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REGULAR ARTICLES

Growth performance and nutrient digestibility of growing rabbits fed diets containing pawpaw (*Carica papaya L.*) leaf protein concentrate

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Abstract

This experiment was carried out to evaluate the growth performance and nutrient digestibility of growing rabbits fed diets containing pawpaw (*Carica papaya* L.) leaf protein concentrate as partial replacement for soybean meal (SBM). Five dietary treatments were formulated such that SBM was replaced with pawpaw leaf protein concentrate (PLPC) at 0, 15, 30, 45, and 60% weight-for-weight. Twenty-five composite growing rabbits of mixed sex and approximately seven weeks of age (736±90 g) were randomly allocated to five dietary treatments of five replicates in a completely randomized design. The rabbits had access to water and the experimental feed *ad libitum* for 12 weeks of feeding trial after one week of adaptation. Results showed that the growth performance and nutrient digestibility of rabbits recorded in this experiment were not significantly affected ($p>0.05$) by the replacement of SBM with PLPC, indicating that PLPC can be used to replace soybean meal up to 60% weight-for-weight without causing any adverse effect on the growth performance and nutrient digestibility of rabbits. The average water-to-feed ratio was 2.54, indicating that rabbit under this condition of experiment requires an average of 2.54 mL of water for every 1 g of feed consumed. The flesh-to-bone ratio of rabbits recorded in this study was between 3.06±0.36 and 3.22±0.22. Rabbits on diets in which 60% SBM was replaced with PLPC resulted in the highest savings in terms of cost differential (₦90.94/kg); therefore, it is cheaper for farmers to replace SBM with PLPC at 60% weight-for-weight in rabbit feeding in Nigeria.

Keywords Growth performance, Nutrient digestibility, Pawpaw leaf protein concentrate · Rabbit · Soybean meal

Introduction

With increasing human population in developing countries, there is competition between man and livestock for available food and feed resources. In recent years, people involved in rabbit production are faced with high cost of feeding (Wafar et al., 2017), possibly because of high cost of conventional feedstuffs, such as soybean meal (SBM), for commercial rabbit production in Nigeria. Apart from feed items accounting for up to 75% of total cost of production of livestock, the protein fraction of the major (basal) ingredients is one of the highest contributing factors to the rising animal feed cost in Nigeria (Nwokoro, 2015). Hence, it has become necessary to explore unconventional feed resources in livestock feeding to reduce the overall cost of production. To optimize food production and meet protein requirements in Nigeria, viable options need to be explored and evaluated (Jiya et al., 2013). The increasing cost and decreasing supply of conventional feed stuffs, especially protein sources, are expected to limit the future expansion of livestock and feed industry (FAO, 2012). Leaf protein concentrates (LPC) have proven to be a viable alternative protein source. Their crude protein value ranged between 20 and 49.15% (Olomu, 2011; Aletor & Adebayo, 2012; Sodamade et al., 2013; Agbonghae & Nwokoro, 2019; Nwokoro et al., 2022). The method of obtaining LPC from leaves (Nwokoro, 2015; Pirie, 1987) may be adopted locally, and the leaf fractionation process can enhance crude protein and gross energy by 34.8 and 22%, respectively (Agbede et al., 2008). Rubber leaf protein concentrate has been used to replace soybean meal (SBM) at 30% weight-for-weight in the diet of growing rabbit (Akaeze et al., 2014). During 2008–2010, India was the leading pawpaw producer with a 38.61% share of the

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world production, followed by Brazil (17.5%), Indonesia (6.89%), and then Nigeria, which is ranked fourth with 6.7% production (FAOSTAT, 2012).

To meet the animal protein requirements of West African populations, emphasis has been placed on the production and health of short cycle animals (Gbangboché et al., 2005) such as rabbit (*Oryctolagus cuniculus*). Orheruata (2014) reported that the manipulation of rabbit through feeding will not only result in the production of more meat at cheaper cost but also make more meat available within a given time to meet the demand of people. It is hypothesized that PLPC can replace SBM at 60% weight-for-weight without causing negative effects on growth performance and nutrient digestibility, and it will be cheaper to partially replace SBM with PLPC in rabbit feeding in Nigeria. Therefore, the objective of this study was to determine the growth performance and nutrient digestibility of growing rabbits fed diets containing pawpaw leaf protein concentrate as partial replacement for soybean meal.

Materials and methods

Experimental location

The experiment was carried out at the Rabbitry Unit of Teaching and Research Farms, University of Benin, Benin City, Nigeria, which is located on Latitude 6°24′17″N and Longitude 5°36′39″E (Google Earth, 2022). Benin is a rain forest zone, with an average temperature of 27.6 °C, annual rainfall of 2162 mm, relative humidity of 72.5%, and daily sunshine of 6.68 h (NAA, 2014).

Production of pawpaw leaf protein concentrate

Pawpaw leaf protein concentrate (PLPC) was produced following the methods of Pirie (1987) and Sayyed (2011) with little modifications. Pawpaw leaves were harvested fresh between October and November (at the beginning of dry season) from Benin City, Edo State, Nigeria. They were rinsed and ground with a grinding machine. The resultant pawpaw slurry was sieved and pressed to obtain pawpaw juice and bagasse. The juice was heated to 80–90 °C to coagulate the leaf protein. Thereafter, the protein curd was filtered with a muslin bag and pressed to separate the leaf whey from the curd. The leaf protein concentrate was sun-dried, milled using a laboratory hammer mill (Dietz, Dettingen-Teck, West Germany), and then kept in an airtight container prior to feed formulation and feeding trial. The flow chart of the fractionation process is shown in Fig. 1.

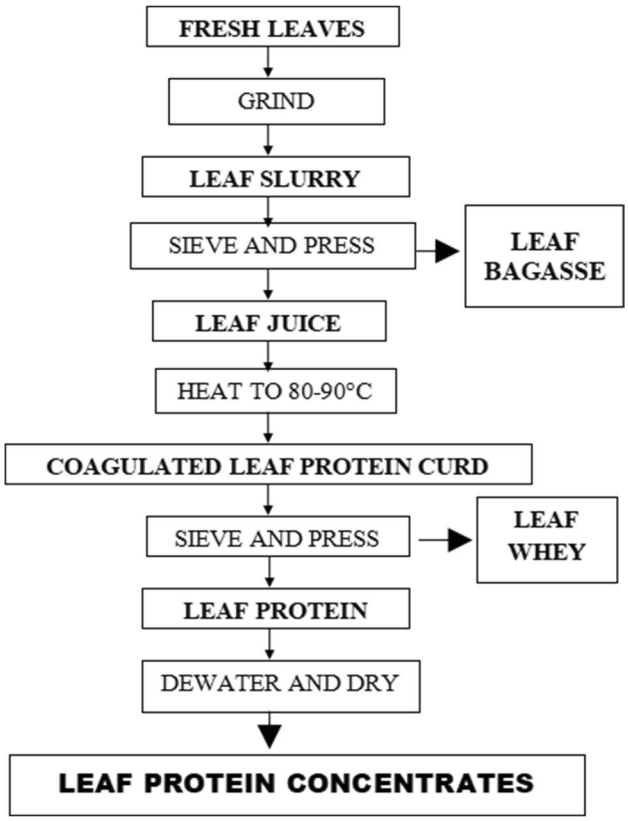

Fig. 1 Flow chart of the production of pawpaw leaf protein concentrate

Animal management and experimental design

Twenty-five composite growing rabbits of mixed sex and approximately seven weeks of age (736±90 g) were purchased from Aduwawa livestock market in Benin City. Rabbits on arrival to the experimental location were subjected to prophylactic treatments for stress. Hutches and equipment were washed and disinfected before the commencement of the experiment, and the rabbits were acclimatized for one week. Hutches with dimension 105 × 85 × 60 cm were placed inside a dwarf-walled house with wire mesh at the upper part for sufficient ventilation and covered roofing sheets. The base of the hutches was made of wire mesh for easy evacuation of feces and urine. The rabbits were randomly assigned to five dietary treatments with five replicates in a completely randomized design, such that each animal served as an experimental unit. Water and the experimental feeds (Table 1) were offered to the rabbits *ad libitum* for 12 weeks. The rabbits were raised under natural ambient temperature and light, and daily routine management procedures were followed to ensure a good hygienic environment throughout the experiment.

Table 1 Composition of experimental diets fed to growing rabbits

Ingredients	Percentage replacement of SBM with PLPC				
	0%	15%	30%	45%	60%
Maize[a]	46.00	46.00	46.00	46.00	46.00
Soybean meal[a]	20.00	17.00	14.00	11.00	8.00
PLPC	0.00	3.00	6.00	9.00	12.00
Palm kernel cake[a]	10.00	10.00	10.00	10.00	10.00
Wheat bran[a]	10.00	10.00	10.00	10.00	10.00
Brewers dried grain[a]	10.00	10.00	10.00	10.00	10.00
Bone meal	2.40	2.40	2.40	2.40	2.40
Limestone	1.00	1.00	1.00	1.00	1.00
Common salt (NaCl)	0.35	0.35	0.35	0.35	0.35
Premix*	0.25	0.25	0.25	0.25	0.25
TOTAL	100.00	100.00	100.00	100.00	100.00
DIET COMPOSITION:					
Crude protein (%)	19.39	19.13	18.87	18.61	18.35
Crude fiber (%)	5.43	5.38	5.34	5.29	5.25
Crude fat (%)	3.95	4.03	4.11	4.18	4.26
Ash (%)	3.37	3.40	3.42	3.45	3.47
Metabolizable energy (Kcal/kg)	2661.04	2680.15	2699.26	2718.37	2737.48

SBM, Soybean meal; PLPC, Pawpaw Leaf Protein Concentrate

The nutrient composition and metabolizable energy contents of each feed ingredients were used to calculation the diet composition. Ingredients with superscript ([a]) had nutrient composition and energy values documented by Olomu (2011). Nutrient composition of PLPC was determined according to AOAC (2016), and the metabolizable energy was estimated according to Adeyeye and Omolayo (2011)

(*) composition of vitamin-mineral premix per kg of diets – Vit A, 5000ui; Vit D_3, 800iu; Vit E, 12 mg; Vit B_6, 1.5 mg; Pantothemic acid, 5 mg; Biotin, 0.02; Vit B12, 0.01 mg; Folic acid, 0.3 mg; Choline Chloride, 150 mg; Manganese, 60 mg; Iron, 10 mg; Zinc, 15 mg; Copper, 0.8 mg; Iodine, 0.4 mg; Cobalt, 0.08 mg; Selenium, 0.04 mg; Anti-oxidant, 40 mg

Economy of feed conversion

The economy of feed conversion of the experimental rabbits was determined using economic parameters such as feed cost, cost of feed consumed, cost conversion ratio, and cost differential from the prevailing prices of ingredients/feed (October 2021) within the experimental period (Ogunsipe et al., 2011).

- Feed cost (₦) = cost of formulating 1 kg of dietary treatment
- Cost of feed consumed (₦/kg) = feed cost (₦/kg) x average feed intake (kg)
- Cost conversion ratio (CCR) = cost of feed consumed (₦kg) / weight gain (kg)
- Cost differential (CD) = CCR of dietary treatments – CCR of 0% treatment

Statistical analysis

Data collected from the experiment were subjected to analysis of variance at 5% ($p<0.05$) level of significance using the Computer Statistical Package GenStat (2009) 12th edition for windows.

Results

Growth performance

The growth performance parameters of growing rabbits fed diets containing PLPC as partial replacement for soybean meal are presented in Table 2. The growth performance indices, such as feed intake, weight gain, feed conversion ratio, and protein efficiency ratio, recorded in this study were not significantly ($p>0.05$) affected by the dietary treatments. The average daily feed intake and weight gain obtained were 66.75–74.50 g and 9.38–9.97 g, respectively. Feed conversion ratio was between 7.21 and 7.66, indicating that an average of 7.45 g of feed was consumed to gain 1 g of weight. Water-to-feed ratio ranged from 2.15 to 3.05, with an average of 2.54, indicating that the rabbits required an average of 2.54 mL of water for every 1g of feed consumed under the condition of this study. The flesh to bone ratio of the rabbits, which was between 3.06 and 3.22, did not show any significant difference ($p>0.05$) among the treatments.

Table 2 Effects of pawpaw leaf protein concentrate (PLPC) as partial replacement for soybean meal on growth performance of growing rabbits

Parameter	TREATMENT (% replacement of soybean meal with PLPC)					SEM
	1 (0 %)	2 (15 %)	3 (30 %)	4 (45 %)	5 (60 %)	
Initial weight (g/rabbit)	744±31.5	744±129.7	725±89	744±124.8	725±79.1	48.80
Final weight (g/rabbit)	1569±97	1531±192	1525±221	1575±275	1562±116	95.90
Weight gain (g/rabbit/12weeks)	825±89	788±171.4	800±132.3	831±153.3	838±149.3	70.90
Daily weight gain (g/rabbit/day)	9.82±1.06	9.38±2.04	9.53±1.58	9.90±1.82	9.97±1.78	0.84
Feed intake (g/rabbit/day)	70.25±1.71	66.75±8.54	72.25±7.81	73.00±12.88	74.50±5.26	4.08
Feed conversion ratio (FCR)	7.21±0.66	7.28±1.16	7.66±0.88	7.44±0.62	7.66±1.47	0.51
Protein intake (g/rabbit/day)	13.63±0.33	12.75±1.63	13.66±1.48	13.58±2.40	13.64±0.96	0.76
Protein efficiency ratio (PER)	0.720±0.07	0.736±0.14	0.697±0.08	0.73±0.07	0.73±0.14	0.05
Water intake (mL/rabbit/day)	214±66.10	194±22.40	170±12.40	162±77.60	159±86.80	30.50
Water-to-feed ratio/rabbit	3.05±0.95	2.95±0.49	2.37±0.24	2.15±0.76	2.17±1.27	0.41
Feed-to-bone ratio/rabbit	3.22±0.22	3.20±0.25	3.17±0.34	3.06±0.36	3.20±0.16	0.12

SEM – Standard error of the means, PLPC – Pawpaw leaf protein concentrates

Table 3 Effects of pawpaw leaf protein concentrate (PLPC) as partial replacement for soybean meal on nutrient digestibility of growing rabbits

Parameter	TREATMENT (% replacement of soybean meal with PLPC)					SEM
	1 (0 %)	2 (15 %)	3 (30 %)	4 (45 %)	5 (60 %)	
Dry matter digestibility	0.745±0.09	0.733±0.08	0.777±0.11	0.765±0.06	0.775±0.07	0.042
Crude protein digestibility	0.793±0.05	0.805±0.04	0.803±0.04	0.808±0.81	0.817±0.82	0.019
Crude fiber digestibility	0.682±0.05	0.690±0.03	0.700±0.07	0.710±0.07	0.715±0.08	0.031
Ether Extract digestibility	0.603±0.07	0.605±0.07	0.657±0.07	0.693±0.04	0.645±0.10	0.036
Ash digestibility	0.640±0.08	0.662±0.05	0.657±0.05	0.650±0.05	0.688±0.03	0.027
NFE digestibility	0.768±0.04	0.787±0.05	0.782±0.05	0.785±0.04	0.777±0.06	0.025

SEM – Standard error of the means, NFE – Nitrogen free extract, PLPC – Pawpaw leaf protein concentrate

Table 4 Economy of feed conversion of rabbit fed diets containing pawpaw leaf protein concentrate (PLPC) as replacement for soybean meal

Parameter	TREATMENT (% replacement of soybean meal with PLPC)				
	1(0%)	2 (15%)	3 (30%)	4 (45%)	5 (60%)
Feed consumed (kg/rabbit/12weeks)	5.90	5.61	6.07	6.13	6.26
Weight gain (kg/rabbit/12weeks)	0.83	0.79	0.80	0.83	0.84
Feed cost (₦/kg)	216.61	211.06	205.51	199.96	194.41
Cost of feed consumed (₦/rabbit/12weeks)	1278.00	1184.05	1247.45	1225.76	1217.01
Cost Conversion Ratio	1539.76	1498.79	1559.31	1476.81	1448.82
Cost differential (₦)	-	40.96	-19.55	62.94	90.94

Calculations were based on the price (₦) of feed ingredients as of October, 2021

Nutrient digestibility

Results of the nutrient digestibility of growing rabbits fed diets containing PLPC as partial replacement for soybean meal are presented in Table 3. There was no significant difference ($p>0.05$) in all the nutrient digestibility determined, indicating that the replacement of SBM with PLPC did not have any significant influence on the nutrient digestibility of the rabbits under the conditions of this study. The crude protein digestibility coefficient obtained in this study was between 0.793 and 0.817.

Economy of feed conversion

Results of the economy of feed conversion of rabbits fed diets containing pawpaw leaf protein concentrates (PLPC) as replacement for soybean meal are presented in Table 4. In 2021, the cost of producing 1 kg of PLPC (₦195.00/kg) was lower than the cost of procuring 1 kg of soyabean meal (₦380.00/kg). Feed cost decreased as PLPC inclusion level increased. The cost of feed consumed for 12 weeks by rabbits on 60% PLPC diet (₦1217.01) was lower than

that consumed by rabbits on 0% PLPC diet (₦1278.00). A negative cost differential was recorded for rabbits on 30% PLPC diet. Rabbits on 60% PLPC diet had the highest cost differential per kg feed (₦90.94/kg).

Discussion

Growth performance

The growth performance indices recorded in this study indicate that PLPC can be used to replace SBM at 60% weight-for-weight without having any deleterious effect on the rabbits. Similar trend was observed in Akaeze et al. (2014) in which rubber leaf protein concentrate was used to replace SBM at 30% weight-for-weight. Water intake decreased as the replacement level of SBM with PLPC increased, because animals tend to consume more water with increasing crude protein. Moreover, the crude protein in SMB (48.5%) is higher than that in PLPC (39.5%) (Agbonghae & Nwokoro, 2019). The average water-to-feed ratio was generally lower than the 3.14 reported by Eberhart (1980) probably because of differences in rabbit strain. The flesh-to-bone ratio ((4.33 and 5.34) reported by Dal Bosco et al. (2000) was higher than the values obtained in this study, possibly because of genetic and environmental differences.

Nutrient digestibility

The crude protein digestibility (0.817±0.82) of rabbit fed diet containing 60% PLPC as a replacement for SBM was lower than the crude protein digestibility reported by Yao Konan et al. (2016) for rabbits fed leafy vegetable at 0–50% replacement of commercial pellets in Côte d'Ivoire; however, in the western part of Nigeria, Ayo-Ajasa et al. (2017) reported a lower crude protein digestibility for rabbits fed *moringa* leaf meal at 0–4.5% inclusion levels. These variation in crude protein digestibility could be due to differences in feed compositions and other environmental factors. Rabbits have the ability to digest high fiber diets than typical monogastric animals because of their hind gut. The values of crude fiber digestibility (0.682±0.05–0.715±0.08) obtained in this study were higher than the values reported by several authors in Africa (Abu Hafsa et al., 2016; Adam, 2013; Adamu et al., 2011; Ogunsipe et al., 2014). Ether extract indicate the crude fat in diets, and the digestibility values obtained in this study are comparable with the values reported by Wafar et al. (2017) and Abdullahi et al. (2017). Overall, PLPC can replace SBM up to 60% without having any significant reduction effect on nutrient digestibility of rabbits.

Economy of feed conversion

Economic indices revealed that the cost of formulated feed (₦/kg) and cost of feed consumed (₦kg) decreased as the inclusion level of PLPC increased. These were expected because in 2021, the cost of producing 1kg of PLPC (₦195.00/kg) was lower than the cost of procuring 1 kg of soybean meal (₦380.00/kg); hence, the cost of feed and cost of feed consumed by rabbits decreased as the replacement level increased. Cost conversion ratio indicates the cost of feed required for a rabbit to gain 1 kg weight. Feed containing 60% PLPC as partial replacement for SBM in rabbit feeding recorded the lowest cost conversion ratio, indicating that less money was spent on feed for rabbit to gain 1 kg weight compared to other dietary treatments. Cost differential explains the extra amount of money spent or saved when SBM is replaced with PLPC in the diet of growing rabbits; the result showed that ₦90.94 was save when 60% SBM was replaced with PLPC. Therefore, for economic purposes, SBM should be replaced with PLPC at 60% weight-for-weight under the conditions of this study.

Conclusion

The demand for meat has been on the increase owing to the need to increase animal protein in diet. Pawpaw leaf protein concentrate is an alternative source of protein in rabbit feeding. Results showed that the replacement of soybean meal with pawpaw leaf protein concentrate at up to 60% weight-for-weight did not have significant influence on growth performance and nutrient digestibility. An extra cost of ₦90.94 was saved for feeding rabbits when 60% SBM was replaced with PLPC. Under this condition of study, PLPC can be used to replace soybean meal in the diet of rabbit without having any deleterious effect on growth performance and nutrient digestibility.

Author contribution All authors contributed to the study conception and design, material preparation, data collection, and analysis. First draft of the manuscript was written by Agbonghae Osagie Wisdom. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability The datasets generated during and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

Declarations

Ethics approval This study is part of an MSc research study in the Department of Animal Science, Faculty of Agriculture, University of Benin. The study was carried out in the research farm of the Faculty of Agriculture; no ethical approval was required for this study.

Competing interests The authors declare no competing interests.

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