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Utilization of Agricultural Waste as a Total Mixed Ratio Pellet Material for Rex Rabbit Feed

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ABSTRACT. This study aimed to evaluate the quality of Total Mixed Ration (TMR) pellets derived from agricultural waste and assess their potential as feed for Rex rabbits. The research employed an experimental approach, utilizing agricultural and plantation waste to produce TMR pellets. The study was conducted in two stages: pellet production and rabbit feeding trials. Three formulations of TMR pellets were developed with varying concentrations of oil palm empty fruit bunches (EFB): P1 (5% EFB), P2 (10% EFB), and P3 (15% EFB). The optimal formulation was subsequently used for the feeding trials. Rabbit feed treatments included T0 (60% commercial pellet + 40% forage), T1 (40% commercial pellet + 20% TMR pellet + 40% forage), T2 (30% commercial pellet + 30% TMR pellet + 40% forage), and T3 (60% TMR pellet + 40% forage). Results from the pellet analysis indicated no significant differences in organoleptic properties among the formulations. The durability test yielded the highest value of 98.77%, while the proximate analysis of the P1 formulation showed a dry matter content of 85.67%, ash content of 10.35%, organic matter of 89.65%, crude protein of 18.65%, crude fat of 18.72%, and crude fiber of 19.18%. In the rabbit feeding trials, there were no significant differences in rabbit performance when compared to those fed with commercial pellets. Based on these findings, it can be concluded that agricultural waste can be effectively utilized as a raw material for rabbit feed pellets, offering comparable quality to commercial alternatives. This research highlights the potential of agricultural waste in reducing environmental pollution while providing an economically viable alternative for animal feed.

Keywords: agricultural waste, alternative feed, rabbit productivity

INTRODUCTION

Food security has become a pressing global issue, intensified by the impacts of climate change and various geopolitical challenges. As governments worldwide focus on addressing these concerns, the agricultural sector plays a crucial role, contributing significantly to a nation's food supply. The rising global population has led to an increased demand for agricultural products, prompting a surge in agricultural industries across the world to meet these needs. However, this rapid expansion of agro-industry has also resulted in a corresponding increase in the volume of agricultural waste generated (Obi *et al*., 2016).

Agricultural waste refers to the by-products of farming activities, which are not the main products and often include animal waste (manure) and crop residues such as stalks, straw, leaves, roots, husks, and shells. These materials, while abundant, renewable, and generally low-cost, are frequently underutilized, particularly in developing countries. In many cases, agricultural wastes are either openly burned or left to decompose in the fields, leading to environmental pollution and missed opportunities for resource recovery. Despite their lower economic value compared to primary agricultural products, these wastes contain materials that could be of significant utility if properly managed (Obi *et al*., 2016). Transforming these wastes into marketable products could not only mitigate their negative environmental impact but also provide an additional income stream for farmers.

Previous research efforts have introduced various innovations aimed at minimizing the adverse effects of agricultural waste and enhancing its economic potential. One such approach is the utilization of agricultural waste as a resource for animal feed, leveraging the high organic content present in these materials. In Indonesia, particularly in regions like West Papua and Manokwari Regency, there is a concentration of specific agricultural commodities such as oil palm and sago. Additionally, these areas cultivate food and horticultural crops like soybeans, peanuts, and corn (Fatubun *et al*., 2019). To maximize the utility of agricultural waste in these regions, it is essential to develop pellet feed formulations that can address nutritional deficiencies in livestock diets.

Using agricultural waste as raw material for feed pellets not only reduces its negative impact on the environment but also offers a cost-effective alternative for farmers. With the rising prices of commercial feed ingredients, this innovative approach can help alleviate the financial burden on farmers by providing a sustainable, affordable solution for livestock nutrition.

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MATERIALS AND METHODS

This research was conducted in 2023 at the Politeknik Pembangunan Pertanian Manokwari and the Pangkep State Agricultural Polytechnic. The study was carried out in two stages: the first stage focused on the production of pellets, and the second stage involved livestock rearing trials.

Research Procedure

Total Mixed Ration Pellet Making

The pellets were produced using three different compositions of agricultural waste, as detailed in Table 1. The quality assessment of the pellets involved data collection on physical properties, chemical composition, and economic analysis. Chemical quality was evaluated through proximate analysis of the pellets, while physical quality assessments included tests for durability as well as organoleptic properties such as color, texture, and aroma.

Table 1. Total Mixed Ration Pellet Formulation (% DM)

TMR Pellet Ingredients	P1	P2	P3
Peanut Straw	32	31	30
Corn Fooder	11.9	10.9	9.9
Palm Oil Empty Fruit Bunches (EFB)	5	10	15
Sago Dregs	12	11	10
Dregs of Tofu	22	21	20
Bran	12	11	10
Tapioca flour	5	5	5
Super Rabbit Minerals	0.1	0.1	0.1
Total	100	100	100
Nutrient Content:			
Crude Protein	14.40	14.42	14.44
Crude Fiber	16.39	17.35	18.31
Crude Fat	6.35	6.49	6.63

Source: Primary Data 2023, Based on the analysis of physical and chemical quality, the selected total mixed ration pellet formulation was used in the feeding trials for rabbit maintenance

Livestock Application

A total of thirty-two female Rex rabbits were housed in individual cages for two rearing periods. The rabbits were fed twice daily, in the morning and evening, with drinking water provided ad libitum. The feed treatment for rabbit maintenance consisted of a total mixed ration pellet formulation selected based on physical and chemical quality. The research employed a completely randomized design (CRD) with four treatments and four replications. Variance homogeneity was verified, and statistical significance was assessed using the Duncan multiple range test.

T0 : Commercial Pellet 60% + Forage 40%

T1 : Commercial Pellet 40% + Total Mixed Ration Pellet 20% + Forages 40%

T2 : Commercial Pellet 30% + Total Mixed Ration Pellet 30% + Forage 40%

T3 : Total Mixed Ration Pellet 60% + Forages 40%

Research Parameters

Organoleptic Test

Organoleptic testing procedures assessed the color, texture, and aroma of the pellets, conducted with 40 panelists to evaluate these attributes (Fathia, 2016) (see Table 2).

Table 2. Pellet Organoleptic Quality Assessment

Indicator	Criteria	Score
Color	Bright chocolate	4
	Dark chocolate	3
	Dull dark brown	2
	Dull close to gray	1
Texture	Very smooth	4
	Fine	3
	Rough	2
	Very rough	1
Aroma	Fresh	4
	A bit Sour	3
	Sour	2
	So Sour	1

* The lower the pellet score, the lower the quality of the rabbit feed pellets

Pellet Durability Index

Durability index can be calculated using the formula (Ismi *et al.*, 2017):

Durability index = weight of remaining pellets / initial pellet weight × 100%

Proximate Analysis

Proximate analysis is a chemical assessment used to determine the nutrient content of a feed or feed ingredient. It is divided into six nutrient fractions: water content, crude protein, crude fat, crude fiber, ash, and nitrogen-free extract.

Body Weight Gain and Average Daily Gain

Body weight gain reflects the growth process of livestock over a specified period. The average daily gain (ADG) is calculated by determining the difference between the initial body weight and the final body weight, divided by the duration of the study. It is expressed in grams per head per day (Cunningham *et al.*, 2015).

Body weight gain = final weight - initial weight of the study

Daily body weight gain = final weight - initial research weight / length of time raising livestock

Feed Consumption and Feed Conversion

Feed consumption refers to the total amount of feed consumed by livestock over a designated time frame. Feed conversion is a parameter used to assess the efficiency of feed utilization (Rinanto *et al*., 2018).

Consumption = Feed given – Leftover feed

Feed conversion = Feed consumption / Average daily gain

RESULTS AND DISCUSSION

Organoleptic Test

Organoleptic physical testing is a method for assessing feed quality using the five senses, allowing for quantitative measurement. The specific attributes evaluated during the organoleptic physical tests included color, texture, and aroma. Quantitative data were collected using a scoring method involving 40 panelists.

Table 3. Organoleptic Pellet Total Mixed Ration

Treatments	Indicator		
	Color^{ns}	Texture^{ns}	Aroma^{ns}
P1	2.65±0.75	1.95±0.69	3.30±0.86
P2	2.55±1.43	2.30±0.80	3.55±0.51
P3	2.35±1.35	2.20±0.77	3.30±0.86

Source: Primary Data 2023

Based on the data presented in Table 3, the values for each indicator are relatively consistent, ranging between 2 and 4. The color indicators for P1, P2, and P3 are all categorized as blackish brown. In terms of texture, P1 falls into the rough category, while P2 and P3 are classified as ranging from rough to fine. Furthermore, the aroma indicators for P1, P2, and P3 show no significant differences, all exhibiting a slightly sour scent.

The data suggest that the various pellet compositions did not significantly affect the color of the pellets. The lack of variation in pellet color is likely due to the similarity in the raw materials used across the different compositions, which leads to a consistent color outcome. Color is often considered one of the quickest and most straightforward indicators of product quality (Utama *et al*., 2020; Wulandari *et al*., 2017). Hidayah *et al*. (2017) further explain that an ideal product color closely resembles that of the original materials. Rakhmawati *et al*. (2017) indicate that pellets exhibiting a light color without spots are categorized as high-quality pellets.

The texture values of the pellets ranged from lowest to highest as follows: 1.95±0.69 for P1, 2.30±0.80 for P2, and 2.20±0.77 for P3 (see Table 3). The texture of a material is influenced by a combination of physical attributes, including size, shape, quantity, and the specific components used in its composition, which are perceptible through the senses of taste and touch. The texture can be affected by the materials used (Alvianto *et al*., 2015; Ismi *et al*., 2017; Midayanto and Yuwono, 2014; Siregar *et al*., 2015). The hardness of the feed can often be determined by the presence of starch content, which acts as a natural adhesive during the pelleting process (Ilmiawan *et al*., 2015; Ismi *et al*., 2017; Juniyanto *et al*., 2015). An effective pelleting process results in a finer texture, leading to larger particle sizes that tend to be softer. High-quality pellets are typically compact, exhibit a smooth texture, do not crack easily, and possess adequate hardness (Akbar *et al*., 2017; Nurhayatin and Puspitasari, 2017).

The aroma values, listed from lowest to highest, are 3.30±0.86, 3.55±0.51, and 3.30±0.86 (see Table 3). The results indicate that the aroma of all pellet compositions falls into the slightly fishy category. This aroma can signify the level of microbial activity present in the feed, which is often associated with higher moisture content (Solihin *et al*., 2015; Utama *et al*., 2020). Aroma is frequently used as an indicator of product quality, distinguishing between good and poor-quality products (Wulandari *et al*., 2017). Additionally, changes in aroma can result from bacterial activity that converts complex compounds into simpler ones (Alvianto *et al*., 2015; Ismi *et al*., 2017; Rakhmawati *et al*., 2017).

Durability

Durability or impact resistance tests are conducted to assess the ability of the pellets to withstand collisions, friction, drops, and crushing during the storage and distribution process.

Table 4. Pellet Durability Index (%)

Treatments	Durability index
P1	98.77± 1.49^{b}
P2	92.55± 4.59^{a}
P3	94.05± 1.21^{ab}

Source: Primary Data 2023

Based on the data presented in Table 4, the average durability of the rabbit pellets treated with P1, P2, and P3 was 98.77±1.49%, 92.55±4.59%, and 94.05±1.21%, respectively. The analysis of variance indicated that the addition of 0% oil palm empty fruit bunches (EFB) significantly reduced the durability of the pellets (P<0.05). The results from the Tukey's multiple comparison test revealed that P1 had the highest durability value at 98.77%. The high durability observed in each treatment can be attributed to the natural adhesive properties of the starch present in the feed, which effectively binds all the feed ingredients together, resulting in compact and strong rabbit feed pellets. It is noteworthy that the compositions of P2 and P3 contained a higher percentage of fiber sources compared to P1, leading to a lower starch content in P2 and P3. Several factors influence the durability of the pellets, including the characteristics of the raw materials (such as protein, fat, fiber, and starch content), density, texture, moisture content, and the stability of the material characteristics. Additionally, the natural adhesive content of the feed ingredients and the level of any added adhesives also play crucial roles in determining pellet durability (Rahmana *et al*., 2016).

Proximate Analysis

The results of the proximate analysis conducted on the nutritional content of the feed formulated with various additions of rabbit pellet raw materials are presented in Table 5.

Table 5. Proximate pellet total mixed ration

Treatments	chemical composition					
	dry matter	ash content	organic matter	crude protein	crude fat	crude fiber
P1	85.67±0.35[a]	10.35±0.89[a]	89.65±0.89[c]	18.65±0.53[b]	18.72±5.05[c]	19.18±0.69[b]
P2	81.99±2.99[b]	8.19±0.84[b]	91.81±0.84[b]	21.23±1.13[a]	26.25±3.63[b]	20.08±0.93[b]
P3	78.96±0.75[c]	5.74±0.09[c]	94.26±0.09[a]	16.87±0.69[c]	30.88±0.79[a]	21.33±0.97[a]

Source: Primary Data 2023

Dry and Organic Matter

Dry matter comprises organic materials, including minerals essential for the body, which play a critical role in bone formation and function as components of enzymes and hormones. The organic material primarily originates from carbohydrates, specifically non-nitrogenous extract material, with starch and sugar being the main constituents utilized by bacteria to produce lactic acid. As shown in Table 5, the dry matter content in P1, P2, and P3 is 85.67±0.35%, 81.99±2.99%, and 78.96±0.75%, respectively. The organic matter content for these treatments is 89.65±0.89%, 91.81±0.84%, and 94.26±0.09%. According to the SNI 8675-2018 standard (Badan Standardisasi Nasional, 2018), the maximum moisture content for biomass pellets should not exceed 12%. Excessive moisture can significantly shorten the storage life of the pellets.

The digestibility of organic matter indicates the proportion of organic material that digestive enzymes can effectively break down (Manikari *et al*., 2020). The digestibility value of organic matter is typically higher than that of dry matter, as the digestibility of dry matter includes ash, whereas organic matter digestibility does not. Organic matter digestibility reflects the availability of nutrients in the feed (Putra *et al*., 2019; Suardin *et al*., 2014).

Ash Content

The ash content of a feed material indicates the mineral content it contains. Minerals are inorganic substances that the body requires in small quantities. Despite their minimal required amounts, feed ingredients must include the essential minerals needed by livestock. According to Ringgita *et al*. (2015), the ash content in animal feed should not exceed 15%. As presented in Table 5, the average ash content of rabbit pellets formulated from agricultural and plantation waste, with varying compositions, is as follows: P1 has an ash content of 10.35±0.89%, P2 has 8.19±0.84%, and P3 has 5.74±0.09%.

Crude Fat

As shown in Table 5, the crude fat content in the pellets for treatments P1, P2, and P3 is 18.72±5.05%, 26.25±3.63%, and 30.88±0.79%, respectively. These results align with findings from previous studies by Minarti *et al*. (1984) and Gunawan and Khalil (2015), which indicated that rations for rabbits with varying fat levels (ranging from 3% to 10%) resulted in different growth outcomes. Specifically, a fat content of 8% was found to yield the best body growth. Fat serves as a primary energy source, providing significantly more energy than carbohydrates and proteins.

Crude Fiber

Feed with high crude fiber and energy content may lead to reduced feed consumption. Elevated crude fiber levels can slow the passage of feed through the digestive tract, causing it to fill quickly and resulting in rabbits feeling satiated more easily (Utami *et al*., 2014). Table 5 shows that the crude fiber content in the pellets for treatments P1, P2, and P3 is 19.18±0.69%, 20.08±0.93%, and

21.33±0.97%, respectively. In comparison, research by Adi *et al*. (2016) indicates that a crude fiber content of 14% positively impacts body weight growth in Rex rabbits. This underscores the importance of considering crude fiber content when formulating feed. In this study, the P1 pellet composition had the lowest crude fiber content at 19.18±0.69%. Crude fiber is challenging for the digestive organs of rabbits to break down, which can affect the digestibility of various feed materials.

Crude Protein

The research findings indicate significant variation in the nutritional content of the feed. The protein content in treatment P1 is 18.65±0.53%, while the pellet with the highest protein content is P2, which contains 21.23±1.13%. Conversely, the lowest protein content is found in P3, at 16.80±0.697%. Interestingly, Rex rabbits fed a diet containing 16% protein achieved the best results in terms of body weight. This suggests that higher protein content does not necessarily guarantee an increase in body weight. Protein plays a critical role in maintaining the function of vital body tissues (Council, 1993) and is an essential nutrient required for the construction of muscle tissue, cell membranes, hormones, and enzymes. Body proteins are formed from amino acids, and non-ruminant livestock, including rabbits, require several essential amino acids (McNitt *et al*., 2013).

Livestock Application

The results of the physical and chemical quality testing identified P1 as the optimal total mixed ration pellet formulation. This formulation was subsequently utilized for the feed treatment during the rabbit rearing process. The composition and nutritional content of the feed provided to the rabbits, along with the rabbits' productivity, are presented in Tables 6 and 7.

Table 6. Composition and nutrient content of feed

	Treatments			
Feed Ingredients (%)	T0	T1	T2	T3
Pellet Commercial Senze Rabbit	60	40	30	20
Pellet Total Mixed Ratio (P1)	0	20	30	40
Teki Grass (*Cyperus rotundus*)	40	40	40	40
Total	100	100	100	100
Nutrient Content (%)				
Dry Matter	86.54	86.79	86.92	87.04
Ash Content	12.11	12.32	12.43	12.54
Crude Fat	5.21	6.95	7.82	8.69
Crude Fiber	13.58	14.83	15.45	16.07
Crude protein	18.73	17.59	17.03	16.46

Source: Primary Data 2023

Table 7. Rabbit productivity

Treatments	Productivity			
	Body Weight Gain (g)^{ns}	Average Daily Gain (g)^{ns}	Feed Consumption (g)^{ns}	Feed Conversion^{ns}
T0	1146.67±185.40	40.95±6.62	9347.82±525.78	5.55±0.71
T1	1179.00±40.04	42.11±1.43	9539.67±237.36	4.69±0.11
T2	1077.67±24.91	38.49±0.89	9203.91±274.01	5.11±0.15
T3	1036.67±80.96	37.02±2.89	9340.48±153.78	5.51±0.41

Source: Primary Data 2023

Body Weight Gain

Data analysis results indicate that treatment T1 (Table 6) resulted in the highest average body weight, although further statistical tests revealed that these differences were not significant. The average increase in rabbit body weight for each treatment was as follows: T0 (1146.67±185.40 g), T1 (1179±40.04 g), T2 (1077.67±24.91 g), and T3 (1036.67±80.96 g). Among these treatments, P1 demonstrated the best results for final body weight. This finding aligns with the study conducted by Adi *et al*. (2016), which also reported that increases in rabbit body weight were not statistically significant, likely due to minimal differences in food consumption among the treatments.

Average Daily Gain

The results of the data analysis indicate that treatment T1 (Table 6) produced the highest average body weight among all treatments. The average increase in body weight for the rabbits was as follows: T0 (40.95±6.62 g), T1 (42.11±1.43 g), T2 (38.49±0.89 g), and T3 (37.02±2.89 g). These findings align with the research conducted by Soleh *et al*. (2022), which suggested that the ideal daily body weight gain falls within the range of 19.27 to 22.96 g/head/day. Thus, the observed daily body weight gains in this study can be considered ideal.

Feed Consumption

The data analysis results indicate that treatment T1 (Table 6) yielded the highest average body weight among all treatments. The average increase in body weight for the rabbits was recorded as follows: T0 (40.95±6.62 g), T1 (42.11±1.43 g), T2 (38.49±0.89 g), and T3 (37.02±2.89 g). These findings are consistent with the research conducted by Soleh *et al*. (2022), which suggests that the ideal daily body weight gain should fall within the range of 19.27 to 22.96 g/head/day. Therefore, the observed daily body weight gains in this study can be considered ideal.

Feed Conversion

The data analysis results indicate that treatment T1 (Table 6) produced the lowest ration conversion ratio, measuring 4.69±0.11. The average increase in rabbit body weight was recorded as follows: T0 (5.55±0.71), T1 (4.69±0.11), T2 (5.11±0.15), and T3 (5.51±0.41). These findings suggest that rations with higher energy content yield lower feed conversion ratios. This occurs because rabbits meet their energy needs more quickly when the energy content in the feed is elevated, resulting in reduced feed intake. McNitt *et al*. (2013) support this notion, indicating that the energy content of the ration significantly impacts its efficiency; specifically, a higher energy content correlates with lower feed conversion ratios and enhanced feed efficiency. Consequently, T3 demonstrates a low feed conversion ratio, which can be attributed to its higher levels of ash, fat, and crude fiber, ultimately leading to decreased feed consumption.

CONCLUSIONS

This research concluded that the best total mixed ration (TMR) pellet formulation, based on physical and chemical quality, was P1 (supplemented with 5% Palm Oil Empty Fruit Bunches (EFB)). In field tests, the productivity of rabbits fed the pellets produced in this study was not significantly different from that of rabbits given commercial pellets. The application of the P1 formulation, comprising approximately 40–60% of the total feed, resulted in rabbit productivity comparable to those fed commercial pellets. This indicates that the pellets developed in this study can effectively compete with commercial alternatives in practical applications.

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