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REGULAR ARTICLES

Performance of weaner rabbits fed a concentrate diet supplemented with pawpaw leaves

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Abstract This experiment investigated the performance of weaner rabbits fed concentrate diets supplemented with pawpaw leaves (PPL). Twenty-four male weaner rabbits aged 5 weeks, weighing between 350 and 450 g were used. Concentrate diet was supplemented with PPL in ratios 100:0, 70:30, 50:50 and 30:70. Rabbits were randomly allotted to the four diets in a completely randomised design for 8 weeks, with six rabbits per diet. Results showed that rabbits supplemented with 30 and 50 % PPL had higher ($P<0.05$) dry matter intake to sole concentrate. At 70 % PPL, dry matter intake did not vary with other treatments. Weight gain was higher ($P<0.05$) in rabbits fed 30 and 50 % PPL than sole concentrate. Rabbits fed 70 % PPL had lower ($P<0.05$) weight gain to animals fed 30 % PPL but gained similarly ($P>0.05$) to those fed on 50 % PPL and sole concentrate. Feed conversion ratio improved ($P<0.05$) in animals fed 30, 50 and 70 % PPL. Rabbits fed 30 % PPL had the highest ($P<0.05$) protein efficiency ratio. Rabbits had higher dry matter digestibility ($P<0.05$) with PPL supplementation than sole concentrate while crude protein and fibre digestibility was higher with 30 and 50 % PPL. Haematological and serum parameters in rabbits were unaltered with feeding PPL. It is concluded that weaner rabbits can utilise PPL as supplement to concentrate diet at 30 to 70 % dry matter with positive responses in performance and nutrient digestibility without deleterious effect on the physiological status of the rabbits.

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Introduction

In rabbit production, feed accounts for about 70 % of total costs if commercial feeds are used (Ramchurn and Dullull 2001), and raising rabbits solely on concentrate diets is rarely economically viable. Rabbits are pseudoruminants, and their potential to utilise forages can be exploited in production systems.

The use of forages in rabbit feeding is normal practise, and rabbit producers are advised to feed nutritious and palatable forages as supplement to a basal concentrate diet to meet the fibre and some vitamin requirements, and to reduce cost of concentrates in the ration to achieve a compromise between level of production and cost that is acceptable to producers (Iyeghe-Erakpotobor and Muhammed 2008).

The relative preference of different forages to rabbits and their utilisation have been studied (Osakwe and Ekwe 2007; Medugu et al. 2012; Safwat et al. 2014) with reports (Aderinola et al. 2009; Abubakar et al. 2011) of varying animal responses at different levels of supplementation depending on forage type. Few of these forages however, have been widely adopted for rabbit feeding. The predominant forage that has gained intense use as rabbit feed is *Tridax procumbens*, while several others subsist which could serve as potential feed resources. With the high cost of conventional concentrate feeds it becomes imperative to increase the range of forages utilised in rabbit feeding systems.

Pawpaw (*Carica papaya L.*) belongs to the fruits and vegetable class, and it is an invaluable plant that is prevalent throughout tropical Africa (Nwofia et al. 2012). Pawpaw

leaves are rich in proteins with reported crude protein values ranging between 23.9 and 33.3 % (Omole et al. 2004; Babalola and Akinsoyinu 2010; Kalio and Etela 2011), and they could be particularly suitable for small holder rabbit production. Pawpaw leaves have also been reported to contain some biologically active compounds, one of which is papain, which aids in digestion (Barger et al. 2009; Ikeyi et al. 2013; Macalood et al. 2013). In spite of the value of pawpaw leaves as good protein source, it has not been extensively investigated as supplemental feed for rabbits. The main purpose of this study therefore, was to evaluate the performance, nutrient digestibility and haematological status of weaner rabbits fed varying levels of pawpaw leaves as supplement to concentrate diet with a view of ascertaining an optimum dietary level for improved rabbit performance.

Materials and methods

Location of study area

The study was carried out at the rabbit unit of the Teaching and Research Farm, Federal University of Agriculture Abeokuta, Nigeria, West (7°15′N, 3°21′ E, altitude 76 m). Mean annual temperature and humidity are 34.7 °C and 82 %, respectively.

Experimental diets

A concentrate mixture consisting of maize, wheat offal, soya bean meal, groundnut cake, fishmeal, bone meal, oyster shell, common salt and mineral/vitamin premix was compounded and was fed alongside with pawpaw leaves in four different ratios of 100:0, 70:30, 50:50 and 30:70, respectively. Pawpaw leaves were harvested fresh and left to wilt overnight for feeding the following day. The concentrate diet and pawpaw leaves were offered to the rabbits in separate feeding troughs. A total of 200 g of feed dry matter was offered to each rabbit daily to ensure ad libitum feeding. Aliquots of the concentrate diet and pawpaw leaves were collected, weighed and oven-dried for dry matter determination. The proximate compositions of the concentrate diet and pawpaw leaves are shown in Tables 1 and 2

Animals and management

Twenty-four weaner male rabbits aged 5 weeks and weighing between 350 and 450 g were used. On arrival at the rabbit unit, the rabbits were administered with antibiotics (tetracycline) orally and dewormed with antihelminthics (piperazine). Initial weights of the rabbits were recorded; after which, they were randomly divided into four groups of six animals each with each group assigned to one of the four experimental diets. The rabbits were housed individually in 60×60×50-cm dimension of wooden hutches with wire screen floors attached underneath with trays which provided facilities for separate collection of faeces and urine. The hutches were thoroughly disinfected before stocking. Each hutch was provided with two concrete feeders and a drinker. The house was designed to ensure cross ventilation and exclusion of rodents and other pests. Experimental animals were fed ad libitum, and clean water was adequately provided throughout the experimental period of 8 weeks which included a 14-day initial adjustment period.

Feed intake and weight gain measurements

During the 8-week experiment, quantities of feeds offered to individual rabbits and quantities of refusals were measured daily to compute feed intake. The initial weights of individual rabbits were measured at the commencement of the trial; and thereafter, individual weekly weights were taken. Feed conversion ratio was calculated by dividing the quantity of the feed intake (g/day) by weight gain (g/day) in animals. Protein efficiency was calculated by dividing the weight gain (g/day) in animals by the protein intake (g/day).

Digestibility measurement

Faecal samples were collected from rabbits in each treatment during the last week of the feeding trial. During the 7-day collection period, total faeces voided were collected and weighed daily. Faeces (about 5 %) was sub-sampled, dried at 60 °C to constant weight, bulked by animal and stored for analysis. Apparent digestion coefficients were calculated using the formula given by Khan et al. (2003) for total collection technique.

Blood sampling

On the last day of the feeding trial, blood samples were collected from each animal for determination of haematological and biochemical indices. Blood samples were collected by venipuncture from the neck slit of the rabbits. Blood samples for determination of haematological parameters were collected into sample bottles containing ethylene-diamine-tetraacetic acid (EDTA). Samples for biochemical indices such as serum glucose, serum protein, serum calcium and phosphorus were collected in plain test tubes. The plain test tubes and their contents were allowed to stand for about 2 hours at room temperature, centrifuged at 1000×g for 10 min and the serum harvested for analysis.

Table 1 Ingredient composition (g/kg), proximate composition (g/kg DM) and metabolisable energy content (Kcal/kg DM) of concentrate diet and pawpaw leaves fed to weaner rabbits

Ingredient	Composition in 1 kg concentrate diet	
Maize	350	
Wheat offal	530	
Soya bean meal	50	
Groundnut cake meal	30	
Fish meal	20	
Bone meal	10	
Oyster shell	6	
Salt	2	
Mineral/vitamin premix[a]	2	
Total	1000	
Proximate and energy composition[b]:		Pawpaw leaves
Dry matter[c]	904.0	326.1
Crude protein	164.8	221.0
Crude fibre	51.0	103.0
Ether extract	34.8	8.0
Ash	66.5	85.0
Nitrogen free extract	682.9	583.0
Metabolizable energy[d]	3316	3535

[a] Composition of premix in 1 kg of diet: 120 IU vit. A, 400 g vit. E, 30 mg vit. K_2, 30 mg vit. B_1, 80 mg vit. B_2, 60 mg vit. B_6, 3 mg vit. B_{12}, 400 mg niacin, 120 mg pantothenic acid, 10 mg folic acid, 1 mg biotin, 1 mg antioxidant, 3000 mg choline chloride, 800 mg Mn, 400 mg Fe, 600 mg Zn, 3 mg Co, 10 mg I and 2 mg Se

[b] Mean of 3 values (df=*2*)

[c] Determined based on fresh matter

[d] Metabolisable energy calculated as 37×% crude protein+81×% ether extract+35.5×% nitrogen-free extract (Pauzenga 1985)

Chemical analysis

Sub-samples of the feeds offered and samples of faeces voided were analysed for proximate composition according to the official methods of A. O. A. C. (2000). The dry matter content was determined by oven-drying known weight of samples, nitrogen (*N*) was determined by Kjeldahl method and crude protein (CP) calculated as *N*×6.25. Nitrogen-free extract was determined by calculation (100% - {% EE +% CP + % Ash + % CF}). The metabolisable energy value of the diets was calculated according to Pauzenga (1985). The packed cell volume (PCV) of blood was determined by the microhaematocrit method. Haemoglobin (Hb) concentration was determined by Sahl's (acid haematin) method (Benjamin 1978). Serum glucose was determined by the glucose oxidase method as described by Bauer et al. (1974). Serum protein was determined using the biuret reaction (Bush 1975).

Table 2 Nutrient composition of the different proportions of concentrate to pawpaw leaves fed to rabbits

Composition[a]	Percentage proportion of concentrate: pawpaw leaves in the diet			
	100:0	70:30	50:50	30:70
Crude protein	164.8	181.7	192.9	204.1
Crude fibre	51.0	66.6	77.0	87.4
Ether extract	34.8	26.8	21.4	16.0
Ash	66.5	72.1	75.8	79.5
Nitrogen free extract	682.9	652.9	633.0	613.0
Metabolizable energy (Kcal/kg)[b]	3316	3382	3426	3470

[a] Nutrient composition based on calculated values

[b] Metabolisable energy calculated as 37×% crude protein+81×% ether extract+35.5×% nitrogen-free extract (Pauzenga 1985)

Statistical analysis

The experimental data were analysed as a completely randomised design according to the following linear model:

$$\gamma_{ij} = \mu + T_i + \epsilon_{ij}$$

Where μ is the population mean, T_i is the pawpaw leaves supplementation effect and ϵij is the residual error. The statistical analyses were carried out using SAS (1999).

Significant differences were accepted if $P \leq 0.05$. The differences between means were separated using Duncan multiple range test according to the procedure of SAS (1999).

Results

The daily intake of concentrate diet was lower ($P < 0.05$) while intake of pawpaw leaves was higher ($P < 0.05$) with increasing levels of pawpaw leaves supplementation in the diet (Table 3). Total dry matter consumed was between 58.6 and 66.0 g/day. Rabbits fed diets supplemented with pawpaw leaves at 30 and 50 % had higher total dry matter intake relative to those fed sole concentrate. At 70 % pawpaw leaves supplementation in the diet, dry matter intake was comparable with dry matter intake of rabbits fed sole concentrate and those fed 30 and 50 % pawpaw leaves. Total crude protein intake was higher ($P < 0.05$) in rabbits supplemented with pawpaw leaves. Crude protein intake increased ($P < 0.05$) from 9.7 g/day in rabbits fed sole concentrate diet to between 11.9 and 12.6 g/day in groups supplemented with pawpaw leaves. There was no variation ($P > 0.05$) in crude protein intake amongst rabbit groups fed pawpaw leaves. There were variations ($P < 0.05$) in the daily, weekly and total weight gain of rabbits fed sole concentrate diets and pawpaw leaves supplemented diets. Rabbits fed 30 and 50 % pawpaw leaves supplemented diet had higher ($P < 0.05$) daily weight gain relative to animals on sole concentrate diet while rabbits fed 70 % pawpaw leaves gained similarly ($P > 0.05$) to those fed sole concentrate diet. Amongst the groups fed pawpaw leaves, rabbits fed 30 % pawpaw leaves gained similarly ($P > 0.05$) to groups fed 50 % but higher ($P < 0.05$) than those fed 70 % pawpaw leaves, respectively. There was however no variation ($P > 0.05$) between groups fed 50 and 70 % pawpaw leaves supplemented diet. The weekly and total weight gain followed similar pattern to the daily weight changes. Feed conversion ratio was better ($P < 0.05$) in animals supplemented with pawpaw leaves at 30, 50 and 70 % compared with the sole concentrate diet. The best ($P < 0.05$) feed conversion ratio was observed in animals fed concentrate diet supplemented with 30 % pawpaw leaves. Similarly, protein efficiency ratio was markedly improved ($P < 0.001$) in rabbits fed diets supplemented with 30 % pawpaw leaves. .

Dry matter, crude protein and crude fibre digestibility were higher ($P < 0.05$) in rabbits fed pawpaw leaves compared with those on sole concentrate diet (Tables 4 and 5). Rabbits on diets supplemented with 30 and 50 % pawpaw leaves however, had higher ($P < 0.05$) digestibility than those on 70 % pawpaw leaves supplementation. There were no variation ($P > 0.05$) in digestibility of ash, ether extract and nitrogen free extract amongst the treatment groups.

Haematological and serum parameters (Table 5) were similar ($P > 0.05$) for rabbits on sole concentrate diet and pawpaw leaves supplemented diets. The packed cell volume ranged between 35.0 and 37.0 %, haemoglobin concentration was between 11.0 and 12.5 g/dL, red blood cell and white blood cell values were between 4.4 and 5.3 10^{12}/L and 4320 and 487510^3/L, respectively. Serum glucose values ranged from 75.0 to 80.0 mg/dL while total serum protein was between 50.0 and 57.0 g/dL. Calcium and phosphorus content was between 10.8 and 12.5 mg/dL, and 5.0 and 5.4 mg/dL, respectively.

Table 3 Performance characteristics of rabbits fed concentrate diet supplemented with pawpaw leaves

Parameter	Supplementation level (%) of pawpaw leaves in the diet				SEM
	0	30	50	70	
Concentrate dry matter intake (g/day)	58.6^{a}	45.4^{b}	35.5^{c}	21.9^{d}	0.95
Pawpaw leaves dry matter intake (g/day)	–	20.2^{c}	30.6^{b}	40.8^{a}	0.87
Total dry matter intake (g/day)	58.6^{b}	65.6^{a}	66.0^{a}	62.7^{ab}	1.07
Concentrate crude protein intake (g/day)	10.6^{a}	10.7^{a}	6.8^{b}	5.7^{c}	0.13
Pawpaw leaves crude protein intake (g/day)	–	12.6^{b}	14.4^{a}	14.8^{a}	0.28
Total crude protein intake (g/day)	9.7^{b}	11.9^{a}	12.6^{a}	12.6^{a}	0.27
Initial weight (g)	365	370	363	358	1.9
Final weight (g)	980^{c}	1245^{a}	1180^{ab}	1100^{bc}	7.2
Average weekly weight gain (g)	77^{c}	109^{a}	102^{ab}	93^{bc}	8.0
Average daily weight gain (g)	11^{c}	16^{a}	15^{ab}	13^{bc}	1.1
Feed conversion ratio	5.4^{a}	4.2^{d}	4.5^{c}	4.7^{b}	0.71
Protein efficiency ratio	1.1^{bc}	1.3^{a}	1.2^{b}	1.1^{c}	0.06

Means along the same row with different superscript letters are significantly different ($P < 0.05$)

Table 4 Nutrient digestibility in rabbits fed concentrate diet supplemented with pawpaw leaves

Digestibility (%)	Supplementation level (%) of pawpaw leaves in the diet				SEM
	0	30	50	70	
Dry matter	70.1[c]	79.2[a]	78.5[a]	73.1[b]	0.89
Crude protein	68.2[b]	78.9[a]	75.2[a]	70.1[b]	1.11
Crude fibre	72.3[b]	77.2[a]	74.6[a]	68.1[b]	1.04
Ether extract	77.0	80.1	78.9	78.3	0.63
Ash	74.2	75.7	74.2	75.4	0.67
Nitrogen free extract	73.1	72.9	70.7	69.4	0.74

Means along the same row with different superscript letters are significantly different ($P<0.05$)

Discussion

The increase in pawpaw leaves and total dry matter intake with increased supplementation of pawpaw leaves in the diet reflects the high acceptability of pawpaw leaves to the rabbits which implies that pawpaw leaves have no characteristic repulsive smell or pungent feeling and therefore, can be fed to weaner rabbits without deterrent effect on acceptability and intake. The higher dry matter intake observed in rabbits fed 30 and 50 % pawpaw leaves in the diet compared with sole concentrate could suggest an optimum inclusion level of 50 % for intake. However, the comparable dry matter intake in rabbits fed up to 70 % pawpaw leaves supplementation signifies that weaners can still be fed up to 70 % pawpaw leaves in their diet without adverse effect. Increased crude protein intake with increased pawpaw leaves supplementation was attributed to the quality of the diet in terms of higher crude protein content which was due to a high crude protein supply from pawpaw leaves. The crude protein value of pawpaw leaves obtained in this study indicates it as a rich source of protein and therefore, could serve as a good source of protein supply for weaner rabbits. Several authors (Omole et al. 2004; Onyimonyi and Onu 2009; Babalola and Akinsoyinu 2010; Kalio and Etela 2011) have reported higher crude protein values than that obtained in our study, and this could be attributed to differences in the age of the plant and soil nutrient.

The higher weight gain observed in rabbits fed 30 and 50 % pawpaw leaves in the diet compared to sole concentrate feeding and the similar gains in weight of animals on 70 % pawpaw leaves and those on sole concentrate feeding signifies the ability of weaner rabbits to utilise the leaves of pawpaw effectively for growth at up to 70 % supplementation in the diet. The better feed conversion ratio in rabbits fed 30, 50 and 70 % pawpaw leaves supplementation further confirms that the animals utilised the feed consumed efficiently to attain an appreciable weight gain relative to the animals on sole concentrate diet. The better protein efficiency ratio notably observed at 30 % pawpaw leaves supplementation reflects better protein utilisation by weaner rabbits at this level of forage supplementation. Supplementing concentrates with forages have been reported to promote better growth than sole concentrate diet (Omoikhoje et al. 2006). The reported levels at which rabbits utilise forages have been varied depending on the type of forage fed. Weaned rabbits have been reported to utilise varying levels of *Moringa oleifera* leaf meal at up to 45 % level in diets without adverse effects on growth performances (Abubakar et al. 2011). Similarly, Bello et al. (2001) reported that weaner rabbits can tolerate up to 45 % level of *Tridax procumbens* in their diet without adverse effect on their performance. When *Syndrella nodiflora* was fed to rabbits at

Table 5 Blood parameters of rabbits fed concentrate diet supplemented with pawpaw leaves

Parameters	Normal values of blood parameters in rabbits[a]	Supplementation level (%) of pawpaw leaves in diet				SEM
		0	30	50	70	
Packed cell volume (%)	34–50 %	36.8	37.0	36.5	35.0	1.00
Haemoglobin (g/dL)	10.0–17.5 g/dL	11.0	12.5	12.1	11.2	0.08
Red blood cell ($\times10^{12}$/L)	4.7–7.2 ($\times10^{12}$/L)	4.6	5.3	5.1	4.4	0.03
White blood cell ($\times10^{9}$/L)	5–12 ($\times10^{9}$/L)	7.3	7.4	7.6	7.8	1.20
Serum glucose (mg/dL)	75.7–149.5 mg/dL	76.0	80.0	78.0	75.0	1.10
Total serum protein (g/L)	28–100 (g/L)	50.0	57.0	55.0	51.0	1.02
Calcium (mg/dL)	8.8–18.4 mg/dL	10.8	12.5	12.1	11.2	1.30
Phosphorus (mg/dL)	2.8–7.4 mg/dL	5.0	5.4	5.2	5.0	0.72

Means along the same row with different superscript letters are significantly different ($P<0.05$)

[a] Flecknell (2000)

Conversion factors: packed cell volume, 1 L/L=100 %; glucose, mg/dL×0.0555=mmol/L; calcium, mg/dL×.25=mmol/L; phosphorus, mg/dL×0.323=mmol/L (McAuley 2014)

varying levels of 0, 25, 50 and 75 % (Omoikhoje et al. 2006), animals were able to utilise up to 50 % forage supplementation for increased weight gain. From our study, a particular level of pawpaw leaves supplementation optimum for increased performance could be suggested at 30 %, however, levels of up to 70 % could be suitable than sole concentrate feeding without negative implications on performance giving consideration for effective feed cost with forage feeding and the value of the final meat product. Most farmers are particular at attaining increased output with minimum input and supplementing concentrates with forages is more likely to be economical compared to sole feeding of concentrate diet.

The higher dry matter, crude protein and crude fibre digestibility observed with pawpaw leaves supplementation could be attributed to the presence of an enzyme papain in the leaves of pawpaw which possibly aided digestibility. Several authors have reported papain as a biologically active compound which aids digestive processes (Barger et al. 2009; Akah et al. 2007 and Aravind et al. 2013). Although rabbits supplemented with 70 % pawpaw leaves had comparable crude protein and crude fibre digestibility to those on sole concentrate diet, the lower digestibility observed relative to rabbits on 30 and 50 % pawpaw leaves supplementation could be an indication that higher levels of pawpaw leaves in the diet of weaner rabbits beyond 70 % may lead to reductions in digestion of feed.

The similarity in haematological and serum parameters in rabbits fed sole concentrate and pawpaw leaves supplemented diets indicates that feeding pawpaw leaves at between 30 to 70 % in the diet of weaner rabbits had no deleterious effect on the nutritional or health status of the animals and therefore, can be safely fed. The measurement of nutritional substances in blood serves as good parameters for evaluating the nutritional status of the body (Annongu and Folorunso 2003) and values obtained for blood parameters measured were within normal values reported for rabbits (Flecknell 2000).

Conclusion

Pawpaw leaves can be utilised by weaner rabbits as supplement to concentrate with positive responses in performance and nutrient digestibility without deleterious effect on the health status of the animals. Although, supplementing concentrate with 30 % pawpaw leaves gave the best feed conversion ratio and protein efficiency ratio, levels of up to 70 % could still be utilised by the animals in place of sole concentrate feeding with considerations for economical benefits in terms of possible feed cost reduction as feed conversion ratio was improved up to this level compared to sole concentrate diet.

Conflicts of interest Authors of this manuscript declare that they have no conflicts of interest.

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