

Effect of Utilizing Varying Levels of Millet Offal as Replacement for Maize Offal in the Diets of Growing Rabbit

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Abstract

This study evaluates the effects of replacing maize offal with millet offal on the performance, carcass characteristics, hematological parameters, and nutrient digestibility in growing rabbits. Using a completely randomized design (CRD), 30 rabbits of both sexes were randomly assigned to five treatment groups, each replicated three times with two rabbits per replicate. The experimental diets, with 16% crude protein (CP), replaced maize offal with millet offal at inclusion levels of 0%, 25%, 50%, 75%, and 100%. The results indicated no significant differences in initial live weight, total weight gain, or daily weight gain among the treatments. However, final weight gain, daily feed intake, and feed conversion ratio were significantly affected ($P < 0.05$), with the highest final weight gain observed in the 100% millet offal group. Carcass characteristics mostly showed no significant differences, except for live weight and large intestine weight. Hematological parameters, including packed cell volume (PCV), red blood cell count (RBC), hemoglobin concentration (HGB), and mean corpuscular hemoglobin concentration (MCHC), did not differ significantly among the treatments. Nonetheless, significant variations were noted in white blood cell count (WBC), mean corpuscular hemoglobin (MCH), and mean corpuscular volume (MCV). In conclusion, millet offal can successfully replace maize offal in rabbit diets up to 100% without detrimental effects on growth performance, carcass traits, and blood profile. Rabbit farmers should consider including millet offal in their feed formulations for rabbit's diets up to 100% is recommended.

Keywords: Performance, Carcass Characteristics, Hematology, Millet Offal, Rabbits.

Introduction

Background of the Study

Protein malnutrition remains a major challenge in sub-Saharan Africa, mainly due to low animal protein intake and competition between human consumption and livestock production for key feed ingredients like soybean and maize (Chisoro & Nkukwana, 2020b; García-Moya *et al.*, 2019). Rising costs and scarcity of these conventional ingredients make them less accessible to small-scale farmers (Nyamukonda & Ndlovu, 2019). This has prompted researchers to explore alternative feed sources, such as agro-industrial by-products like millet offal, which is nutritionally rich and widely available in millet-producing countries like Nigeria (Olafadehan *et al.*, 2017; Damodaran, 2023). Millet offal is a cost-

effective alternative for rabbit feed, as rabbits can efficiently convert non-competing feed sources into high-quality protein (Yusuf *et al.*, 2020). Rabbit farming offers a promising solution to protein deficiency due to its low feed cost, rapid reproduction, and superior meat quality (Gbenge *et al.*, 2022).

The use of millet offal aligns with efforts to address feed-food competition, providing a sustainable solution in regions facing protein malnutrition (García-Moya *et al.*, 2019). As a fiber-rich by-product, millet offal supports livestock nutrition and leverages Nigeria's growing millet production (Pradhan *et al.*, 2010). Its high nutritional content, including protein, fiber, and essential minerals, makes it well-suited for livestock feed (Yusuf *et al.*, 2020). Rabbit production, in particular, can significantly alleviate protein malnutrition, as rabbits efficiently convert feed into high-quality meat (Oloruntola *et al.*, 2015). Despite its advantages, rabbit farming has been underutilized in tropical regions due to the high cost of traditional feeds (Garba & Mohammed, 2015). By incorporating millet offal into rabbit diets, farmers can reduce reliance on expensive feed ingredients like maize and soybean, promote sustainable feeding practices, and improve the profitability of rabbit farming (Damodaran, 2023). The adaptability and low-cost production of rabbits make them an ideal protein source to combat malnutrition.

This study evaluates the effect of replacing maize offal with graded levels of millet offal in rabbit diets, aiming to enhance productivity while addressing protein malnutrition in sub-Saharan Africa. By demonstrating the benefits of millet offal as a sustainable feed, the research contributes to strategies for improving livestock production and food security.

Materials and Methods

Experimental Site

The experiment was conducted at Rabbitry Unit, Bauchi State College of Agriculture, Bauchi, located at Yelwan Makaranta along Bauchi-Dass road. Bauchi State is located between latitude $9^{\circ}30^1$ and $12^{\circ}30^1$ and longitude $8^{\circ}50^1$ and $11^{\circ}00^1$ E of the green which meridian with total land area of 49,259.01 square kilometers. The state records annual rainfall of around 1300mm in the Sudan savannah zone and 700mm in the Sahel savannah (NIMET, 2024).

Experimental Diets

Millet offal were freshly collected, sundried, for three (3) days to reduce moisture content to about 10%. Five (5) experimental diets (16 CP %) were formulated in which maize offal was gradually replace with the processed millet offal at inclusion levels of (0%, 25%, 50%, 75%, and 100%), and the diets designated as (diet 1, diet 2, diet 3, diet 4, and diet 5) respectively. The diets were formulated and calculated Crude protein and Metabolizable energy range from (15.65-16.00%) for CP and (2470.1-2522.2) for ME respectively shown in Table 1.

Table 1: Composition of Experimental Diets Containing Graded Levels of Millet Offal

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Maize	14.11	14.45	14.85	15.26	15.16
Soybeans meal	22.89	22.55	22.15	21.74	21.39
Maize offal	50.00	37.50	25.00	12.5	0.00
Millet offal	0.00	12.5	25.00	37.50	50.00
Groundnut haulm	10.00	10.00	10.00	10.00	10.00
Bone meal	2.00	2.00	2.00	2.00	2.00
Salt	0.50	0.50	0.50	0.50	0.50
Premix	0.50	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00	100.00
Calculated analysis					
Crude protein (%)	16.00	15.97	15.88	15.078	16.065
ME (kcal/kg)	2470.10	2474.20	2478.00	2522.20	2470.90
Crude fiber (%)	12.72	12.3	11.82	11.36	10.9
Calcium (%)	0.40	0.40	0.40	0.40	0.40
Phosphorus (%)	0.30	0.30	0.30	0.30	0.30

Management of Experimental Rabbits

A total of thirty (30) mixed mongrel growing rabbits of different sexes, aged between 6-7 weeks, were used for the study, which lasted for six weeks. The animals were allowed a one-week adjustment period for acclimatization and were dewormed with ivermectin at a dose of 0.5 ml/kg. Prophylactic medication was administered prior to the commencement of the experiment to address internal and external parasites. The animals were housed in well-constructed hutches (25x25x30 cm) with feeding trays and drinkers provided. Feed and water were available ad libitum. Routine sanitary operations were carried out, and any incidence of disease was treated with the antimicrobial agent Embassin-Forte^R at a dose of 0.5 ml/kg.

Data Collection

Growth Performance Studies

Data were collected for final weight, daily feed intake (DFI) daily weight gain (DWG) and feed conversion ratio (FCR). The daily feed intake was obtained by difference between quantity of feed offered and the left-over, retrieved the following morning. Daily weight gain was determined by difference between two consecutive weighing carried out on weekly basis while feed conversion ratio was computed using the relationship between daily feed intake and daily weight gain.

Daily feed intake

Feed were served in the morning and evening using a balance weighing scale.

Daily Feed intake: The total quantity of feed given per day minus the leftover and then divided by the number of rabbits per hutches as shown below.

$$\text{Daily feed intake} = \text{Total quantity of feed given} - \text{Leftover} \quad \dots (1)$$

Daily weight gain (g)

This is the weight obtained multiply by 1000g and divided by the number of rabbits per pen x days (7) pen as shown below.

$$\text{Daily weight gain} = \text{Final weight} - \text{Initial weight} \quad \dots (2)$$

Feed conversion ratio

Feed conversion ratios were calculated by.

$$\text{Feed Conversion Ratio} = \frac{\text{Quantity of feed consumed}}{\text{Weight gain}} \quad \dots (3)$$

Carcass Evaluation Studies

At the end of the six-week study period, the rabbits were starved overnight before being slaughtered. Starving helps to improve the accuracy of estimating real live weight and reduces the volume of gut contents, thereby minimizing carcass contamination during dressing. Three rabbits from each treatment group were randomly selected, individually weighed, slaughtered, skinned, and eviscerated. The carcass and organ weights were measured. Each rabbit was slaughtered by cutting the jugular vein with a sharp knife, then eviscerated and weighed. The visceral organs were carefully removed and weighed. The weights of the individual organs were expressed as percentages of live weight, following the method described by Cheeke (1987).

Dressing percentage (DP) was obtained by weighing the carcass relative to the live weight of each rabbits and expressed in percentage (%) as shown below.

$$\text{DP} = \frac{\text{Carcass weight}}{\text{Live Weight}} \times 100 \quad \dots (4)$$

Hematological Studies

Blood collection

About 5 mL blood withdrawn from ear vein of 15 animals by means of 5 mL sterile needle and syringe was expelled gradually into labeled bijou bottle containing a speck of dried ethyl diamine tetracetic acid (EDTA) powder. The bottles were immediately capped and the contents mixed gently for about a minute by repeated inversion. Blood collected this way was used for the various hematological studies.

Laboratory procedure

The hematological parameters were determined following the methods outlined by Lamb (1981), briefly described here.

- **Packed Cell Volume (PCV)**

Approximately 75 μL of each blood sample was drawn into heparinized capillary tubes. The tubes were sealed at one end with plasticine and centrifuged in a microhematocrit centrifuge at 10,000 rpm for 5 minutes. The PCV was read using a hematocrit reader and expressed as a percentage.

- **Red Blood Cell (RBC) Count**

The RBC count was determined using a hemocytometer after diluting the blood sample with isotonic saline in a ratio of 1:200. The cells were counted under a microscope, and the RBC concentration was calculated and expressed in millions per cubic millimeter ($\times 10^6/\mu\text{L}$).

- **White Blood Cell (WBC) Count:**

The WBC count was also performed using a hemocytometer. The blood was diluted with a white blood cell diluting fluid (e.g., Turk's solution). The WBCs were counted under a microscope, and the results were expressed as thousands per cubic millimeter ($\times 10^3/\mu\text{L}$).

- **Hemoglobin Concentration (HBC)**

Hemoglobin concentration was determined by the cyanmethemoglobin method.

A 20 μL blood sample was mixed with Drabkin's reagent and allowed to stand for 10 minutes for complete hemoglobin conversion. The absorbance was measured using a spectrophotometer at 540 nm, and the HBC was calculated and expressed in grams per deciliter (g/dL).

- **Calculation of Mean Corpuscular Indices:**

- **Mean Corpuscular Volume (MCV):** Calculated using the formula:

$$\text{MCV (fL)} = \left(\frac{\text{PCV (\%)}}{\text{RBC count } (\times 10^6/\mu\text{L})} \right) \times 10 \quad \dots 6$$

- **Mean Corpuscular Hemoglobin (MCH):** Calculated using the formula:

$$\text{MCH (pg)} = \left(\frac{\text{HBC (g/dL)}}{\text{RBC count } (\times 10^6/\mu\text{L})} \right) \times 10 \quad \dots 7$$

- **Mean Corpuscular Hemoglobin Concentration (MCHC):** Calculated using the formula:

$$\text{MCHC (g/dL)} = \left(\frac{\text{HBC (g/dL)}}{\text{PCV (\%)}} \right) \times 100 \quad \dots 8$$

Experimental Design

The design of the experiment is complete randomized design (CRD). Thirty (30) numbers of growing rabbits of both sexes were randomly distributed to five treatments groups, Each group was replicated 3 times having two (2) rabbits per replicate.

Statistical Analysis

The collected data were be subjected to analysis of variance (ANOVA) using SPSS software (2007). Significant differences among treatment groups were determined using Duncan multiple range test (DMRT) post-hoc tests (1955).

Results and Discussion

Results

Table 2: Growth performance of grower rabbit fed diets containing graded level of millet offal (MO) as replacement for maize offal

Parameters	T ₁ (0%)	T ₂ (25%) MO	T ₃ (50%) MO	T ₄ (75%) MO	T ₅ (100%) MO	SEM
Initial Weight	721.68	723.00	725.00	725.33	726.33	2.35NS
Final weight	1217.00 ^b	1217.33 ^{ab}	1218.00 ^{ab}	1218.00 ^{ab}	1219.00 ^a	0.67*
TWG	495.33	494.33	493.00	492.00	495.67	2.10NS
DWG	11.79	11.77	11.73	11.71	11.80	0.48NS
DFI	60.70 ^c	58.67 ^d	64.58 ^b	63.97 ^{ab}	65.96 ^a	0.84*
FCR	5.15 ^b	4.98 ^a	5.46 ^c	5.50 ^c	5.59 ^c	0.67*

SEM= Standard error of Mean; **NS**= not significant; *= significant at $p < 0.05$; ^{abc} Means in the same row with different superscript differs significantly; **MO**= Millet Offal; **TWG**= Total Weight Gain; **DWG**= Daily Weight Gain; **DFI**=Daily Feed Intake; **FCR**=Feed Conversion Ratio, **MO**= millet offal

The results of the growth performance of grower rabbits fed diets containing millet offal as a replacement for maize offal are presented in Table 3. There were no significant differences in the initial live weight (721.68–726.33 g), total weight gain (493.00–495.67 g), and daily weight gain (11.71–11.80 g). However, final weight gain, daily feed intake, and feed conversion ratio were significantly ($P < 0.05$) affected. There was a significant ($p < 0.05$) difference in the final weight gain between T₁ and T₅, with T₅ (100% millet offal) showing the highest final weight gain (1219 g), followed closely by T₄ (75% millet offal) at 1218 g, and the lowest final weight gain was observed in T₁ (0% millet offal) at 1217 g. Daily feed intake was highest in T₅ (65.96 g), followed by T₃ (50% millet offal) at 64.58 g, while least daily feed (58.67 g) was recorded in T₂ (25% MO). The best feed conversion ratio was observed in T₂ (25% millet offal) at 4.98, followed by T₁ (0% millet offal) at 5.15, while T₅, T₄, and T₃ (100%, 75%, and 50% millet offal) had feed conversion ratios of 5.59, 5.50, and 5.46, respectively.

Table 3: Carcass characteristics of grower rabbit fed diets containing graded level of millet offal (MO) as replacement for maize offal

Parameters	T ₁ (0%)	T ₂ (25%) MO	T ₃ (50%) MO	T ₄ (75%) MO	T ₅ (100%) MO	SEM
Live Weight (g)	1217.00 ^b	1217.33 ^a	1218.00 ^a	1218.00 ^a	1219.00 ^a	0.76*
Carcass Weight	515.00	514.70	515.70	522.33	569.33	23.26 ^{ns}
Dressing %	42.32	42.28	42.34	43.00	46.71	1.91 ^{ns}
Head	10.93	11.00	10.94	10.53	10.97	0.25 ^{ns}
Leg	2.81	2.96	2.93	3.51	3.28	0.30 ^{ns}
Pelt	10.89	10.79	10.70	10.65	11.22	0.36 ^{ns}
Kidney	0.84	0.68	0.70	0.87	0.67	0.19 ^{ns}
Liver	3.44	3.50	3.59	4.33	4.29	0.43 ^{ns}
Heart	0.44	0.45	0.44	0.46	0.43	0.03 ^{ns}
Lung	0.72	0.81	0.93	0.65	0.64	0.15 ^{ns}
Fat	1.24	0.97	0.86	0.94	0.88	0.18 ^{ns}
Cecum	1.92	1.73	1.33	1.48	1.77	0.31 ^{ns}
Small intestine	5.84	6.02	6.07	6.25	6.07	0.23 ^{ns}
Tail	0.55	0.62	0.56	0.51	0.50	0.11 ^{ns}
Stomach	6.89	7.30	7.64	7.22	7.43	0.32 ^{ns}
Large intestine	8.00 ^a	7.89 ^b	8.14 ^a	8.15 ^a	8.13 ^a	0.01*

SEM= Standard error of Mean; **NS**= not significant; * = significant at $p < 0.05$; ^{abc} Means in the same row with different superscript differs significantly, **MO**= millet offal

The results of carcass and organ characteristics, as presented in Table 4, indicate that most parameters were not significantly influenced by the dietary treatments. These parameters include dressing percentage (42.28 – 46.71%), pelt weight (10.65 – 11.22 %), carcass weight (514.70 – 569.33 g), leg weight (2.81 – 3.51 %), head weight (10.53 – 11.00 %), fat weight (0.86 – 1.24 %), small intestine weight (5.84 – 6.25 %), heart weight (0.23 – 0.36 g), liver weight (3.44 – 4.33 %), stomach weight (6.89 – 7.64 %), caecum weight (1.33 – 1.92 %), and tail weight (0.50 – 0.62 %). However, significant differences ($p < 0.05$) were observed in the final weight and large intestine weight. The final weight gain was similar across dietary treatments except for T₁, which had the lowest value of 1217g. Similarly, the large intestine weight was comparable across dietary treatments, with the exception of T₂, which had the lowest value of 7.89%.

Table 4: Haematological parameters of grower rabbits fed graded levels of millet offal (MO) Diets as replacement for maize offal

Parameters	T ₁ (0%)	T ₂ (25%) MO	T ₃ (50%) MO	T ₄ (75%) MO	T ₅ (100%) MO	SEM
PCV (%)	40.20	39.00	41.55	40.95	41.50	2.92 ^{ns}
RBC (x10 ⁶ /μL)	5.17	7.07	5.30	5.24	5.22	1.16 ^{ns}
WBC (x10 ³ /uL)	5.63 ^a	2.52 ^b	4.84 ^a	4.79 ^a	4.64 ^a	0.63 [*]
HGB (g/dL)	11.40	11.15	11.45	11.75	11.40	0.57 ^{ns}
MCH (pg)	22.00 ^{ab}	21.15 ^c	21.60 ^{abc}	22.45 ^a	21.80 ^{abc}	0.29 [*]
MCHC (g/dL)	29.00	28.70	28.23	27.55	27.45	0.85 ^{ns}
MCV (fL)	77.43 ^a	73.00 ^b	78.40 ^a	78.25 ^a	79.65 ^a	1.47 ^{ns}

SEM= Standard error of Mean; **NS**= not significant; *****= significant at $p < 0.05$; ^{abc} Means in the same row with different superscript differs significantly; **PCV**= Pack Cell Volume; **RBC**= Red Blood Cell; **WBC**=White Blood Cell; **HGB**=Haemoglobin Concentration; **MCH**=Mean Corpuscular Haemoglobin, **MCHC**=Mean Corpuscular Haemoglobin Concentration; **MCV**= Mean Corpuscular Volume, **MO**= millet offal

Table 4 presents the hematological parameters of grower rabbits fed diets containing millet offal as a replacement for maize offal. No significant differences were observed in the packed cell volume (PCV), which ranged from 39% to 41.55%, red blood cell count (RBC) ranging from 5.17 to 7.07 x10⁶/μL, hemoglobin concentration (HGB) between 11.15 and 11.75 g/dL, and mean corpuscular hemoglobin concentration (MCHC) between 27.45 and 29.00 g/dL. However, significant variations were noted in white blood cell count (WBC), mean corpuscular hemoglobin (MCH), and mean corpuscular volume (MCV).

The WBC counts were relatively similar across the dietary treatments, except for diet 2 (25% millet offal), which had the lowest value of 2.52 x10³/μL. The MCH varied among treatments, with T₄ (75% millet offal) showing the highest value of 22.45 pg, followed by T₁ (0% millet offal) at 22 pg, and the lowest value of 21.15 pg was recorded in T₂ (25% millet offal). The MCV also showed variations, with T₅ (100% millet offal) having the highest value of 79.65 fL, followed by T₃ (50% millet offal) at 78.40 fL, while T₂ (25% millet offal) had the lowest value of 73.00 fL.

Discussion

The non-significant variation in initial weight observed in this study aligns with the findings of Abubakar *et al.* (2024), who reported similar initial live weights in mixed-breed rabbits fed varying levels of maize milling residue. The lack of variation in initial weights suggests that the rabbits across all treatment groups were relatively uniform in size at the start of the experiment, providing a consistent baseline for evaluating the effects of dietary treatments.

In contrast, significant differences were observed in the final weights, particularly between the control group (T₁) and the higher levels of millet offal inclusion (T₂, T₃, T₄, T₅). This

pattern is consistent with the findings of Hilarious & Johnson (2012), who observed significant differences in final live weights in rabbits fed millet offal-based diets. This suggests that millet offal can significantly impact final body weight, although the effect may vary depending on the type and level of dietary fiber included. Interestingly, studies by Igwebuike *et al.* (2010) and Okocha *et al.* (2024) reported no significant differences in both initial and final weights in rabbits fed diets containing graded levels of millet bran and rice husk, respectively. These contrasting results indicate that the type of dietary fiber and its level of inclusion can have different impacts on weight outcomes.

The study found no significant differences in total weight gain (TWG) and daily weight gain (DWG) among the treatments, suggesting that the inclusion of millet offal up to 100% level does not adversely affect growth performance. This is in contrast to the findings of Sudik *et al.* (2024), who reported significant differences in total weight gain in rabbits fed diets with varying levels of soybean curd residue. The discrepancy could be due to differences in the nutritional composition of millet offal compared to soybean curd residue, with the latter potentially offering a more balanced nutrient profile that supports growth more effectively. Significant differences in daily feed intake (DFI) were observed, particularly at higher levels of millet offal inclusion (T₄, T₅), where feed intake increased. This finding is similar to Igwebuike *et al.* (2010), who reported variations in daily feed intake with graded levels of millet bran, suggesting that higher fiber content can stimulate feed intake. However, Okocha *et al.* (2024) found no significant differences in daily feed intake with increasing levels of rice husk, indicating that not all high-fiber feed ingredients have the same impact on feed intake. The significant variation in daily feed intake observed in the present study may also be attributed to the physiological state and the different breeds of rabbits used, which is consistent with the observations of Ayandiran and Adekunle (2023) regarding differences in daily feed intake among rabbits fed various high-fiber diets.

The feed conversion ratio (FCR) varied significantly across treatments, with the best FCR observed in the control group and a worsening trend with higher levels of millet offal inclusion. This suggests that while rabbits may consume more feed with higher fiber diets, their efficiency in converting feed to body mass decreases, likely due to the lower digestibility of the fibrous components. This finding is in agreement with Abubakar *et al.* (2023), who observed similar variations in FCR when feeding maize milling residue to grower rabbits, as well as with Ogunsiye *et al.* (2014), who reported a decline in FCR with increasing levels of sorghum offal in rabbit diets. These results highlight the potential trade-offs between feed intake and feed efficiency in diets with high fiber content.

Carcass Characteristics of Grower Rabbit Fed Graded Levels of Millet Offal (MO) Diets as Replacement for Maize Offal

The non-significant variation observed in the carcass characteristics of grower rabbits fed millet offal as a replacement aligns with the findings of Umar *et al.* (2021). They reported no significant differences in most parameters measured, except for the lungs, when weaner

rabbits were fed palm kernel cake (PKC) as a replacement for wheat offal. The dressing percentage in the current study falls within the range of 43.24% to 53.83% recorded by Umar *et al.* (2021), though it is lower than the 55.35% to 57.35% reported by Nuamah *et al.* (2019). However, these findings contrast with those of Mafimidiwo *et al.* (2024), who observed significant differences in carcass weight and internal organs when feeding grower rabbits with urea-molasses treated maize cob as a replacement for wheat offal.

The variation in final weight gain and large intestine weight observed in this study could be attributed to factors such as nutritional plane, age, breed, and the general health conditions of the experimental animals (Nuamah *et al.*, 2019). They emphasize that nutrition, age, sex, environmental factors, stage of development, and efficiency of feed utilization significantly affect carcass quality. The live weight across the different millet offal inclusion levels (0-100%) in the current study ranged from 1217.00g to 1219.00g, showing significant differences ($p < 0.05$). Comparatively, Hilarious & Johnson (2012) reported a range of 810.00g to 1814.50g across different levels of millet offal, while Okocha *et al.* (2024) found final live weights between 1728.08g and 2270.16g when feeding rabbit's rice husk. Anongo *et al.* (2024) reported a range of 1389.00g to 1717.00g when using rice by-products. The live weight values in the current study are relatively lower than those reported by Okocha *et al.* (2024) and Anongo *et al.* (2023), but similar to the lower range reported by Hilarious & Johnson (2012). This suggests that millet offal, when used as a sole dietary component at high inclusion levels, may not support growth as effectively as other by-products like rice husk or rice bran.

Carcass weight in the current study varied slightly from 514.70g to 569.33g, with dressing percentages ranging from 42.28% to 46.71%. In contrast, Hilarious & Johnson (2012) reported carcass weights between 798.95g and 854.65g, with dressing percentages from 48.15% to 50.98%. Okocha *et al.* (2024) noted carcass weights ranging from 825.49g to 1123.09g and dressing percentages between 47.17% and 51.77%. Anongo *et al.* (2023) reported a dressing percentage range of 60.51% to 65.55%. The current study's carcass weight and dressing percentage are generally lower than those in previous studies, indicating that while millet offal supports growth to some extent; it may not be as efficient in producing high carcass yields compared to other dietary components like rice by-products or sorghum offal.

Significant variations were observed in the large intestine across treatments in the current study, with weights ranging from 7.89% to 8.15% of body weight. Other organ weights, including the liver, kidney, and heart, showed no significant differences. Hilarious & Johnson reported varying organ weights with significant differences in the lung, pelt, and head weights. Okocha *et al.* found significant differences in liver and kidney weights across treatments with rice husk, while Anongo *et al.* reported differences in organ weights, particularly in the heart, liver, and pancreas, across different rice by-product treatments. The current study's findings align with previous studies in terms of significant variations in specific organs, though the specific organs affected differ. This variability could be due to differences in the nutrient composition of the by-products and their effects on organ

development. The significant impact on the large intestine in the current study might indicate specific dietary effects of millet offal on gastrointestinal development.

No significant differences were noted in carcass cuts such as the leg, pelt, kidney, liver, heart, lung, and tail weights in the current study. This contrasts with Hilarious & Johnson, who observed differences in the thigh, shoulder, and ribs, as well as Okocha *et al.*, who found significant variations in the thigh, shoulder, and loin. Anongo *et al.* reported differences in the head, neck, ribs, and forelimbs. The lack of significant differences in carcass cuts in the current study suggests that millet offal may not influence carcass composition as strongly as other by-products like rice husk or sorghum offal. This could be due to differences in protein content, fiber levels, or energy availability in millet offal compared to other by-products.

Haematological Parameters of Grower Rabbits Fed Graded Levels for Millet Offal (MO) Diets as Replacement for Maize Offal

Packed Cell Volume (PCV) represents the percentage of red blood cells (RBCs) in whole blood, reflecting the blood's oxygen-carrying capacity. In this study, PCV values ranged from 39.00% in T₂ to 41.55% in T₃, which are within the typical reference range for rabbits (33%-50%) as noted by Marshall (2008). The consistent PCV values across treatments suggest that millet offal inclusion does not significantly impact hematocrit levels, thereby indicating stable RBC volume and oxygen-carrying capacity. This finding is further supported by Wafar *et al.* (2019), who reported similar results when feeding weaner rabbits different legume haulms supplemented with concentrate.

The current study's findings on PCV are consistent with those reported by Hilarious & Johnson, who also observed no significant variation in PCV among rabbits, fed millet offal-based diets. However, in contrast, Ogunsipe *et al.* (2014) observed significant differences in PCV when rabbits were fed sorghum offal-based diets, with higher offal inclusion levels leading to a reduction in PCV. This discrepancy suggests that while millet offal may not significantly impact PCV, other types of offal, such as sorghum, might have different effects on this parameter.

Red Blood Cell (RBC) count is crucial for oxygen transport, with values in this study ranging from $5.17 \times 10^6/\mu\text{L}$ in T₁ to $7.07 \times 10^6/\mu\text{L}$ in T₂. These values fall within the standard range of 5 to $8 \times 10^6/\mu\text{L}$ for rabbits (Leineweber, 2018). The higher RBC counts in T₂ suggest that millet offal might support higher erythropoiesis in this group, although since other groups have RBC values closer to the lower end of the range, this variation might reflect individual physiological responses rather than a consistent dietary effect. This aligns with the findings of Awoyomi *et al.* (2022), who also reported variations in RBC counts that could be attributed to individual differences rather than dietary impacts.

The current study's RBC count findings align with those of Hilarious & Johnson, who also found no significant variations in RBC count with millet offal-based diets. However, Ogunsipe *et al.* (2014) reported significant differences in RBC count with varying levels of

sorghum offal, where higher levels resulted in a decrease in RBC count. This difference may be due to the varying nutritional compositions of millet and sorghum offal, which could differentially affect erythropoiesis in rabbits.

White Blood Cell (WBC) count, which is crucial for immune function, ranged from $2.52 \times 10^3/\mu\text{L}$ in T₂ to $5.63 \times 10^3/\mu\text{L}$ in T₁. The normal WBC range for rabbits is between 5 and $12 \times 10^3/\mu\text{L}$ (Marshall, 2008). The low WBC count in T₂ suggests potential immunosuppression or a lower immune response, possibly due to dietary factors or environmental stressors. In contrast, T₁ falls within the normal range, indicating that lower levels of millet offal support a healthier immune profile.

Significant differences in WBC count were observed in the current study, with the highest count in T₁ (10% millet offal) and a significant reduction at 25% millet offal inclusion (T₂), followed by an increase at higher inclusion levels. This trend differs from the findings of Hilarious & Johnson, who observed a consistent increase in WBC count with higher levels of millet offal. Similarly, Ogunsipe *et al.* (2014) reported a reduction in WBC count at higher levels of sorghum offal inclusion. The varying trends in WBC count suggest that different offal types and their inclusion levels can modulate immune responses in rabbits in distinct ways.

Hemoglobin (HGB) levels ranged from 11.15 g/dL in T₂ to 11.75 g/dL in T₄, which are within the normal range of 10-17 g/dL for rabbits (Leineweber, 2018). This indicates that millet offal does not adversely affect hemoglobin levels, ensuring adequate oxygen transport across all treatment groups. Mean Corpuscular Hemoglobin (MCH), which measures the average hemoglobin content per RBC, varied from 21.15 pg in T₂ to 22.45 pg in T₄, consistent with the normal range of 17-23 pg (Leineweber, 2018). This suggests that millet offal maintains normal hemoglobin content per RBC.

The current study found significant differences in MCH, particularly between the lower and higher inclusion levels of millet offal. This is consistent with the findings of Hilarious & Johnson, who reported that higher millet offal levels led to increased MCH values. In contrast, Ogunsipe *et al.* (2014) found no significant differences in MCH when rabbits were fed sorghum offal-based diets. This suggests that millet offal may influence hemoglobin content per RBC more than other offal types, such as sorghum, potentially due to differences in the micronutrient content of the offal.

Mean Corpuscular Hemoglobin Concentration (MCHC), which measures hemoglobin concentration within RBCs, ranged from 27.45% in T₅ to 29.00% in T₁. The standard range for MCHC in rabbits is 30-36% (Marshall, 2008). The slightly lower values across all treatments might indicate mild anemia or a deficiency in hemoglobin concentration per cell, possibly due to millet offal affecting hemoglobin synthesis or stability. Mean Corpuscular Volume (MCV), which measures the average size of RBCs, ranged from 73.00 fL in T₂ to 79.65 fL in T₅, within the normal range of 60-80 fL (Leineweber, 2018). This indicates that the size of RBCs is maintained within the standard range, suggesting that millet offal does not significantly affect RBC morphology.

Both MCHC and MCV showed no significant differences in the current study, which aligns with the findings of Hilarious & Johnson for millet offal-based diets. Ogunsipe *et al.* (2014) also reported no significant changes in MCHC but did find significant differences in MCV, particularly a reduction at higher levels of sorghum offal. The lack of variation in MCV in the current study suggests that millet offal does not significantly affect cell size, whereas sorghum offal may have a more pronounced effect.

Conclusion

The study examined the growth performance, carcass characteristics, and hematological parameters of grower rabbits fed diets containing graded levels of millet offal (MO) as a replacement for maize offal. The final weight, total weight gain (TWG), and daily weight gain (DWG) did not significantly differ across treatments, indicating that millet offal can replace maize offal without negatively affecting growth. Feed conversion ratio (FCR) and daily feed intake (DFI) showed variation, with T₂ (25%) having the best FCR and lower DFI, suggesting improved feed efficiency at this level of millet offal inclusion.

Carcass characteristics, particularly live weight, dressing percentage, and carcass weight, improved with higher inclusion levels of millet offal, particularly at 100% replacement (T₅). The increase in liver weight and dressing percentage in T₅ also suggests better utilization of the diet. Hematological parameters remained within normal ranges, indicating no adverse effects on rabbit health due to millet offal inclusion.

Recommendations

- i. Millet offal is a suitable alternative to maize offal in regions where maize is less available or more expensive. Farmers can confidently use millet offals in the diets of growing rabbits up to 100% without negatively affecting the growth or health of their rabbits.
- ii. There should be awareness on the importance of rabbits meat in order to increase the protein per capita consumption from 4.5-35 g, recommended by FAO (2013)

Study's Limitations:

1. **Sample Size and Representation:** The relatively small sample size of 30 rabbits may limit the generalizability of the results. The study only includes mixed mongrel rabbits of different sexes, which may not represent other breeds or genetic variations that could influence the growth performance and carcass traits.
2. **Duration of the Study:** The study duration of six weeks might be insufficient to capture long-term effects of millet offal (MO) replacement in the diet, particularly with respect to growth trends and potential health impacts on the rabbits. Longer feeding trials could provide more insight into the sustainability of such diets.
3. **Limited Carcass and Hematological Parameters:** While the study includes several important parameters like PCV, RBC, WBC, and HGB, other critical health or

performance indicators (e.g., immune response, nutrient digestibility, or organ health beyond the heart, liver, and kidney) were not measured. This limits the holistic assessment of the dietary treatments.

4. **Sex-Related Differences:** Although both sexes were used, the study does not analyze growth performance, carcass, or hematological parameters separately by sex. The differences in metabolism and growth rates between male and female rabbits could influence the results.
5. **Environmental and Management Factors:** The study does not account for possible environmental factors (such as temperature, housing, and feed quality) that could affect the rabbits' performance. Standardizing and reporting these conditions could improve the reproducibility of the results.

Directions for Future Research:

1. **Larger and More Diverse Sample:** Future studies should involve a larger sample size and possibly include different breeds to determine whether the findings are applicable to a broader population of rabbits.
2. **Longer-Term Feeding Trials:** Extending the study duration beyond six weeks could provide a better understanding of the long-term effects of millet offal on rabbit growth performance, health, and reproduction. This would also help in assessing the impact of dietary replacement over multiple growth phases.
3. **Sex-Specific Analysis:** Further research should focus on investigating sex-specific responses to diets containing millet offal. This could help determine whether male or female rabbits respond differently to varying levels of millet offal replacement, leading to tailored dietary recommendations.
4. **Nutritional Profiling:** Future studies should conduct a comprehensive analysis of the nutrient profile of millet offal, especially in terms of amino acids, fiber, and anti-nutritional factors, to better understand its nutritional value compared to maize offal.
5. **Incorporation of Additional Health Parameters:** Future research should include more detailed health assessments, such as the impact of diets on immune function, blood biochemistry, and nutrient absorption efficiency, to evaluate the overall impact of millet offal as a dietary replacement.
6. **Environmental Influence:** Future studies could investigate the role of environmental factors (housing conditions, climate) in modifying the effect of dietary changes, ensuring that any observed differences in performance are truly diet-related.
7. **Economic Feasibility:** It would be beneficial to include an economic analysis in future research, evaluating the cost-effectiveness of using millet offal as a feed ingredient compared to maize offal, which could have practical implications for rabbit producers.

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