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Dried Rice for Alternative Feed as a Waste Management Product for Sustainable Bioeconomy in Rice-Producing Countries

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Abstract: Dried rice, an organic waste recycling product, is made from dried rice leftovers. With a carbohydrate content nearly equivalent to corn but at a lower price, it has potential as an energy-generating feed, especially in poultry farming. The nutrient content and price of dried rice were evaluated to assess its efficiency for animal feed use. Dried rice samples from three areas in East Java, Indonesia, were analyzed for moisture, ash, crude protein, crude fat, and crude fiber content. Additionally, this research assesses the effectiveness of dried rice as a corn substitute in broiler feed by observing its impact on feed intake, average daily gain, feed conversion ratio, and broiler performance index. Proximate analysis showed insignificant differences among treatments, with moisture content ranging 12.45–12.71%, ash content 0.55–1.31%, crude protein 10.34–10.64%, crude fat 0.12–2.48%, and crude fiber from 0.81 to 1.55%. Although all samples were assessed as efficient, products from Lumajang and Pasuruan were preferred for feed production due to their similarity to corn nutrient content. Dried rice costs approximately USD 213–228 per ton, significantly lower than corn. Dried rice production reduces both organic waste and poultry production costs concurrently, serving as a sustainable waste management model in Indonesia and other rice-producing countries, shifting towards a bioeconomy from a linear economy.

Keywords: dried rice leftover; poultry feed substitute; organic waste management; waste recycling products; waste to feed; waste utilization

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1. Introduction

The survival of the livestock breeding business depends in the majority on the availability of feed [1,2]. Animal feed covers around 70% of the total production cost [3–5], while quality feed at an affordable price is the key to poultry meat production [1,3]. Despite attempts to keep feed cost-efficient, they are often challenged by the seasonal volatility of corn as the main feed ingredient. The situation calls for cheaper substitutes that constantly exist. Preferably, the alternative feed is made of food substances no longer suitable for human consumption, thus reducing organic waste amounts affecting the environment [6,7].

Food remains make up a great part of organic waste, with an annual assembly of 30×10^6 t in Indonesia [8,9]. They may serve as a source of sustainable energy production or can be turned into fertilizers or animal feed [7,8,10–14]. Considering rice production, the national staple food in Indonesia and many other Asian countries, the remains can be as high as 276×10^3 t per year. Since any organic waste can serve as an energy source or fertilizer, recycling rice into animal feed could suit best in obtaining higher added-value products [15,16]. Air-dried, sun-dried, or oven-dried rice leftovers after cleaning may serve as a feasible solution.

Dried rice has been proven to be beneficial in poultry farming. Being a cheap and highly palatable feed ingredient means that it can cut down production costs efficiently, resulting in better income for the farmers [17–20]. It is quite widely used in local poultry (e.g., chicken, geese, and duck) farms; however, is not yet that popular in broiler farming.

This study aims to evaluate the nutritional content of dried rice obtained from three regions in East Java, Indonesia, including the analysis of moisture, ash, crude protein, crude fat, and crude fiber to determine its potential to be used as an effective and economical poultry feed. Additionally, this research assesses the effectiveness of dried rice as a corn substitute in broiler feed by observing its impact on feed intake, average daily gain, feed conversion ratio, and broiler performance index. The study also analyzes the cost of dried rice compared to corn and its environmental impact, particularly in reducing organic waste and valuably utilizing food materials unsuitable for human consumption.

The study hypothesizes that incorporating dried rice, derived from rice production remains, into broiler chicken feed would reduce production costs while maintaining or enhancing broiler growth performance and feed efficiency. It further asserts that dried rice from East Java tends to have similar nutritional content, providing a viable alternative to traditional animal feed ingredients like corn. Additionally, it suggests that broilers fed with a diet containing 20% of dried rice may exhibit comparable or improved feed intake, average daily gain, and feed conversion ratio compared to a conventional basal diet, ensuring cost efficiency and optimal broiler breeding performance.

2. Materials and Methods

2.1. Materials and Methods for Making Dried Rice

Dried rice samples were obtained in three different sections of East Java, a province in Indonesia. The first sample (T1) was obtained from Lumajang (112°53′ 113°23′ E; 7°54′ 8°23′ S), the second (T2) from Pasuruan (112°33′ 113°05′ E; 7°32′ 7°57′ S), and the third (T3) from Malang (112°06′ 112°07′ E; 7°06′ 8°02′ S). Five replications totaled 15 samples [18]. Employing an experimental method of proximate analysis [18,21], the contents of moisture, ash, crude protein, crude fat, and crude fiber were the study variables. Additionally, the price was evaluated to determine the most advantageous product. The study was performed at the Nutrition Laboratory of the University of Muhammadiyah Malang. All chemicals and materials used in this study were of technical grade, purchased from a chemical supplier, CV Dunia Kimia Lestari, in Malang.

The moisture content test applied the thermogravimetry principle, using an oven at 105 °C [22,23]. Each sample was scaled (Osuka HWH, Taiwan) at 1–2 g and transferred in a 75 mL dried, measured porcelain evaporating dish before being dried in a furnace (Elba EG8021S-B, Italy) at 105 °C for 3 h and cooled in desiccators (Duran DN 300, Germany). Once the constant weight was verified, the moisture content was established according to Equation (1):

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

where W is the sample weight before drying (g); W1—the dish and sample weight after drying (g); and W2—the empty dish weight (g).

Ash is the residue of a sample heated at ≥500 °C [24–27] after all organic contents are completely oxidized into CO_2 and H_2O, leaving inorganic matters such as minerals. Following the Indonesia National Standard (SNI) and the official method of the Association of Official Analytical Chemists (AOAC) in Chapter 4 regarding the feed test, graphimetry was applied. A clean porcelain dish was dried in an oven (Elba EG8021S-B, Italy) at 105 °C for 1 h and cooled in desiccators (Duran DN 300, Germany) for 15 min before scaling. Once 1.5 g to 2 g of a sample was added, it was heated in a muffle furnace (Thermolyne™ Benchtop 1, China) at 600 °C, rested outside of the furnace until its temperature reached 120 °C, then sent to the desiccators. Once the constant weight was settled, the ash content was calculated using Equation (2):

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

Kjeldahl digestion was applied to determine the protein content in the material [18,28]. An amount of 1 g of each sample was put in a 100 mL Pyrex® Kjeldahl flask, and then 2 g of selenium and 25 mL of concentrated sulfuric acid were added. It was heated for 2 h on an induction stove (Kirin kic-1000, Indonesia) until it turned greenish; afterwards, the mixture was cooled and diluted in a 100 mL Pyrex® volumetric flask up to the line mark. An amount of 5 mL of the solution was transferred to a Pyrex® condenser with a pipette, mixed with 5 mL NaOH 40% and a few drops of PP indicator, then distilled for approximately 10 min—the end of the distillatory was dipped into 10 mL boric acid 2% and PP indicator mix, and later rinsed with distilled water. The titration involved the use of HCl 0.01 N, followed by a blank setup [29,30]. The protein content was then tallied based on Equation (3):

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

where V1 is the titrant volume in sample (mL); V2—the titrant volume in the blank (mL); N—normal titrant (N); f—diluting factor; W—the sample weight (g); and 14.008 is the relative atomic mass of nitrogen (g mol^{-1}).

The Soxhlet method was applied to determine the crude fat content in a material [31,32]. An amount of 1–2 g of each sample was put in a cotton-padded, cotton-plugged filter paper cylinder (Whatman No. 1/1001-090) and oven-dried (Elba EG8021S-B, Italy) at <80 °C for 1 h before being transferred to a 50 mL class-A Pyrex® Soxhlet extractor—which was connected to a Pyrex® boiling flask containing dried, measured boiling chips—and extracted using hexane/other fat solvents for ±6 h. Hexane was then distilled, and the fat extract was oven-dried (Elba EG8021S-B, Italy) at 105 °C for 1 h before being cooled and measured. The drying process was repeated to reach the constant weight. The crude fat content was then computed according to Equation (4):

$$\text{Fat content } (\%) = \frac{\text{W} - \text{W1}}{\text{W2}} \times 100 \quad (4)$$

where W is the sample weight (g); W1—the fat weight before extraction (g); and W2—the boiling flask weight after extraction (g).

The crude fiber test employed the Weende method [33–35]. An amount of 2 g of each sample was put in a 250 mL Pyrex® Erlenmeyer flask, and 200 mL boiling H_2SO_4 (0.255 N) was added. Once plugged shut with a back-cooler, the flask was heated on an induction stove (Kirin KIC-1000, Indonesia) for 30 min. Afterwards, the suspension was filtered (Whatman No.1/1001-090). The residues in the flask were rinsed with boiled distilled water. Once the acidity of the residues on the filter was rinsed off, they were scooped into an Erlenmeyer flask using a stainless steel spatula (JSE, Indonesia), rinsed with 200 mL NaOH (0.313 N), and boiled for 30 min before going through premeasured filter paper while being washed with K_2SO_4 10% at the same time; then, they were washed with boiled distilled water and finally washed with 15 mL 95% alcohol. Next, the filter paper was oven-dried (Micra SDL093739334, Indonesia) at 110 °C and burned in a muffle furnace (Thermolyne™ Benchtop 1100 °C, China). After cooling in a desiccator (Duran DN 300, Germany), the measurements were made. The procedure was repeated three times to gain the same weight. The crude fiber content was then totaled in line with Equation (5):

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

The data obtained were analyzed for the mean and the standard deviation of each content before run-through analysis of variance (ANOVA) for any distinction in the observed variables [36,37], followed by the Least Significant Difference (LSD) test when significant differences were found [38–41].

2.2. Experimental Farming Study Description

The research was conducted in 2022 at PT Zakiyah Jaya Mandiri, a broiler chicken farm in Lumajang, East Java, Indonesia, with approval from the Ethical Commission on Health Studies of the Faculty of Medicine, University of Muhammadiyah Malang (No.E.5.a/222/KEPK-UMM/X/2022), with a document outlining the materials and methods used in the study.

The materials used included day-old chicks from PT Multibreeder Adirama Indonesia Tbk. given ad libitum feed with Wonokoyo BR1 during the starter age (1 d to 21 d), transferred to battery cages at 14 days old for adaptation, and treated at 21 days old. The research was conducted during the dry season with temperatures ranging from 28 °C to 33 °C, using 100 W light bulbs to maintain the temperature at 30–33 °C. Fifteen units of battery cages were arranged, each housing 12 chickens.

Dried rice was used at 20% for treatments T2 and T3. The nutritional content of dried rice was based on proximate analysis results from the nutrition laboratory of the University of Muhammadiyah Malang.

The research method followed a completely randomized design, with five replications to make 15 tests, each consisting of 12 chickens. Three treatments were prepared: T1 (100% basal feed), T2 (20% dried rice sprinkled on top of 80% basal feed), and T3 (20% dried rice evenly mixed with 80% basal feed).

The references [42–44] indicate the investigation of the impact of feeding schedules and nighttime lighting on broiler chicken carcass production. The feed intake, average daily gain, and feed conversion ratio were assessed to analyze the effect of feeding practices and lighting on broiler performance.

Feed intake was measured between 10 a.m. and 4 p.m. at 32 °C, with any leftovers scaled the next day. Feed intake, average daily gain, and the feed conversion ratio were calculated to evaluate broiler performance. Feed intake was determined by the total feed consumption during the 14-day treatment period. Average daily gain was calculated by subtracting the initial weight from the final weight of the chickens. The feed conversion ratio, indicating productivity, was determined by dividing the daily feed consumption by the daily weight gain [45–47].

Data were analyzed for average and standard deviation and subjected to analysis of variance (ANOVA) followed by the Least Significant Difference (LSD) test if a significant effect was detected [44,48,49]. The performance index was calculated to assess treatment efficacy based on the live chicken percentage, body weight, average harvest age, and feed conversion ratio.

3. Results

3.1. Quality of Dried Rice as a Feed Ingredient

The appearance of the tested dried rice was as shown in Figure 1 (T1, T2, and T3). Figure 1A,C are darker and have more colors, which indicates mélange content such as meat and vegetables. Figure 1B indicates that the sample from Lumajang is not only lighter but also plain—signs that mélange is absent.

Figure 1. Image of dried rice obtained in Lumajang (**A**), Pasuruan (**B**), and Malang (**C**).

The results of the proximate analysis covering moisture, ash, crude protein, crude fat, and crude fiber contents of dried rice—as well as their prices—are presented in Table 1.

Table 1. Composition and prices of dried rice.

Sample	Composition of Dried Rice (%)					Price (USD per t)
	Moisture	Ash Content	Crude Protein	Crude Fat	Crude Fiber	
T1	12.69 ± 1.66	0.55 ± 0.26	10.64 ± 2.80	0.49 ± 0.42	0.81 ± 0.20	225
T2	12.71 ± 1.34	1.31 ± 1.38	10.34 ± 1.82	0.12 ± 0.18	0.84 ± 0.28	228
T3	12.45 ± 1.30	1.27 ± 0.99	10.64 ± 2.82	2.48 ± 2.68	1.55 ± 1.03	213

Moisture content assessment indicated that sample T3 contained the lowest moisture content (12.45%), while T2 had the highest (12.71%), with no significant difference in all samples. The sample comparison is reflected in Figure 2.

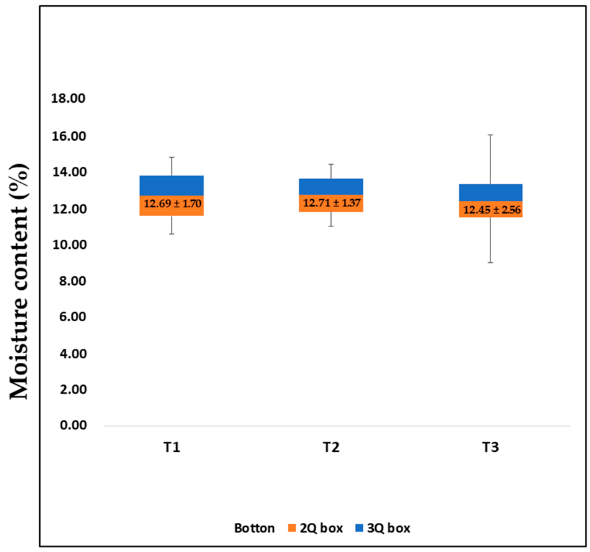

Figure 2. The moisture content of dried rice samples.

The highest ash content was recorded by the sample T2 (1.31%), followed by T3 (1.27%) and T1 (0.55%). While gaps appear in the figures (Figure 3), they are statistically insignificant. The ash content stated is in accordance with laboratory test results. The ash content in dried rice ranges from 0.3% to 3%. These results are strengthened by the findings of previous studies [21,30,36,50].

Since the crude protein contents in the samples were detected alike—10.64%, 10.30%, and 10.64% in T1, T2, and T3, respectively—the difference can be assessed as insignificant. The sample comparison is demonstrated in Figure 4.

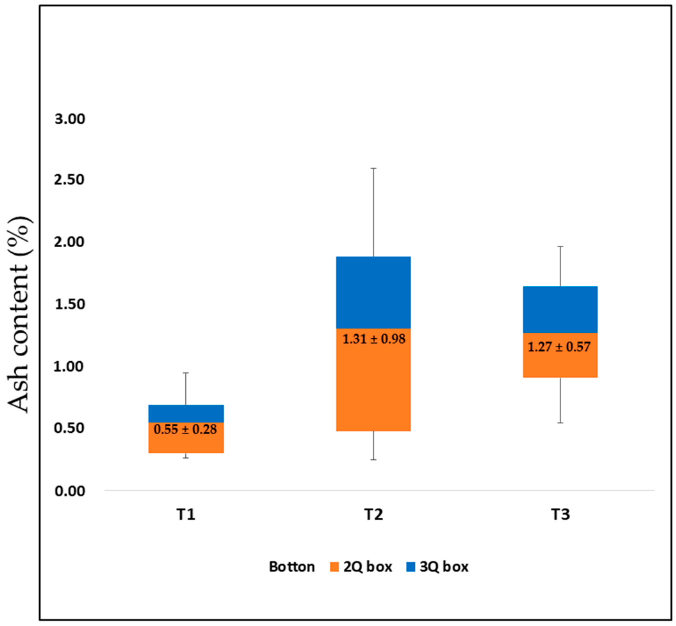

Figure 3. The ash content of dried rice.

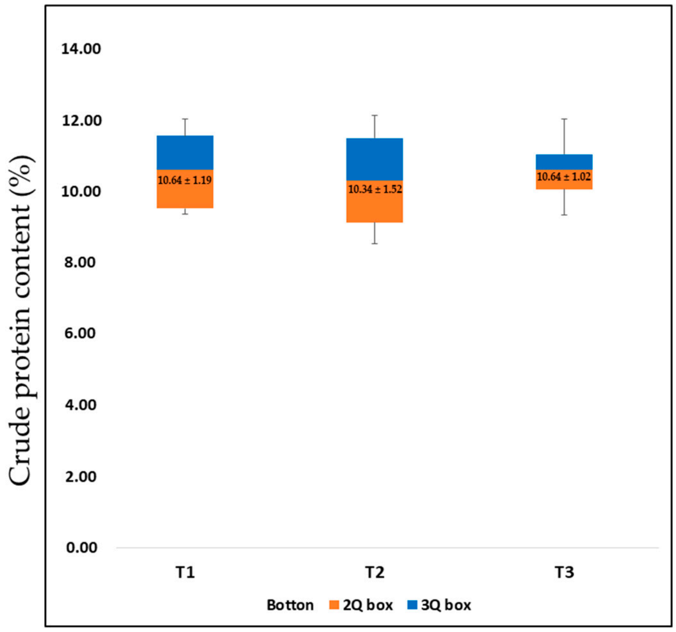

Figure 4. The crude protein content of dried rice.

The highest crude fat content was found in the sample T3 (2.48%), followed by T1 (0.49%) and T2 (0.12%). The spike in T3 does not signify a statistical difference from the other samples. The sample comparison is revealed in Figure 5.

The highest crude fiber content was found in the sample T3 (1.55%), but the lowest was found in T2 (0.84%), with no significant difference in all samples. The sample comparison is presented in Figure 6.

The results indicate negligible difference (<1%) for samples T1 and T2 compatible with other studies [18,42]. The high fiber level in T3 apparently appears from the mélange presence—colorful substances in the sample—which can be meat and/or vegetable remains. Referring to the insignificant difference, all dried rice produced in the three areas is able to be used in feed since the crude fiber content is low. The maximum limit of crude fiber in poultry feed should not exceed 6%, considering the avian uncomplicated digestive system [27,45].

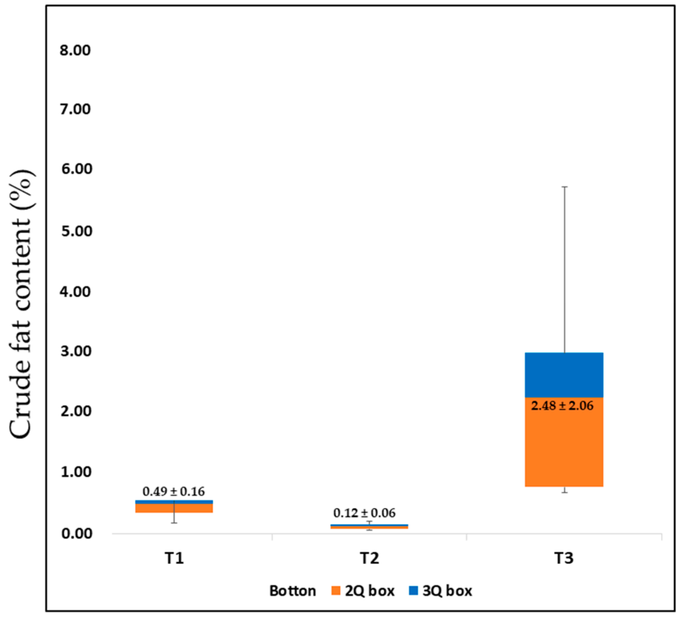

Figure 5. The crude fat contents of dried rice.

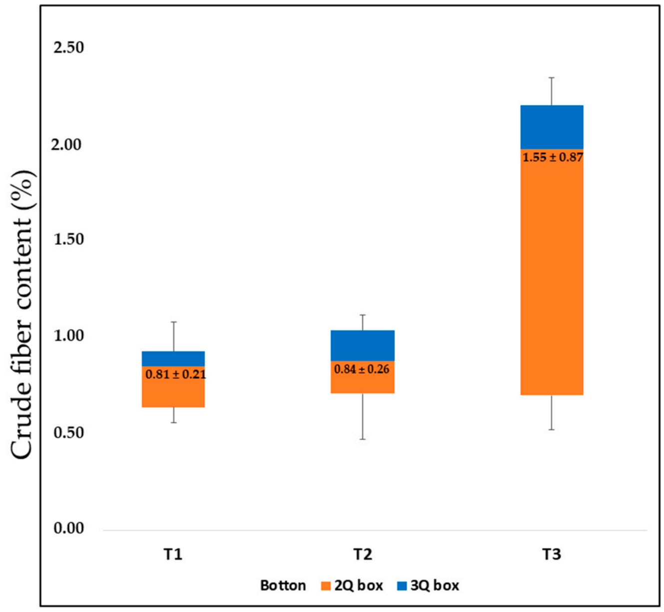

Figure 6. The crude fiber content of dried rice.

3.2. Estimation of Dried Rice Prices

Regarding prices, dried rice (also known as aking rice in Asian countrues) costs are estimated at USD 213 to USD 228 per t, which is a significantly lower price than corn (USD 346.46 per t) based on the data of 2023. The highest price was estimated for the sample T2 (USD 228 per t), followed by T1 (USD 225 per t) and T3 (USD 213 per t), with insignificant differences among them. The price comparison is presented in Figure 7.

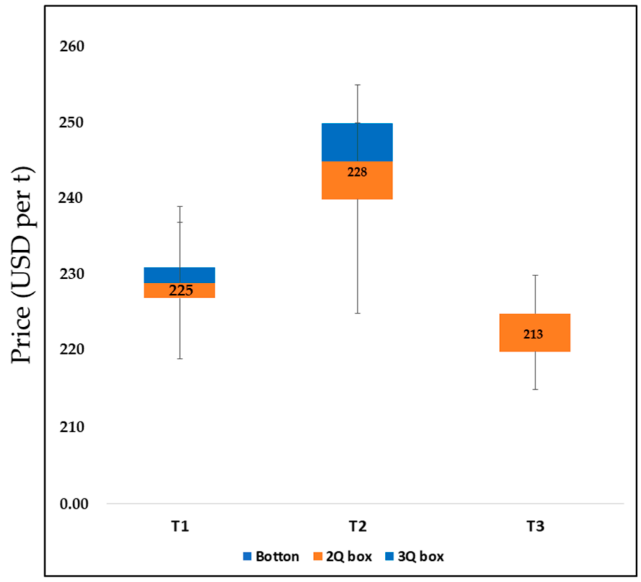

Figure 7. Dried rice price (USD per t).

3.3. Results of Treatment on Broilers

Table 2 displays the outcomes of a research study investigating the effects of three distinct treatments on broiler chickens. These treatments, denoted as Tr1, Tr2, and Tr3, were evaluated based on parameters including the feed intake, average daily gain, feed conversion ratio, and overall performance index.

Table 2. Broiler treatment indicators.

Treatment	Feed Intake (%)	Average Daily Gain (%)	Feed Conversion Ratio	Performance Index
Tr1	99.02 ± 1.44	37.07 ± 2.47	2.68 ± 0.21	374.81 ± 36.36 [a]
Tr2	97.45 ± 1.50	40.40 ± 3.19	2.42 ± 0.19	433.84 ± 47.36 [b]
Tr3	96.58 ± 4.21	36.40 ± 2.64	2.66 ± 0.11	372.67 ± 31.84 [a]

[a, b]—significant diffierence in the same column indicated by different superscripts ($p < 0.05$).

The results of three different treatments on broiler chickens are presented. In treatment Tr1, the highest feed intake value was recorded at 99.02%, with an average daily gain value of 37.07%. Despite Tr1 having the highest feed intake, the average daily gain was better in treatment Tr2, where it reached 40.40%. Additionally, the feed conversion ratio in Tr2 was also the best, with a value of 2.42, indicating better feed conversion efficiency compared to Tr1 and Tr3. Since the feed conversion factor is an indicator of good feed efficiency, the highest performance index occurred in treatment Tr2 with a value of 433.84.

Treatment Tr3 revealed different results. Although it had a lower feed intake than Tr1 and Tr2, Tr3 recorded an average daily gain value almost comparable to Tr1, at 36.40%. However, the feed conversion factor in Tr3 was almost the same as that for Tr1, at 2.66. The performance index for Tr3 also indicated fairly good performance but not as good as treatment Tr2.

Overall, the differences in results among the three treatments were highlighted. Despite Tr1 having the highest feed intake, Tr2 showed a better average daily gain and a more efficient feed conversion index, resulting in the highest performance index achieved in Tr2. This indicates that the treatment involving sprinkling dried rice on top of the feed (Tr2) resulted in better performance in broiler chickens compared to the treatment involving evenly mixing dried rice (Tr3) or no dried rice at all (Tr1).

4. Discussion

4.1. Dried Rice Feed Ingredients

The research data indicated the differences in the observed moisture content in dried rice produced in various locations of Indonesia, showing slight variations compared to specific references. The percentage of moisture content in the dried rice from the study area is reported to be slightly different from previous findings, notably lower than one source (14.71%) but close to another (12.58%). These variations are attributed to the diverse drying periods employed during rice processing [16,21]. This implies that the drying duration and drying methods influence the final moisture content in dried rice [48,51].

Further insight can be drawn from the observation that the moisture content in dried rice from all three areas meets the nationally recommended standards, as outlined in the SNI 01-3931-2006 regulation [52], which sets the maximum allowable moisture content at less than 14%. This consistency across the regions suggests adherence to regulatory guidelines and standardized practices in rice processing, ensuring product quality and safety.

The slight differences observed in the ash content of dried rice from various locations may be due to inconsistencies in the characteristics of the rice sources. If dried rice contains a mixture of different varieties or types of ingredients called a mélange, it tends to have higher ash content [18]. These findings are consistent with the reported range of ash content, namely between 0.43% and 2.56% [21]. Variations in ash content can be influenced by several factors, such as the type of ingredients mixed in the basic ingredients for making dried rice.

Differences in ash content among the dried rice samples tested were significant, and some sources showed much higher ash content than others. These differences underscore the importance of understanding the composition and quality of dried rice from various sources, especially when considering its suitability for specific applications such as feed production.

Even though the ash content is different, the dried rice produced in the third region is still suitable for use as feed. This is because they generally have a low ash content, which is desirable in animal feed formulations. Low ash content indicates minimal minerals, ensuring better digestibility and nutritional value for the animals consuming the feed. Additionally, low ash content can also contribute to improved feed efficiency and overall animal performance.

The statement provided discusses the protein content observed in dried rice and its application to potential use in feed formulation. The reported protein content is higher than the value reported in some references (8.96%) [16,18] but slightly lower than in other sources (11.66%) [21]. However, this figure is much lower than the range of 13–16% [21].

The variability in protein content among different sources of dried rice underscores the importance of understanding the characteristics of the raw materials used in its production. Factors such as the mixture in the food waste used and the processing method can influence the final protein content of dried rice.

Although there are variations, dried rice produced in the third region is considered suitable for replacing corn and rice bran in feed formulations. This is mainly because it contains approximately the same amount of protein as both feed ingredients. Protein is an essential nutrient in animal feed, contributing to growth, development, and overall health. The comparable protein content to corn and rice bran makes dried rice offer an efficient alternative in feed production, potentially reducing dependence on traditional feed ingredients and encouraging sustainable agricultural practices.

A comparison of crude fat content between different treatments revealed interesting insights into the composition of dried rice samples. It was noted that the crude fat content in the T1 and T2 consistencies was below 1% [18,21]. This shows that there is uniformity in the fat content in the treatments, thus indicating the same processing method or raw material composition.

On the other hand, the much higher fat content observed in T3 is noteworthy. The increase in fat content in T3 is most likely caused by the large amount of oil contained in food waste used in making dried rice.

Although the fat content between treatments varied, all dried rice samples from the three regions contained crude fat levels that were low enough to be considered suitable for feed production. The insignificant differences in fat content indicate that the observed variations are within the acceptable range for the feed formulation. This shows that the crude fat content of dried rice is not a limiting factor in its suitability for use as feed.

In addition, the consistent survival of dried rice samples from the three regions highlights the potential of dried rice as a reliable feed ingredient. Its low fat content makes it suitable for inclusion in animal feed without compromising the nutritional balance or feed quality.

The analysis of the test results from treatments T1 and T2 showed a consistent crude fat content of less than 1%, which is in line with previous findings [18,21]. This indicates a uniformity of fat content across treatments, meaning that processing methods or the raw material composition are similar. However, the T3 treatment stood out with higher fiber levels. The increase in fiber content in T3 is likely due to the presence of mélange, a colored substance in the sample that may consist of meat and/or vegetable residues. These components, in addition to contributing to the texture and appearance of the final product, also increase the fiber content.

Even though there were variations in fiber content between treatments, dried rice samples from the three regions were still suitable for use as feed because of their low crude fiber content. This means that the observed differences in fiber content do not significantly hinder its utilization in feed formulations. However, it is important to consider the maximum limit of crude fiber allowed in poultry feed. According to the literature references [21,27,49], poultry feed's maximum allowable crude fiber level should not exceed 6%. This is very important considering the relatively simple digestive system of birds. Therefore, the low crude fiber content in dried rice of these three regions indicates its suitability for poultry feed formulations, because the content is far below the maximum recommended threshold.

Although there were variations in fiber content between treatments, dried rice samples from the three regions showed low levels of crude fiber, making it suitable for inclusion in feed formulations. The presence of mélange in some samples may have contributed to the higher fiber levels, but overall, the differences observed did not preclude the potential use of the feed.

4.2. Dried Rice Price Significance

Price differences between treatments can be caused by several factors, with appearance being one of the main considerations. The T2, while the most expensive, likely commands a higher price due to its clean, visually appealing appearance. T2's clean presentation gives the impression of purity, which can influence consumer perceptions of quality and value. As a result, suppliers may justify T2's higher price based on its aesthetic characteristics.

On the other hand, T3, although containing similar nutritional content to T2, may appear less attractive due to the presence of mélange, which gives the product a "dirty" appearance. Despite comparable nutritional profiles, T3's less attractive visual appearance may result in a lower market value than T2. However, it should be noted that T3 offers optimal potential benefits in feed formulation, especially considering its lower price.

Price differences between product types show the influence of appearance on consumer preferences and market demand. While T2 may have a higher price due to its clean appearance, T3 provides an opportunity for a cost-effective feed formulation, given its lower price and comparable nutritional content [53–55]. This suggests that feed manufacturers should consider the visual appeal and economic efficiency of raw materials when formulating feed products.

4.3. Dried Rice Treatment in Broiler Chickens

The impact of adding dried rice to broiler chicken feed on the feed intake, average daily gain, and feed conversion ratio is illustrated in Table 1, along with the results of performance index analysis.

Table 1 shows that the highest feed intake rate was observed in treatment Tr1 (99.02%), followed by Tr2 (97.45%) and Tr3 (96.58%). Despite minor differences, Tr2 exhibited the best average daily gain, even with a lower intake. Additionally, Tr2 recorded the lowest feed conversion ratio rate (2.42) compared to T1 (2.68) and T3 (2.66). Significantly, dried rice in Tr2 performed better ($p < 0.05$), indicating that sprinkling dried rice on top of the feed is advantageous in enhancing the performance index, especially when administered at high temperatures.

Higher average daily gain rates and a lower feed conversion ratio are crucial in achieving a higher performance index value. These differences are attributed to nutrient absorption in broiler feed [56]. Although there were no significant differences in feed intake, Tr2 showed the highest average daily gain rate, suggesting better nutrient absorption compared to other treatments. Stress, especially heat stress, likely contributed to low nutrient absorption in Tr1 and Tr3.

The presence of resistant starch in dried rice is believed to be the reason for its higher performance. Resistant starch, being indigestible and unhydrolyzed, prevents absorption in the small intestine [57,58], thereby reducing metabolic burden. Sprinkling dried rice on feed ensures higher consumption, leading to increased resistant starch intake. Consequently, chickens feel satiated longer, maintain stable weight gain, and exhibit improved intestinal health, essential for enhanced performance.

Resistant starch also enhances the digestive system by promoting the growth of beneficial bacteria in the colon. These bacteria produce bacterial acids, which enhance insulin production and support the formation of short-chain fatty acids. Additionally, resistant starch accelerates the recovery process from diarrhea in broiler chickens.

Besides the resistant starch content in dried rice, the low calorie content of this feed ingredient is also a reason why the body temperature of broiler chickens given dried rice under heat stress conditions (Tr2) is lower compared to treatments Tr1 and Tr3.

Income analysis revealed that incorporating dried rice into broiler chicken feed can potentially improve farmer welfare by reducing feed costs due to the lower price of dried rice. Furthermore, the performance achieved can be better. Given that feed costs constitute a substantial portion of production costs in broiler farming, reducing feed costs can lead to higher revenue. This study emphasizes the importance of dried rice in improving feed efficiency and ultimately advancing the success of broiler farming.

5. Conclusions

The nutrient contents of dried rice produced in three areas in East Java, Indonesia, are basically similar and, therefore, equally applicable in poultry farming to serve as energy-generating feed. It was estimated that its moisture, ash, crude protein, and crude fat contents are similar to corn and rice bran, but its lower crude fiber content is more beneficial for poultry; simultaneously, its lower price is favorable for farmers. Dry rice has the potential to be used as a feed ingredient, being an environmentally friendly and sustainable material for feed production.

Furthermore, dried rice can be used as an alternative, cost-effective, and efficient feed for broiler chickens, especially when used as a supplement to the basal diet. These results indicate the potential for reducing feed costs while supporting more sustainable farming practices in Indonesia. Implementing dried rice as an additional feed can provide significant economic and environmental benefits for broiler chicken farmers.

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