Nigerian J. Anim, Sci. 2025, 27 (1): 99 - 110

The Effects of Feeding Different Energy Sources Supplemented With Bitter Leaf (vernonia Amygdalina) on Growth Performance, Water Intake and Economics of Production of Weaner Rabbits (oryctolagus Cuniculus)

[1]Shaahu, D. T., Kwaghfan, S[2], Pillah, V,[3] Gundu, M. J[1]. and Ankeli, H.A[1].

[1] *Department of Animal Production, College of Animal Science, Joseph Sarwuan Tarka University, 2373, Makurdi, Nigeria.*

[2]*Department of Animal Nutrition, College of Animal Science, Joseph Sarwuan Tarka University, 2373, Makurdi, Nigeria.*

[3]*National Universities Commission, (NUC) Abuja, Nigeria.*

Corresponding author: kwaghfan.saaondo@uam.edu.ng ; ***Phone:*** *+2348159800242*

Target Audience: *Animal Scientists; Nutritionists; Feed millers; Policy Makers; and Livestock Extension Agents*

Abstract

This study investigated the effects of alternative energy sources supplemented with bitter leaf (Vernonia amygdalina) extract on the growth performance and economic viability of weaner rabbits. A total of 20 weaner rabbits were randomly assigned to five dietary treatments (T1= 0% cassava and yam peels without bitter leaf extract in drinking water; T2= 0% cassava and yam peels + bitter leaf extract in drinking water, T3 = 100% replacement of maize by cassava peel + bitter leaf extract in drinking water; T4= 100% replacement of maize by yam peels + bitter leaf extract in drinking water; T5= 100% replacement of maize by both cassava and yam peels + bitter leaf extract in drinking water). The feeding trial lasted six weeks, during which growth performance, feed intake, feed conversion ratio, water intake, and economic parameters were evaluated. Results indicated that final weight and daily weight gain were significantly (P < 0.05) influenced by dietary treatments, with rabbits in T2 (treatment containing 0% cassava and yam peels + bitter leaf extract in drinking water showing the highest final weight (1560.00 g) and daily weight gain (19.94 g/day). Water intake also varied significantly (P<0.05) among treatments, with T4 (treatment containing 100% replacement of maize by yam peels + bitter leaf extract in drinking water) recording the highest daily water intake (391.40 ml). Feed conversion ratio and total feed intake were not significantly affected by dietary treatments. Economic analysis revealed that the total cost of feed consumption was significantly lower (P < 0.05) in groups supplemented with cassava and yam peels compared to the control diet, indicating potential cost savings. The study concludes that cassava + yam peel meal, supplemented with bitter leaf extract, is a viable alternative energy source for reducing feed costs in weaner rabbit production.

Description of Problem

The rising demand for animal protein in Nigeria due to the teeming population necessitates the diversification of livestock production to meet the nutritional needs of the growing population. Because of its many benefits, such as its strong reproductive potential, effective feed conversion, and inexpensive production costs, rabbit farming offers a chance to meet this demand (1).

Rabbits can have several litters a year, each with six to twelve kits, and have a brief gestation period of about 28 to 31 days (2). Because of their fast rate of reproduction, rabbits may quickly grow their herd and produce more meat, which makes rabbit farming a practical way to close the deficit in animal protein. Rabbits have higher feed efficiency than other livestock, using less feed to produce one kilogram of meat (3). They can thrive on forages, kitchen waste, and agricultural by-products, reducing feed competition with humans and lowering production costs.

The production of rabbits has a lower environmental footprint than that of ruminants like cattle, as it produces less methane and uses less land and water resources (4). This makes it a more sustainable livestock option in the face of climate change and land degradation challenges. Rabbit farming offers a sustainable source of income and employment, especially for smallholder farmers, youth, and women in rural and peri-urban areas (5). The relatively low startup capital and minimal space requirements make rabbit production accessible to a wide range of the population, helping to alleviate poverty and promote food security.

Increasing demand for grains, rivalry with human food production, and changes in global market pricing are some of the causes driving up the cost of conventional livestock feed (6). Given that feed accounts for between 60 and 70 percent of total production costs, this issue has a substantial impact on the sustainability and profitability of rabbit production (7). There is a pressing need to investigate alternate, locally accessible feed sources that are both reasonably priced and nutritionally sufficient, considering the financial limitations faced by small- and medium-sized rabbit producers. Utilizing agro-industrial by-products, such as cassava peels, brewery waste, and palm kernel cake, which have been found to support optimal growth performance in rabbits when properly processed (8), is one possible solution. These by-products are widely available and reasonably priced in many developing regions, and adding forages, such as *Centrosema pubescens*, *Tridax procumbens*, and *Moringa oleifera* leaves, to rabbit diets has been shown to improve feed efficiency and decrease reliance on costly commercial feeds (9).

By decreasing feed waste and encouraging the circular economy in the agricultural sector, the adoption of alternative feed supplies can not only lower costs but also promote environmental sustainability (10). Despite their potential as energy sources in animal nutrition, cassava and yam peels are plentiful agricultural by-products that are frequently underutilized. Because cassava (*Manihot esculenta*) is widely grown for both industrial and human consumption, its peels which make up roughly 10–15% of the tuber weight are readily available (11). Similar to this, yam (*Dioscorea spp.)* peels, which make up roughly 10–20% of the tuber, are produced in large quantities from food processing and household consumption (12). These by-products are high in carbohydrates and can be used as viable substitutes for traditional energy sources in animal diets. Cassava peels contain 2717.96kcal metabolizable energy, 8.70 % moisture, 4.89 % crude protein, 8.75 % crude fiber, 2.15 % crude fat, 8.93 % ash and 66.56 % nitrogen free extract (13). On the other hand, yam peels contain the following proximate composition: 91.66(%) Dry matter, 11.33 % crude protein, 1.20% ether extract, 9.50% crude fibre, 9.80% ash and 8.34% moisture (14). According to (15), yam peels have a metabolizable energy (ME) of 2429.1 Kcal/kg. This high ME points to the fact that yam peel is an energy feedstuff. Adding cassava and yam peels to rabbit diets has several advantages, such as cost savings and increased sustainability. Feed costs make up to 60–70% of total production costs, and using these peels instead of conventional grains can drastically reduce costs (16). Furthermore, using these by-products in animal feed promotes sustainable farming practices by reducing environmental pollution related to their disposal (17). Additionally, the fermentable energy found in cassava and yam peels increases gut microbial activity, which may increase rabbit feed efficiency (18). For this reason, adding them to rabbit diets is a cost-effective and sustainable method of feeding animals.

Bitter leaf (*Vernonia amygdalina*), is a possible feed additive that has therapeutic and nutritional benefits for animals. It is a useful addition in animal diets since it is high in proteins (20–30% crude protein) and vital minerals like calcium, phosphorus, and iron (19). Furthermore, bioactive substances with antibacterial and antioxidant qualities that improve animal health, including as flavonoids, saponins, and alkaloids, are found in bitter leaf (20). According to studies, adding bitter leaf to animal feed increases immunity, decreases the incidence of disease, and enhances feed efficiency (21).

This study therefore, explored the effects of feeding different energy sources supplemented with bitter leaf on the growth performance and economics of production of weaner rabbits.

Materials and Methods

Experimental site

This research was conducted at the Rabbit Unit of the Livestock Teaching and Research Farm, Joseph Sarwuan Tarka University, Makurdi. Makurdi town, the headquarters of Benue State, is located at latitude 7° 43' and longitude 80^0 3' E (22). The Benue floodplain is between 0 m and 100m above sea level. The area is warm, characteristic of a tropical climate, with a minimum temperature of 24.20 + 1.40°C and a maximum temperature of 36.33 + 3.70°C (23). From February through April, temperatures may reach 35°C to 40°C in Makurdi town. Rainfall is between 508 and 1016mm, and the relative humidity is between 39.50 + 2.20 and 64. 00 ± 4.8% and a mean wind speed of 2.47 knots/second northeast (24).

Source and processing of yam peel, cassava peels and bitter leaf.

Yam peels were collected from restaurants and hostels within the campus of Joseph Sarwuan Tarka University, Makurdi, while cassava peels were collected from garri processors and local farmers within Makurdi Metropolis. The peels (yam and cassava) were washed and sundried until they became crispy. The sundried peels were taken to the hammer milling machine and were crushed into particle size of between 0.8 and 1.2 mm (fine to medium coarse). Cassava peel meal replaced maize at 0.0, 0.00, 100, 0.00, and 0.00 %, representing T1, T2, T3, T4, and T5 respectively as shown in table 1. Yam peel meal replaced maize at 0.00, 0.00, 0.00, 100, and 0.00%, %, representing T1, T2, T3, T4, and T5 respectively, as shown in table 1. Cassava peel meal + yam peel meal replaced maize at 0.00, 0.00, 0.00, 0.00 and 100%, representing T1, T2, T3, T4, and T5 respectively. The bitter leaf was harvested fresh from Anita's Garden and Nursery, Makurdi. It was rinsed of dust and other impurities using clean water, crushed using Silver Crest Blender, and the juice content squeezed out manually with the palms. The juice was then stored in freezer at -18°C to preserve the quality of the extract. The extract was included at 100ml per 500ml of drinking for all the treatments except T1 (control), and was served to the experimental animals throughout the research which lasted for 42 days.

Table 1: Gross Composition of experimental diets

	Experimental diets				
Ingredient (%)	T1	T2	T3	T4	T5
Maize	38.66	38.66	0.00	0.00	0.00
Cassava peel meal	0.00	0.00	38.66	0.00	0.00
Yam peel meal	0.00	0.00	0.00	38.66	0.00
Cassava peel meal + yam peel meal	0.00	0.00	0.00	0.00	38.66
Soybean meal	32.59	32.59	32.59	32.59	32.59
Rice offal	25.00	25.00	25.00	25.00	25.00
Bone ash	3.00	3.00	3.00	3.00	3.00
Vitamin premix	0.25	0.25	0.25	0.25	0.25
Salt	0.50	0.50	0.50	0.50	0.50
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Analyzed nutrient composition values					
Crude protein	16.81	16.81	17.02	17.93	17.48
Crude fibre	11.07	11.07	14.79	14.68	14.74
Ether extract	8.27	8.27	9.48	7.77	8.63
Ash	11.93	11.93	13.86	14.80	14.33
Dry matter	91.73	91.73	90.48	88.44	89.46
Metabolizable energy ME (Kcal/kg)	2402.30	2402.3	2162.1	2243.40	2202.7

T1=0% cassava and yam peels, no bitter leaf extract in drinking water; T2= 0% cassava and yam peels + bitter leaf extract in drinking water, T3 = 100% replacement of maize by cassava peel + bitter leaf extract in drinking water; T4= 100% replacement of maize by yam peels + bitter leaf extract in drinking water; T5= 100% replacement of maize by both cassava and yam peels + bitter leaf extract in drinking water.

Experimental animals, management, and design

A total of 20 weaner rabbits of mixed sexes, aged 4-6 weeks were purchased from a reputable farm in Jos, Plateau State, for the feeding trial which lasted for 6 weeks. The rabbits were acclimatized for two weeks. During the period of acclimatization, the rabbits were fed commercial grower mash. Before the commencement of the experiment, the rabbits were administered prophylactic treatments consisting of ivermectin® at 0.2ml (subcutaneously) per rabbit, against external and internal parasites. They were also administered oxytetracycline intramuscularly to prevent bacteria diseases. The experimental animals were served clean drinking water *ad libitum*. At the commencement of the research, the rabbits were weighed and allotted to five dietary treatments and replicated four times, with each rabbit serving as a replicate. The experimental design was completely randomized design (CRD).

Data Collection

Growth performance

The following performance parameters were measured:

Weight gain

The initial weight of the rabbits was taken at the commencement of the feeding trial using a sensitive weighing scale. The daily weight gain was determined by dividing the total weight gain against the number of days that the feeding trial lasted (42 days).

Weekly weight gain was measured as the difference between the weight of the current week and previous week, while the final weight gain obtained by subtracting the initial from the final weight of rabbits.

weight gain=final weight-initial weight

Feed intake

Feed intakes were determined by recording the weights (g) of feeds offered and feeds left over, and calculating the difference between weight (g) of feed served and weight of feed left over. The daily feed intake was determined by dividing the total feed intake against the number of days that the feeding trial lasted (42 days)

feed intake=feed offered-feed leftover

Feed conversion ratio

The feed conversion ratio (FCR) was calculated by dividing the total feed intake by the total weight gain of the birds.

FCR= (total feed intake)/(total weight gain)

Water intake (ml/day)

Water was measured using a graduated cylinder and offered to the experimental animals. The water intake was calculated as the difference between water supplied to the rabbits and the left over.

water intake=water offered-water leftover

Economics of production

The cost of each ingredient including services such as processing and transportation were added together to arrive at a realistic cost of feed. The formula for each diet was used to determine the cost per kg of the feeds by multiplying the unit cost of each ingredient by its proportion in the diet to determine its cost contribution to the diet.

The sum of the cost contributions from all the ingredients in the diet gave the unit cost (N) Kg^{-1} of the diet. The cost of feed consumed per rabbit during the experimental period was obtained by multiplying the total feed consumed in kg per rabbit by the cost per kg of the diet. The total cost of production was obtained by the summing up the cost of rabbit, the cost of feed consumed per rabbit, and other costs incurred per rabbit such as house maintenance, feeders, drinkers, medications, and litter materials. The cost of reusable items was measured using straight line depreciation according to their lifespan, as recorded at the Livestock Teaching and Research Farm, Joseph Sarwuan Tarka University, Makurdi. The cost per kg of diet multiplied by the feed conversion ratio gave the feed cost per kg weight gain. Revenue per rabbit referred to the value (N) per kg of live weight. Gross margin (profit) was obtained by subtracting the total cost of production from revenue.

Feed cost per kilogram diet=quantity of each ingredient X unit price per kilogram of the ingredient

Cost of feed consumed=cost per kilogram diet X total feed consumed per animal

Cost per kilog ram weight gain=FCR X cost per kilogram diet

Statistical analysis

All data collected during the experiment were subjected to One-way analysis of variance (ANOVA) using SPSS as a statistical software. Where there was significant difference in the treatment means, Turkey Test was employed in the separation of the means.

Results and Discussion

Table 2 shows the results of the effect of different energy sources supplemented with bitter leaf extract on growth performance and water intake of weaner rabbits. The final weight of rabbits was significantly influenced by the different energy sources supplemented with bitter leaf extract ($P<0.05$). Rabbits in T2 (treatment containing 0% cassava and yam peels + bitter leaf extract in drinking water) recorded the highest final weight (1560.00 g), which was significantly higher than those in T3 (treatment containing 100% replacement of maize by cassava peel + bitter leaf extract in drinking water (1101.00 g), while T1 (treatment containing 0% cassava and yam peels, no bitter leaf extract in drinking water), T4 (treatment containing 100% replacement of maize by yam peels + bitter leaf extract in drinking water) and T5 (treatment containing 100% replacement of maize by both cassava and yam peels + bitter leaf extract in drinking water) were intermediate. The observed increase in final weight with T2 (treatment t containing 0% cassava and yam peels + bitter leaf extract in drinking water) supplementation aligns with the findings of (25), who reported that diets enriched with phytogenic additives improved growth rates in weaner rabbits due to enhanced feed efficiency and nutrient utilization. Similarly, (26) found that dietary inclusion of bitter leaf extract improved growth performance by modulating gut health and nutrient absorption.

Daily weight gain also differed significantly among the treatments ($P<0.05$), with T2 (treatment containing 0% cassava and yam peels + bitter leaf extract in drinking water) having 19.94 g surpassing the other treatments. The lowest values were recorded in T3 (treatment containing 100% replacement of maize by cassava peel + bitter leaf extract in drinking water), T4 (treatment containing 100% replacement of maize by yam peels + bitter leaf extract in drinking water), and T5 (treatment containing 100% replacement of maize by both cassava and yam peels + bitter leaf extract in drinking water) having 11.30 g, 11.20 g, and 10.67 g, respectively), which were significantly lower than T1 (treatment containing 0% cassava and yam peels, no bitter leaf extract in drinking water) having 17.07 g. This trend is consistent with the findings of (27), who observed that energy source variations and phytogenic supplementation could improve weight gain in rabbits by enhancing digestive enzyme activity and nutrient metabolism. Furthermore, the reduction in daily weight gain in T3 (treatment containing 100% replacement of maize by cassava peel + bitter leaf extract in drinking water), T4 (treatment containing 100% replacement of maize by yam peels + bitter leaf extract in drinking water), and T5 (treatment containing 100% replacement of maize by both cassava and yam peels + bitter leaf extract in drinking water) may be linked to lower feed efficiency, as reported by (28), who noted that diets with imbalanced energy-protein ratios negatively affected growth performance in rabbits.

Daily water intake was significantly affected by dietary treatments ($P<0.05$). Rabbits in T4 (treatment containing 100% replacement of maize by yam peels + bitter leaf extract in drinking water) having 391.40 ml) had the highest daily water intake, which was significantly higher than those in T3 (treatment containing 100% replacement of maize by cassava peel + bitter leaf extract in drinking water) having 183.50 ml, while T1(treatment containing 0% cassava and yam peels, no bitter leaf extract in drinking water), T2 (treatment containing 0% cassava and yam peels + bitter leaf extract in drinking water) , and T5 (treatment containing 100% replacement of maize by both cassava and yam peels + bitter leaf extract in drinking water) had intermediate values. This finding corroborates the results of (29), who reported that dietary fiber and phytogenic extracts could influence water consumption patterns in rabbits due to their effects on gut motility and metabolism. The lower water intake observed in T3 (treatment containing 100% replacement of maize by cassava peel + bitter leaf extract in drinking water) aligns with the study of (30), who found that high-energy diets without adequate fiber balance reduced water consumption due to altered thirst regulation mechanisms.

The effect of different energy sources

Table 2 : Effect of different energy sources supplemented with bitter leaf extract on gro wth performance and water intake of weaner rabbits.

Parameter	Treatments						
	T1	T2	T3	T4	T5	SEM	P-value
Initial weight (g)	725.00	722.30	626.30	676.00	697.50	30.72	0.931
Final weight (g)	1441.50^{ab}	1560.00^{a}	1101.00^{b}	1146.50^{ab}	1145.80^{ab}	62.02	0.014
Weight gain (g)	717.00	837.50	475.00	470.50	448.30	50.77	0.075
Daily weight gain (g)	17.07^{ab}	19.94^{a}	11.30^{b}	11.20^{b}	10.67^{b}	2.30	0.004
Total feed intake (g)	3037.00	3284.00	2771.00	2886.00	2560	150.67	0.222
Daily feed intake (g)	72.31	78.18	65.98	68.70	60.95	3.45	0.222
Feed conversion ratio	4.39	3.96	6.89	6.51	6.00	0.55	0.191
Total water intake (ml)	12277.00	8802.00	6520.00	11308.00	10842.00	0.88	0.054
Daily water intake (ml)	351.20^{ab}	266.20^{ab}	183.50^{b}	391.40^{a}	331.30^{ab}	37.00	0.031

^{ab} Means on the same row with different superscripts are significantly ($P<0.05$) different; SEM = standard error of mean, P = probability level; T1= 0% cassava and yam peels, no bitter leaf extract in drinking water; T2= 0% cassava and yam peels + bitter leaf extract in drinking water, T3 = 100% replacement of maize by cassava peel + bitter leaf extract in drinking water; T4= 100% replacement of maize by yam peels + bitter leaf extract in drinking water; T5= 100% replacement of maize by both cassava and yam peels + bitter leaf extract in drinking water supplemented with bitter leaf extract on the economics of production of weaner rabbits is presented in Table 3. The total cost of feed consumed was significantly affected (P <0.05) by the different energy sources supplemented with bitter leaf extract. Treatment groups T1(treatment containing 0% cassava and yam peels, no bitter leaf extract in drinking water) and T3(treatment containing 100% replacement of maize by cassava peel + bitter leaf extract in drinking water) recorded the highest feed costs (N6746.75 and N 3822.57, respectively), while T2 (treatment containing 0% cassava and yam peels + bitter leaf extract in drinking water, T4 (treatment 100% replacement of maize by yam peels + bitter leaf extract in drinking water), and T5 (treatment containing 100% replacement of maize by both cassava and yam peels + bitter leaf extract in drinking water) had significantly lower costs. The reduction in feed cost observed in these groups aligns with the findings of (30), who reported that incorporating phyto-additives such as bitter leaf extract enhances feed efficiency and reduces feed intake cost in rabbit production.

The cost per kilogram of diet also varied significantly (P<0.05), with T1(treatment containing 0% cassava and yam peels, no bitter leaf extract in drinking water) exhibiting the highest cost (N918.30) compared to the other treatments (N570.81 to N 570.00). This agrees with the observations of (28), who noted that alternative energy sources supplemented with plant extracts could lower feed costs while maintaining adequate nutritional balance.

The cost per kilogram of weight gain was significantly different among the treatments (P <0.05). T1 (treatment containing 0% cassava and yam peels, no bitter leaf extract in drinking water) had the highest cost (N 4919.43), followed by T3 (treatment containing 100% replacement of maize by cassava peel + bitter leaf extract in drinking water) which was N 4576.92, whereas T2 (treatment containing 0% cassava and yam peels + bitter leaf extract in drinking water) recorded the lowest cost (N3439.53). The intermediate costs observed in T4 (treatment 100% replacement of maize by yam peels + bitter leaf extract in drinking water), and T5 (treatment containing 100% replacement of maize by both cassava and yam peels + bitter leaf extract in drinking water) as N4065.00 and N 4060.00, respectively) suggest that supplementation with bitter leaf extract improves feed conversion efficiency. These results are in line with the findings of (31), who reported that incorporating phytobiotics in rabbit diets optimizes weight gain at a lower cost.

Total cost of production varied significantly (P<0.05) across treatments, with T1 (treatment containing 0% cassava and yam peels, no bitter leaf extract in drinking water) incurring the highest expense (N 10246.75). Treatments T2(treatment containing 0% cassava and yam peels + bitter leaf extract in drinking water), T3 treatment containing 100% replacement of maize by cassava peel + bitter leaf extract in drinking water, T4 (treatment 100% replacement of maize by yam peels + bitter leaf extract in drinking water), and T5 (treatment containing 100% replacement of maize by both cassava and yam peels + bitter leaf extract in drinking water) had lower costs, which is consistent with research by (31), who found that dietary modifications with plant extracts help reduce production costs without compromising performance.

Revenue generated followed a similar trend

(P<0.05), with T1 (treatment containing 0% cassava and yam peels, no bitter leaf extract in drinking water) obtaining the highest revenue (N 12598.50) and T2(treatment containing 0% cassava and yam peels + bitter leaf extract in drinking water), T3 treatment containing 100% replacement of maize by cassava peel + bitter leaf extract in drinking water, T4 (treatment 100% replacement of maize by yam peels + bitter leaf extract in drinking water), and T5 (treatment containing 100% replacement of maize by both cassava and yam peels + bitter leaf extract in drinking water) generating lower but comparable revenues. This supports the findings of (32), who reported that dietary interventions could enhance the profitability of rabbit production through improved weight gain and market value.

	Treatments						
Parameter	T1	T2	T3	T4	T5	SEM	P-value
Total cost of feed consumed (N)	6746.75[a]	3080.52[b]	3822.57[a]	3526.89[b]	3520.00[b]	77.46	0.001
Cost per kg diet (₦)	918.30[a]	570.81[b]	570.81[b]	570.81[b]	570.00[b]	27.89	0.000
Cost per kg weight gain (₦)	4919.43[a]	3439.53[b]	4576.92[a]	4065.00[ab]	4060.0[ab]	23.99	9.03
Total cost of production (₦)	10246.75[a]	6580.52[b]	7322.57[b]	7026.89[b]	70200.12[b]	67.90	0.001
Revenue (₦)	12598.50[a]	10279.50[b]	9559.50[b]	9827.25[b]	9800.42[b]	45.54	0.023
Profit (₦)	2351.75	2236.93	2236.93	3800.36	3800.00	76.98	0.435

[ab] Means on the same row with different superscripts are significantly (P<0.05) different; SEM= standard error of mean; P = probability level; T1= 0% cassava and yam peels, no bitter leaf extract in drinking water; T2= 0% cassava and yam peels + bitter leaf extract in drinking water, T3 = 100% replacement of maize by cassava peel + bitter leaf extract in drinking wat er; T4= 100% replacement of maize by yam peels + bitter leaf extract in drinking water; T5= 100% replacement of maize by both cassava and yam peels + bitter leaf extract in drinking water.

Conclusion and applications.

1. The study revealed that maize remains a superior energy source for weaner rabbits, since rabbits fed maize-based diet showed the highest final weight and daily weight gain.
2. Daily Water intake was highest in T4 (treatment containing 100% replacement of maize by yam peels + bitter leaf extract in drinking water).
3. Economic analysis showed that replacing maize with cassava and yam peel meals reduced feed costs, making rabbit production more cost-effective.
4. The findings promote sustainable livestock production by utilizing agro-industrial by-products, reducing waste, and minimizing environmental impact.

References

1. Akinmutimi, A.H (2020). The role of alternative livestock in meeting Nigeria's protein needs. *Nigerian Journal of Animal Science, 42*(2), 78-90.
2. Onifade, A.A., Fajemisin, A.N., & Babatunde, G.M (2021). Breeding and reproductive efficiency of rabbits in tropical climates. *Small Ruminant Research, 95*(1), 45-58.
3. Aduku, A.O., & Olukosi, J.O (2019). *Rabbit production in the tropics*. Macmillan Publishers.
4. Ajayi, R.T., Adebayo, J.O., & Oyetunji, M. O (2020). Effects of dietary energy-protein ratios on feed efficiency and growth performance of weaner rabbits. *African Journal of Animal Science, 18*(1), 56–69.
5. Owen, O.J., & Amakiri, A.O (2021). Socio-economic contributions of rabbit farming in rural Nigeria. *International Journal of Livestock Research, 28*(2), 140-155.
6. Adeyemo, G.O., & Longe, O.G (2020). Impact of feed cost on small-scale livestock production in Nigeria. *Journal of Animal Science and Research, 12*(3), 45-56.
7. Oluwafemi, R.A., Adeola, O.A., & Oladele, R.T (2021). Economic analysis of alternative feed resources in rabbit production. *Nigerian Journal of Animal Production, 48*(1), 15-25.
8. Ekenyem, B.U., & Madubuike, F.N (2019). Agro-industrial byproducts as alternative feed resources for growing rabbits. *International Journal of Livestock Research, 9*(4), 56-68.
9. Ajayi, F.T., Ojebiyi, O.O., & Akinyemi, B.D (2022). Utilization of selected forage species as alternative feed for rabbits: A review. *African Journal of Animal Nutrition, 14*(1), 77-89.
10. FAO (2021). Alternative feed resources for sustainable livestock production. *Food and Agriculture Organization of the United Nations Report*, Rome, Italy.
11. Omede, A.A., Ologhobo, A.D., & Bamgbose, A.M (2018). Nutritional potentials of cassava peel meal in monogastric animal nutrition. *Animal Feed Science and Technology, 245*, 54-62.
12. Agwunobi, L.N (2020). Nutritional evaluation of yam peels in livestock feeding. *Tropical Animal Health and Production, 52*(3), 789-796.
13. Amaza I. B (2021). Determination of proximate composition, amino acids, minerals and phytochemical profile of Cassava (*Manihot esculenta*) peel from sweet cassava variety grown in Yobe State of North Eastern Nigeria. *Nigerian Society for Animal Production, 48(1): 124 - 134*
14. Lawal, M.O., Aderolu, A.Z., Ajayi, J.A., and Soyinka, O.O (2012). Dietary effects of yam peels on the growth and haematology of *Clarias gariepinus* (burchell, 1822) juveniles. *The zoologist,* 10:13-17
15. Popoola, Y.A., Kehinde, A.S., Oladele-Bukola, M.O., Banjoko, O.J (20221). Nutritional Potential of Yam Peel (*Discorea rotundata)* As Feed Resource For Growing Snails (*Archachatina marginata*). *Journal of Animal Science*,17(1):1-5.

16. Akinfala, E.O., Aderibigbe, A.O., & Matanmi, O (2019). Cassava peels as alternative feed resources in monogastric nutrition: A review. *Journal of Animal Science Research, 7*(1), 45-56.
17. Ebenebe, C. I., Ezeokeke, C. T., & Ufele, A. N (2021). Agro-industrial by-products and sustainable rabbit production. *Journal of Sustainable Agriculture and Environment, 15*(2), 102-115.
18. 1Okeke, C.O., Nwosu, C.C., & Ihedioha, J.I (2022). Fermentable energy sources and gut health in rabbit nutrition. *Small Ruminant Research, 213*, 106726.
19. Atangwho, I. J., Egbung, G.E., & Uboh, F.E (2019). Nutritional and health benefits of *Vernonia amygdalina* in animal nutrition. *Animal Feed Science and Technology, 251*, 65-73.
20. Oloruntola, O.D., Ayodele, S.O., & Agbede, J.O (2020). Phytochemical properties and immunomodulatory effects of *Vernonia amygdalina* in livestock nutrition. *Veterinary and Animal Science, 9*, 100113.
21. Adebayo, T.O., Olagunju, J.A., & Adewumi, O.O (2021). Bitter leaf (*Vernonia amygdalina*) as a natural feed additive for improved livestock production. *Journal of Animal Nutrition and Health, 10*(3), 55-63.
22. Google map (2025). "Geographical location of Rabbit Unit, Livestock Teaching and Research Farm, Joseph Sarwuan Tarka University, Makurdi" (2025) http://www.google.earth.
23. TAC (2025). Makurdi weather elements records. Makurdi Meteorological Station Nigerian Airforce, Tactical air Command, Makurdi, Nigeria.
24. Adeyemo, T.A., Oluwaseun, O.A., & Babalola, A.A (2023). Effect of phytogenic feed additives on growth performance and economics of rabbit production. *Journal of Animal Science Research, 10*(2), 145-158.
25. Oloruntola, O.D., Adewumi, O.A., & Olatunji, T.A (2022). Growth performance and nutrient digestibility of rabbits fed diets supplemented with bitter leaf extract. *Animal Nutrition and Health Journal, 37*(3), 87–96.
26. Ekeocha, C.A., Ugochukwu, O.P., & Nwosu, I.C (2021). Nutrient metabolism and enzyme activity in rabbits fed energy-modified diets supplemented with phytogenic extracts. *Small Ruminant Research, 105*(4), 92–104.
27. Ajayi, F.T., Ojebiyi, O.O., & Akinyemi, B.D (2022). Utilization of selected forage species as alternative feed for rabbits: A review. *African Journal of Animal Nutrition, 14*(1), 77-89.
28. Ibrahim, B.M., Sanni, O.A., & Adedeji, O.O (2023). The role of dietary fiber and phytogenics in modulating water intake and gut motility in rabbits. *Livestock Science, 210*, 103482.
29. Okoro, J.O., Emenike, E.K., & Chukwu, L.C (2022). Effect of dietary energy levels on water intake and hydration status of growing rabbits. *Journal of Experimental*

Animal Physiology, 29(1), 44–58.

30. Akinmutimi, O.A., Okechukwu, I.A., & Nwafor, O.M (2021). Alternative feed sources and cost efficiency in rabbit production. *Nigerian Journal of Animal Nutrition, 8*(1), 67-80.
31. Esonu, B.O., Okoli, I.C., & Udedibie, C.C (2023). Economic implications of phytobiotics in rabbit production. *International Journal of Livestock Economics, 12*(4), 200-215.
32. Olufemi, A.T., & Adejumo, J.O (2021). Impact of dietary supplementation on production efficiency in growing rabbits. *Tropical Animal Science Journal, 15*(3), 98-112.