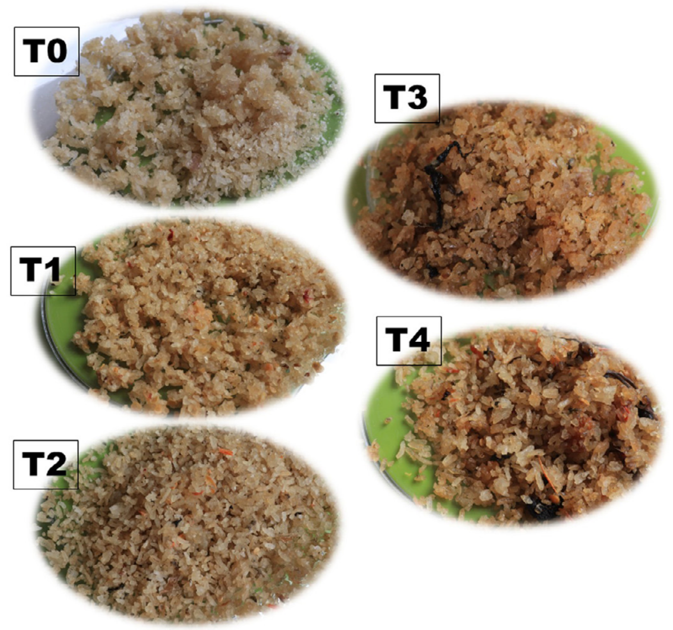

Figure 2: *Aking rice.*

Resting at room temperature for 24 h allowed microorganism activities in the samples T1 to T4, leading to changes in color and odor; however, it did not occur in T0. It attests to the possibility of 24 h storing rice leftover before processing. Since the more extended the storing period, the more acidic it will be (Noviatri *et al*., 2020; Rusli, 2009; Suryaningsih, 2019), it is advised to keep the material no longer than 24 h at room temperature (Fahmy *et al*., 2015; Malia and Yusuf, 2021).

Water content

Considering its essential role in determining feed quality (Coudron *et al*., 2022; Wubshet *et al*., 2022) due to its dry matter, water content represents the nutrient content of a specific feed. Therefore, feed containing more water gets damaged more quickly, which is attributable to the faster growth of microorganisms and fungi.

Figure 3 depicts the findings that the highest water content was found in non-oily aking rice without rinsing before drying (T4) at 12.19 %, while the lowest was in control (T0) at 11.16 %. Therefore, the five treatments are considered proper since their water contents are below the maximum of 14 % (Cheah *et al*., 2017; Kook *et al*., 2014; Tonda *et al*., 2022).

Ash content

The highest ash content was found in non-oily aking rice without rinsing before drying (T4) at 3.72 %, which far exceeds the ones of the control and the other treatments. A comparison of ash contents in all treatments is presented in Figure 4.

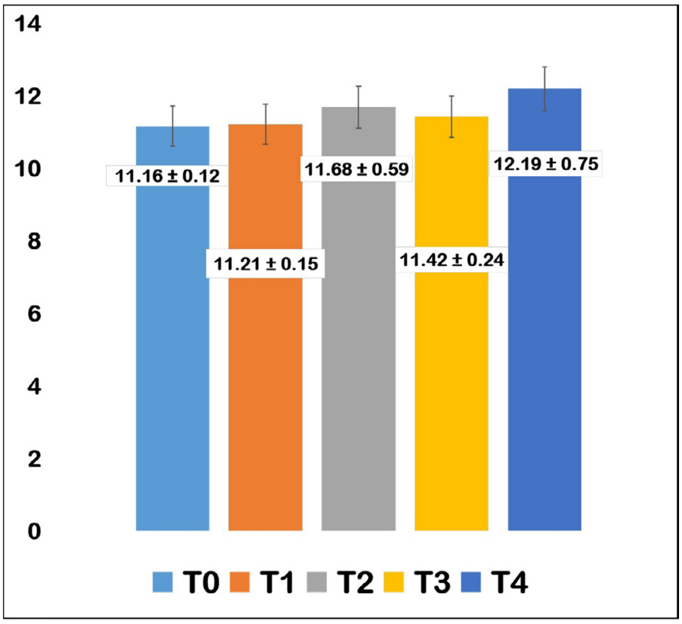

Figure 3: *Water contents of aking rice (%).*

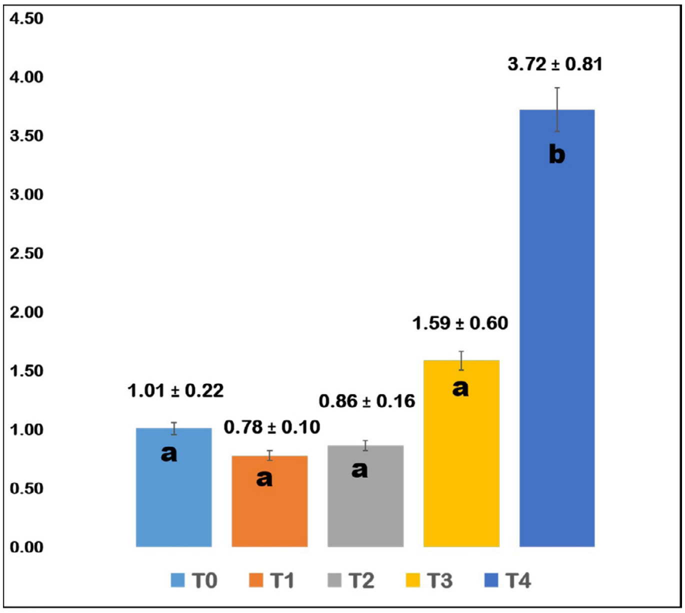

Figure 4: *Ash contents of aking rice (%).*

Mélange in rice left probably carried extra minerals, which stayed in the sample considering the absence of a rinsing process, and it tallied to the actual ash content of the sample. The higher ash content in feed indicates a higher mineral content (Onuegbu *et al*., 2016; Seymour *et al*., 2019), and its limit differs from one feed to another and from one targeted animal to another (Sahraei *et al*., 2012; Shim *et al*., 2012). Cattle require only a little mineral to digest lipids of which the digestive rate relies heavily on carbon, oxygen, and hydrogen and an excessive amount of it in feed is deemed ineffective (Hendroko *et al*., 2014).

Crude protein

Formed by amino acids containing N, absent in fat or carbohydrate (Vieira and Angel, 2012; Sharipova *et al*., 2017), protein is an organic substance with carbon, hydrogen, nitrogen, oxygen, sulfur, and phosphor. As depicted in Figure 5, the lowest protein content is T2 (6.69 %), and the highest is T4 (12.02 %). The rinsing procedure towards non-oily material washed protein-containing particles away from T2. On the other hand, protein from different foods like meat, tofu, or tempeh in T4 material stayed even after being separated from its mélange since it skipped the rinsing. This finding supports the statement that the rinsing procedure affects the protein content of aking rice (Tonda *et al*., 2022; Wecke and Liebert, 2013).

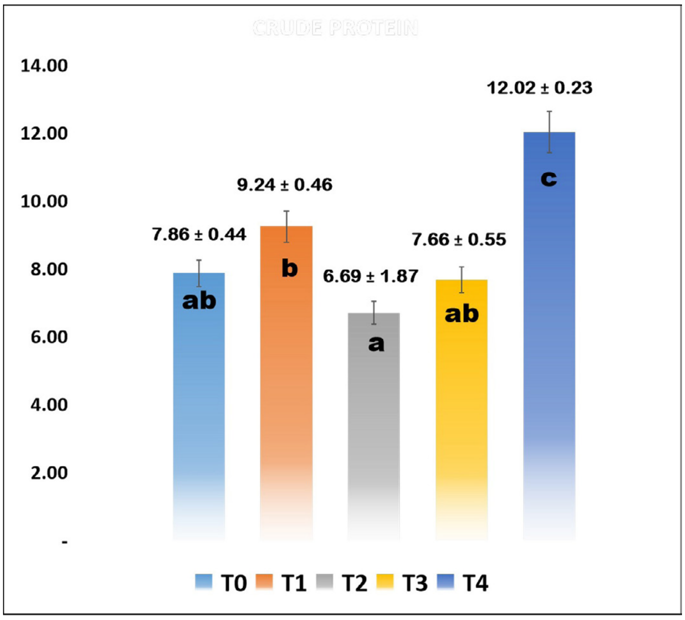

Figure 5: *Crude protein contents of aking rice (%).*

Crude fat

Rather than pure fat, the crude fat content observed in this study was a mixture of substances like chlorophyll, xanthophyll, carotene, etc. (Malia and Yusuf, 2021; Moningkey *et al*., 2019; Podolian, 2017; Rousseau *et al*., 2016). Figure 6 shows that the lowest fat content is T0 (0.01 %), and the highest is T3 (7.67 %). Therefore, it is inferred that the high fat content is due to unrinsed cooking oil seeping into the material. T4 was also unrinsed and contained 2.43 % fat, higher than T1 (0.80 %) and T2 (0.32 %). It proves that rinsing feed material under running water before processing lowers the fat content (Hamdi *et al*., 2015; Yair *et al*., 2015).

While its existence is indispensable for its role in growth, crude fat in poultry feed should be 5 % to 6 % of the total formula (Jimenez-Moya, 2021; Rachmawati *et al*., 2018; Widodo *et al*., 2019). Too much fat decreases the storing age of the feed as it triggers a rancid odor. Conversely, low fat obstructs the absorption of vitamins A, D, E, and K in poultry and reduces feed durability making it easy to crumble to dust and palatability (Sugiharto and Ranjitkar, 2019; Von Schaumburg *et al*., 2019).

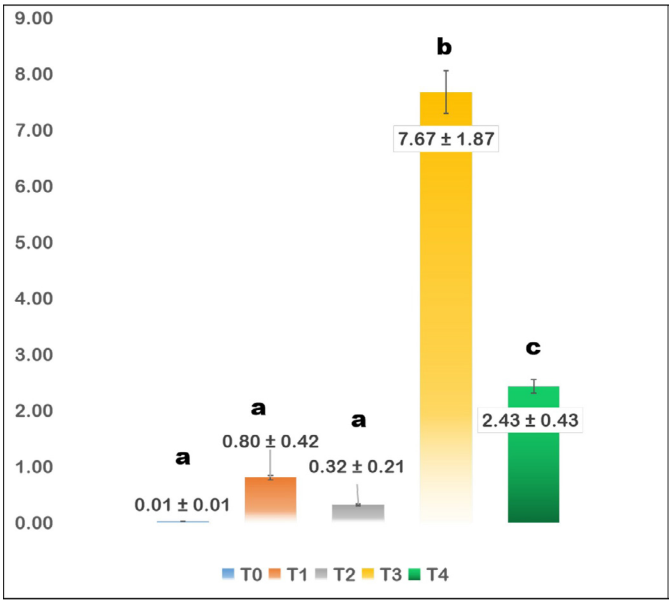

Figure 6: *Crude fat contents of aking rice (%).*

Crude fiber

Figure 7 reveals that the lowest crude fiber content is T0 (0.66 %), and the highest is T3 (1.63 %), followed by T2 (1.44). The unrinsed materials noticeably contain more fiber.

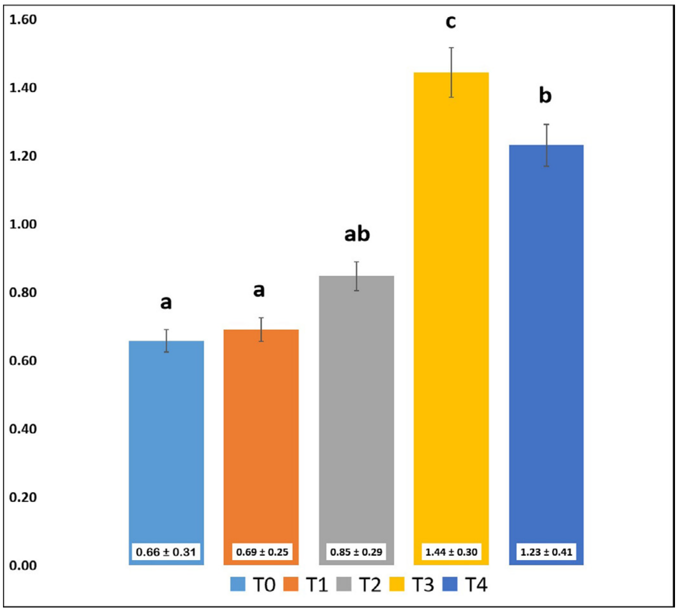

Figure 7: *Crude fiber contents of aking rice (%).*

A part of carbohydrate-containing cellulose compound, hemicellulose, and lignin compound, crude fiber is tough to digest. Specifically, broiler chicken feed's content should not exceed 5 % of the total feed formula (Choct, 2015; Varastegani and Dahlan, 2014). Aking rice generally contains less than 2 % fiber, far less than one in corn and rice bran. This result confirms Isharyudono's *et al.* (2019) discovery that aking rice as energy feed is feasible to 100 % or 60 % substitute corn, as well as Zulfikar's *et al.* (2014) that aking rice is viable to 100 % or 10 % substitute rice bran.

Taken together, the five treatments of aking rice demonstrated acceptable water content (< 14 %) and relatively low crude fiber (< 2 %), making them suitable as energy feed components, particularly for poultry. The unrinsed non-oily sample (T4) had the highest crude protein (12.02 %) and ash content (3.72 %), suggesting its superior nutritional density, although care must be taken in mineral balancing. Meanwhile, T3 had the highest fat content (7.67 %), exceeding ideal poultry feed fat levels, indicating the need for fat control during processing. Compared to corn and rice bran, aking rice showed favorable crude fiber levels and comparable protein content, particularly in T4. While some treatments may require further refinement, these findings affirm that aking rice, especially T4, holds promise as a partial or full substitute for rice and corn in poultry feed, aligning with previous research (Isharyudono *et al.*, 2019; Zulfikar *et al.*, 2014).

In addition to its nutritional value, the safety of aking rice as feed material must be addressed, particularly the risk of microbial contamination and toxic compounds such as mycotoxins. Since aking rice is derived from leftover cooked rice, improper handling may allow microbial growth during storage and processing (Noviatri *et al.*, 2020). However, the treatments applied in this study including rinsing under running water and controlled drying below 14 % moisture are known to significantly reduce microbial activity and prevent fungal growth (Cheah *et al.*, 2017; Fahmy *et al.*, 2015). Previous studies (Tonda *et al.*, 2022; Isharyudono *et al.*, 2019) have shown that aking rice processed with similar methods had total plate counts within acceptable safety limits and undetectable levels of aflatoxins. Therefore, when processed and stored properly, aking rice poses minimal microbial or toxic risk and can be considered safe for animal feeding purposes.

Conclusions and Recommendations

The high content of crude protein between 7 % and 9 % almost as high as corn and rice bran and the low ranges of oil fiber and fat at < 5 % should be evident to the viability of aking rice to substitute corn and rice bran in poultry feed. Despite being a waste-reusing product, it's nutritious, which adds to its merit. Rinsing rice waste before drying is recommended to ensure product consistency.

Acknowledgments

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Novelty Statement

Broiler farms have been using corn as the primary energy source, which is irreplaceable. The discovery of aking rice and its contents of 9 % crude protein and < 5 % crude fiber replaces corn and rice bran, which is environmentally friendly as it is made of processed food waste.

Author's Contribution

Wahyu Mushollaeni: Research supervisor, guarantor, performed literature search, funding acquisition, and manuscript review.
Rusli Tonda: Conceptualized and designed the study, performed the literature search, data acquisition, data analysis, visualization, manuscript preparation, and manuscript revision.
Ida Ekawati and Zane Vincēviča-Gaile: manuscript review
Eka Fitasari and Razhika Faradila: Investigation, performed literature search, grammarly checks, and similarity check.
All authors have read and approved the final manuscript.

Generative AI and AI-assisted technology statement
The authors stated that they didn't use generative AI and AI-assisted technology in preparing this

manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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