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# Concentrate diets fed sole to rabbits by smallholder farmers in Greater Port Harcourt City, might not satisfy their nutrient requirements

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***Target Audience**: Feed millers, animal nutritionists, rabbit farmers, feed marketers*

## Abstract

*Nutritive value of concentrate feeds fed to rabbits by smallholder farmers in Greater Port Harcourt City (GPHC) were assessed in two of its eight Local Governments. Thirty-five rabbit farmers; 20 and 15 from Obio-Akpor and Ikwerre, respectively, were sampled, using snowballing method. Overall, five samples: three commercial poultry (D1, D2, D3), one commercial rabbit-specific (D4), and one on-farm mixed feed (D5), were collected and analyzed for proximate, fiber fractions, minerals and anti-nutritional factors contents. Descriptive statistics, one-way analysis of variance at 0.1% level of significance and Duncan Multiple Range Test in SPSS data analysis software were used to analyze data. Results indicate percent dry matter, crude protein, ether extract, crude fiber, ash, nitrogen free extract, organic matter and metabolizable energy (kcal/kg) ranged from 91.90–90.97, 18.03–16.64, 4.05–3.55, 9.67–5.55, 7.13–5.97, 58.87–54.20, 85.94–84.24, 3014.80–2813.30, respectively. Minerals (mg/kg) ranged from 0.402–0.385 (sodium), 0.626–0.612 (calcium), 0.962–0.947 (potassium), 0.539–0.521 (phosphorus), 0.346–0.321 (magnesium), 48.15–46.75 (iron), 5.53–5.37 (copper), 61.87–60.52 (zinc), 4.86–4.48 (manganese) and 0.089–0.076 (selenium). Percent neutral detergent fiber, acid detergent fiber, acid detergent lignin, hemicellulose and cellulose ranged from 44.87–31.27, 33.05–19.66, 7.13–3.24, 13.0–7.46, 25.92–16.16, respectively. Trypsin inhibitors (mg/g) and percent tannins, phytate, oxalate, saponins and alkaloid ranged from 2.58–2.19, 0.0046–0.0030, 0.409–0.386, 0.292–0.269, 0.402–0.367 and 0.596–0.543, respectively. All feeds may supply enough proximate components to rabbits, except crude fiber. Actively reproducing rabbits fed those feeds may not cover their needs for calcium, phosphorus, iron, zinc, manganese, lysine, potassium, magnesium, copper, acid detergent fiber, neutral detergent fiber, hemicellulose and cellulose. Only acid detergent lignin contents of D5 and D4 were sufficient for rabbit needs. D5 followed by D4 may be fed sole to rabbits, if fortified, especially, with dietary fiber from sources like forages. There is need in Nigeria, needs to produce more commercial rabbit-specific concentrate feeds, that meet rabbit nutrient requirements.*

***Keywords**: Compound feed, anti-nutrients, feed milling, nutrients, fiber fractions, minerals*

## Description of Problem

The rabbit, *Orytolagus cuniculus*, is an herbivore, known for fast growth rate, high prolificacy, effective conversion of fodder to meat, and capable of transforming 20 percent of proteins they consume, into edible meat, in efficient production systems (1). But, in Nigeria and Greater Port Harcourt City (GPHC), the productivity of small holder rabbit systems is low. This low performance is mostly traced to poor rabbit nutrition; a challenge to adoption of improved rabbit production innovations (2).

Rabbit nutrition is mediated by several factors, some of which include animal genetics, feed ingredients and their nutritive value, health of the animal and others. But, poor rabbit nutrition in Nigeria is attributed to the feeding of mostly forage, to rabbits, by farmers, who barely supplement those forages with concentrate feeds. Common forages fed to rabbits in Nigeria include grasses (e.g. *Panicum maximum* and *Cynodon dactylon*); legumes (e.g. *Pueraria phaseoloides*, groundnut and cowpea haulms); root crops (e.g. sweet potato leaves and cassava leaves); and herbs (e.g. *Tridax procumbens* and *Aspilla africana*). For instance, in Enugu, Nigeria, 79% of rabbit farmers feed their animals only forages (3). Yet, optimum growth of rabbits cannot be attained by feeding them forages alone, especially, in the dry season, when forages are scarce, dry, highly fibrous and of low quality, thus, constituting the biggest threat to rabbit production (3). Intensive rabbit production, therefore, would require placing rabbits solely on concentrate feeds or supplementing them with forages, to balance the most critical nutrients, for better productivity.

Hence, few farmers supplement the forages they feed their rabbits with agro-processing by-products, household food wastes, do-it-yourself concentrate feeds formulated on-farm, or commercial poultry diets; such as broiler starter and finisher diets, or growers and layers diets, produced by brands such as Top®, Vital®, and Hybrid® feeds (4). Example, about 21% of farmers in Enugu, Nigeria combined forages with concentrates (3). But, such farmers complain about the low quality of the concentrates. Therefore, the challenge in feeding rabbits these diverse groups of diets and feedstuffs is that, while the commercial poultry diets were formulated to satisfy the nutrient requirements of broiler and layer birds, the on-farm made rabbit concentrate feeds and feeding stuffs are fed to rabbits not knowing whether they satisfy the recommended nutrient needs of the rabbits. Rabbits eating such feed are bound to consume more or less of the nutrients required for their growth and production. One reason why this practice of feeding non-specialized feeds to rabbits in Nigeria had persisted could be due to non-availability of rabbit-specific commercial concentrate feeds in the Nigerian market. Recently, however, either due to competition for customers or innovation in the feed industry, some feed companies have diversified into making rabbit-specific concentrate feeds. One of such feed brands targeting the rabbit market is Bella® feed (5).

As rabbit production and urbanization in Nigeria intensifies, placing rabbits solely on concentrates will gradually become a reality. Thus, assessment of the nutritive value of these emerging feed brands compared to poultry and on-farm made feeds fed to rabbits, by smallholder farmers, is required. An overview of present research in this area reveals a focus on the feeding value of indigenous forages supplemented with commercial or experimental concentrate diets, formulated using local agro-processed by-products and kitchen wastes (4, 6, 7 and 8). Comparative studies on commercial poultry feeds used in feeding rabbits and emerging rabbit-specific commercial feed as well as concentrate diets formulated on-farm is critical to innovating the emerging trends. The studies could reveal the potential of the feeds in meeting the nutrient requirements of rabbits, when fed sole, thereby, giving opportunity for their improvement.

This research, therefore, investigated the proximate composition, minerals content, fiber fractions and anti-nutritional factors in on-farm mixed formulated, commercial poultry and rabbit-specific feeds, fed to rabbits, by smallholder farmers, in GPHC, to reveal their potentials, deficiencies and give direction for innovation in the rabbit feeding systems.

## Materials and Methods

### *Description of study area*

This study was conducted in Greater Port Harcourt City (GPHC), Rivers State, Nigeria (see Figure 1). The GPHC has eight Local Government Areas (LGAs). They include Port Harcourt City, Obio-Akpor, Ikwerre, Etche, Oyigbo, Okrika, Eleme and Ogu-Bolo, with a landmass of 4820 $km^2$ (9). The city is mainly flat landscape, sitting 20 meters above sea level, with a slope of <3% (10), between latitudes $4^o42$'N and $4^o47$'N and longitudes $6^o55$'E and $7^o08$'E (9). The population of GPHC was estimated to be 2,130,000 people in 2019 (11). The main occupation of the people is farming, fishing and civil service. Most of the businesses are aligned with the oil industry.

### *Sampling procedure and data collection*

The study population was all rabbit farmers in GPHC. The sample population was smallholder rabbit farmers in two of the eight LGAs in GPHC, of which Obio-Akpor is urban and Ikwerre is peri-urban. Thirty-five rabbit farms, twenty from Obio-Akpor and fifteen from Ikwerre were purposively selected. The selection criteria were (i) the farm must presently rear a minimum of five rabbits (ii) rearing must have been ongoing for the past 12 calendar months (iii) a minimum of 40 % of the respondents must be from each of the two LGAs and (iv) the farmer must have been feeding concentrates to the rabbits, at least as supplement. The snowballing method was used to get the respondents because there was no register of rabbit farmers in the Rivers State Agricultural Development Programme office. In the snowballing method, after interviewing a respondent farmer, they were asked to link up the researcher to any other rabbit farmer they knew. A call or visit was then made to the newly suggested farm to get the consent of the farmer, and verify the location of the farm. Each farmer was briefed on the research objective and potential benefit to them, if they participated.

Thereafter, 200 grammes of each concentrate feed used in feeding their rabbits was collected into a tagged sample bag. Other information such as brand of the feed, type and class of animal the feed was formulated for (e.g. broiler chicken starter), name and location of the farm and phone number of the farmer were also collected. After collection, the samples were sorted based on brand, type and class of animals they were meant for. One sample per brand, type and class were picked for laboratory analysis. In all, five feed samples were picked. They included four commercial feed brands (Hybrid, Top, Vital and Bella) and one on-farm mixed feed. Hybrid, Top and Vital brands were pelletized broiler finisher diets, while Bella was the only commercial brand formulated specifically for rabbits. Hybrid, Top, Vital, Bella and On-farm Mixed (unbranded) were then tagged as D1, D2, D3, D4 and D5, respectively for the laboratory analysis. The samples were analyzed for proximate composition, fiber fractions, minerals and anti-nutritional factors.


**Figure 1**: Map of Rivers State showing the eight Local Government Areas of Greater Port Harcourt City

***Proximate composition***

Proximate components analyzed for included dry matter, crude protein, ether extract, crude fiber, ash and, nitrogen free extract. Samples were analyzed chemically in triplicates, according to official methods of analysis of Association of Official Analytical Chemist (12). Dry matter was determined by placing two grams of sample in oven set to 100°C for 24 hours and drying the sample to constant weight. If the weight of empty crucible was $W_o$, weight of crucible plus sample was $W_1$, weight of crucible plus oven-dried sample was $W_3$, then percent dry matter was:

$$Percent\ Dry\ Matter = \frac{W_3 - W_o}{W_1 - W_o}\ x\ \frac{100}{1}$$

Crude protein was determined by routine semi-micro Kjeldahl procedure consisting of digestion, distillation and titration techniques. The percent nitrogen content was multiplied by percentage nitrogen content by a constant factor of 6.25 (percent crude protein = % N x 6.25). Ether extract was determined using Soxhlet apparatus method. If initial weight of dry Soxhlet flask was $W_o$, final weight of oven-dried flask + oil was $W_1$, the percentage oil was obtained by the formula:

$$Percent\ ether\ extract = \frac{W_1 - W_0}{Weight\ of\ sample}\ x\ \frac{100}{1}$$

Ash was determined by burning two grammes of sample in a muffle furnace at 550°C for 4 hours. Percentage ash was calculated from the formula:

$$Percent\ ash = \frac{Weight\ of\ ash}{Original\ weight\ of\ sample} = \frac{100}{1}$$

Fiber content was determined using two grammes of sample in fiber flask where $W_1$ = weight of oven-dried crucible containing residue, $W_2$ = weight of cooled crucible containing white or grey ash (free of carbonaceous material). Percent fiber was obtained from formula:

$$Percent\ fiber = \frac{W_1 - W_2}{Weight\ of\ sample}\ x\ \frac{100}{1}$$

Nitrogen free extract (NFE) was calculated through difference by subtracting the sum of percent moisture, crude protein, ether extract, crude fiber and ash from 100, i.e. NFE = 100 – (% Moisture + % CP + % EE + % CF + % Ash).

***Minerals determination***

The macro-minerals analyzed for included sodium, calcium, phosphorus, potassium, and magnesium, while the micro-minerals included zinc, iron, copper, manganese, and selenium. Calcium, potassium and sodium were analyzed using Jenway Digital Flame Photometer (PFP7 Model). Concentration of any element was calculated using the formula: % calcium or % potassium or % nitrogen = meter reading x slope x dilution factor, where meter reading x slope x dilution factor = concentration ppm or mg/kg. Concentration in % =concentration in ppm÷10000. Phosphorus was determined by vanado-molybdate spectrophotometric method. Concentration of phosphorus expressed as percent phosphorus was calculated:

$$Percent\ phosphorus = \frac{Absorbance\ x\ Slope\ x\ Dilution\ factor}{10000}$$

Selenium, magnesium, copper, manganese, iron, and zinc were determined using digest of ash from calcium and phosphorus analysis and Buck 200 Atomic Absorption Spectrophotometer method. Meter reading for each element was used to calculate concentration of each element using the formula: element (ppm) = meter reading x slope x dilution factor while, percent element = ppm÷10000.

***Fiber fractions***

Fiber fractions that were analyzed and calculated include neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), hemicellulose and cellulose according to methods of (13). NDF was determined using one gramme of dried ground sample, neutral detergent solution, decaline and sodium sulphite. Percent NDF was calculated using:

$$\%\ NDF = \frac{(weight\ of\ crucible + dry\ NDF - weight\ of\ empty\ crucible)\ x100}{weight\ of\ sample}$$

Percent cell soluble constituents = 100 – percent NDF

ADF was determined using one gramme of dried sample, cold sulphuric acid-CTAB solution and decaline. Percent ADF was calculated with formula:

$$\%\ ADF = \frac{(weight\ of\ crucible + dry\ ADF - weight\ of\ empty\ crucible)\ x100}{weight\ of\ sample}$$

Percent hemicellulose = %NDF – %ADF, while percent cellulose was calculated as:
% cellulose = %ADF – %ADL.
To determine ADL, ADF residue obtained was treated with 72% sulphuric acid and calculated using formula:

$$Percent\ ADL = \frac{W1 - W2\ x\ 100}{weight\ of\ sample}$$

Where $W_1$ = weight of crucible plus acid free residue, $W_2$ = residue ash weight plus weight of crucible.

***Anti-nutritional factors analysis***

Phytates were determined using chromatophore reagent according to methods described by (14). Tannins were analyzed using the modified Vanidlin-HCl method as described by (15). Saponins were extracted and estimated according to standard methods (15). Estimation of oxalates was by the procedures described by (17).

***Statistical analysis***

Data collected in triplicate were analyzed using Statistical Package for Social Sciences (SPSS) software, version 21.0 (18). Analyses done included descriptive statistics and analysis of variance (ANOVA) for comparison of means at 0.1% level of significance. Significant means were separated using Duncan Multiple Range Test in SPSS.

## Results and Discussion

### *Proximate composition of concentrates used as rabbit feed by smallholder farmers*

Table 1 shows the proximate composition of concentrate diets fed rabbits by smallholder farmers in GPHC. Results indicate significant differences ($p<0.001$) among treatment means, for all parameters observed (dry matter, crude protein, ether extract, crude fiber, ash, nitrogen free extract and metabolizable energy), except organic matter ($p>0.001$).

D3 (91.90%) had the highest ($p<0.001$) dry matter content, while D1 (90.97%) had the least. However, the dry matter content of D3 was not different ($p>0.001$) from that of D2 (91.89%). Compared to values reported in literature (5), the dry matter contents were within range for concentrate feeds. The dry matter content indicates that all feeds had less than 10% moisture content (>90% dry matter). According to (19), these moisture contents are adequate for preventing mold growth and promoting optimal shelf-life of concentrate feeds.

Also, D1 (18.03%) had the highest ($p<0.001$) crude protein content, while D5 (16.74%) had the least. However, the crude protein of D5, was not different ($p>0.001$) from those of D4 (16.64%) and D2(16.84%). The crude protein requirement for growing rabbits in small and medium-scale enterprises is 16% (20). In this study, all crude protein values were within acceptable range, with D1 (18.03%), exceeding ($p<0.001$) the requirements for growers but within the range for gestation and lactating rabbits (21). The result implies that feeding diet D1 to grower rabbits could be wasteful and cause obesity in terms of excess crude protein intake. This is because rabbits can satisfy some of their crude protein requirement from consuming forage, as is usually the case with smallholder systems (20).

D2 (4.05%) recorded the highest ($p<0.001$) ether extract content, followed by D3 (3.87%), while D4 (3.55%) had the least. Generally, rabbits require 2–3.5% ether extract in diets or 2.5% in smallholder systems (20, 22). All treatment groups had ether extract values that were higher than recommended values. This high fat level can increase palatability but, prone the animals to obesity, hepatic lipodisis and aortic atherosclerosis (21). Hence, caution should be exercised when feeding any of these concentrates to rabbits.

**Table 1:** Proximate composition of concentrate diets used as rabbit feed by smallholder farmers in Greater Port Harcourt City

| | Concentrate | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Component** | D1 | D2 | D3 | D4 | D5 | SEM | *p*-value | *LOS* |
| Dry matter (%) | 90.97$^{d}$ | 91.89$^{a}$ | 91.90$^{a}$ | 91.21$^{c}$ | 91.36$^{b}$ | 0.10 | 0.000 | *** |
| Crude protein (%) | 18.03$^{a}$ | 16.84$^{bc}$ | 16.93$^{b}$ | 16.64$^{c}$ | 16.74b$^{c}$ | 0.14 | 0.000 | *** |
| Ether extract (%) | 3.81$^{b}$ | 4.05$^{a}$ | 3.87$^{b}$ | 3.55$^{d}$ | 3.63$^{c}$ | 0.05 | 0.000 | *** |
| Crude fiber (%) | 5.55$^{e}$ | 5.90$^{d}$ | 6.79$^{c}$ | 8.65$^{b}$ | 9.67$^{a}$ | 0.43 | 0.000 | *** |
| Ash (%) | 6.66$^{c}$ | 6.24$^{d}$ | 5.97$^{e}$ | 6.81$^{b}$ | 7.13$^{a}$ | 0.11 | 0.000 | *** |
| Nitrogen free extract (%) | 56.92$^{c}$ | 58.87$^{a}$ | 58.35$^{b}$ | 55.57$^{d}$ | 54.20$^{e}$ | 0.46 | 0.000 | *** |
| Organic matter (%) | 84.31 | 85.66 | 85.94 | 84.41 | 84.24 | 0.29 | 0.169 | NS |
| Metabolizable energy (kcal/kg) | 2971.0$^{c}$ | 3014.8$^{a}$ | 3003.4$^{b}$ | 2850.7$^{d}$ | 2813.3$^{e}$ | 22.09 | 0.000 | *** |

$^{a,b,c,d,e}$*Means in the same row with different superscripts are significantly different (p<0.001); SEM=Standard Error of Mean; NS=Not significant; LOS=Level of significance*

Crude fiber content of D5 (9.67%) was the highest ($p<0.001$), while that of D1 (5.55%) was the least. Crude fiber requirement for rabbits in smallholder systems is 15% (20) or up to 20% for other systems (22). Though D5 had the highest ($p<0.001$) crude fiber, all crude fiber, including that of D4, formulated specifically for rabbits, were lower than recommended values. This agrees with a report (20) that commercial pellets are deficient in fiber and require supplementation with forages, if concentrates are the main diets for rabbits. Also, the fiber in these feeds would mostly be the digestible type since commercial poultry feeds are mainly made of grains. A highly digestible dietary fiber could predispose rabbits to enteritis (21). Feeding these rabbits more forage, as is common with smallholders in Nigeria, could ameliorate the potential nutritional setback that may appear (23).

Furthermore, D5 (7.13%) had the highest ($p<0.001$) ash content, while D3 as value (5.97%) was the least. Growing rabbits require 4–6.5% dietary ash (22). Ash content of all commercial feeds revolved around upper range of recommended value, except D5, whose value was higher ($p<0.001$). The higher value for D5 could be due to wide variety of ingredients used by smallholder farmers in formulating rabbit diets while the commercial feed companies are looking to cutting down costs using few variety of ingredients. Nevertheless, any potential limitations with the ash content can be obviated when the animals are fed forages as supplements.

Nitrogen free extract content of D2 (58.87%) was the highest ($p<0.001$), while D5 (54.20%) had the least. The nitrogen free extract requirement for growing rabbits is 43– 47% (22). In this study, all nitrogen free extract values, including the special commercial feed for rabbits, were higher (54.20–58.87%) than recommended. This higher content could be because the feeds were originally formulated for poultry (which have higher energy requirements than rabbits), not rabbits. Therefore, energy deficiency might not be an issue when the rabbits are fed any of these concentrates as the main feed.

Organic matter content ranged from 85.94% (D3) to 84.24% (D5). There was no significant difference ($p>0.001$) in organic matter content of all concentrate feeds. D2 (3014.80 kcal/kg) had the highest ($p<0.001$) metabolizable energy, followed by D3 (3003.4 kcal/kg), while D5 (2813.30 kcal/kg) had the least. Metabolizable energy requirement for growing rabbits is 2400 kcal/kg (24). In this study, all diets had higher energy values than the recommended. This agrees with (20), that concentrate feeds are rich in energy, as is the case in this study.

***Macro-mineral content of concentrate diets used as rabbit feed by smallholder farmers***

Table 2 shows the macro-mineral content (sodium, calcium, potassium, phosphorus and magnesium) in mg/kg of concentrate diets used as rabbit feed by smallholder farmers. Results indicate significant differences ($p<0.001$) among treatment means for all the macro-minerals determined.

D5 had the highest ($p<0.001$) sodium content (0.402 mg/kg), followed by D4 (0.396 mg/kg), while D2 value (0.385 mg/kg) was the least. However, sodium content of D4 was not different ($p>0.001$) from D1value (0.393 mg/kg), while that of D1, was also not different ($p>0.001$) from that of D3 (0.391 mg/kg). Sodium is needed to maintain good heart health in rabbits. In this study, sodium values were comparable to or higher than 0.30% recommended for rabbits (24). This implies that normal consumption of these diets should not be a problem to the animals as their needs could be met.

**Table 2:** Macro-mineral contents of concentrate diets used as rabbit feed by smallholder farmers in Greater Port Harcourt City

| | Concentrate feeds | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Minerals** | D1 | D2 | D3 | D4 | D5 | SEM | *p*-value | *LOS* |
| Sodium (%) | $0.393^{bc}$ | $0.385^{d}$ | $0.391^{c}$ | $0.396^{b}$ | $0.402^{a}$ | 0.003 | 0.000 | *** |
| Calcium (%) | $0.612^{c}$ | $0.615^{bc}$ | $0.614^{bc}$ | $0.618^{b}$ | $0.626^{a}$ | 0.001 | 0.000 | *** |
| Potassium (%) | $0.951^{bc}$ | $0.947^{c}$ | $0.948^{c}$ | $0.953^{b}$ | $0.962^{a}$ | 0.001 | 0.000 | *** |
| Phosphorus (%) | $0.522^{bc}$ | $0.516^{d}$ | $0.521^{c}$ | $0.526^{b}$ | $0.539^{a}$ | 0.002 | 0.000 | *** |
| Magnesium (%) | $0.328^{bc}$ | $0.321^{d}$ | $0.324^{cd}$ | $0.331^{b}$ | $0.346^{a}$ | 0.002 | 0.000 | *** |

*$^{a,b.c,d}$ Means in the same row with different superscripts are significantly different (p<0.001); SEM=Standard Error of Mean; LOS=Level of significance*

The calcium content of D5 (0.626 mg/kg) was the highest (p<0.001), followed by D4 (0.618 mg/kg), while 0.612 mg/kg recorded for D1 was the least. Nevertheless, D1 and D4 values were not different (p>0.001) from those of D3 (0.614 mg/kg) and D2 (0.615 mg/kg). Calcium values were higher than recommended, except those for pregnant, lactating and nursing does (24), which were lower. Hence, the feeds need to be fortified with calcium content of the feed before feeding to these classes of rabbits as deficiency of calcium can lead to rickets (25).

Potassium content of D5 (0.962 mg/kg) was the highest (p<0.001), followed by D4 (0.953 mg/kg), while that of D2 (0.947 mg/kg) was the least. However, D4 potassium content was not different (p>0.001) from that of D1 (0.951 mg/kg), while that of D2 was also not different from those of D3 (0.948 mg/kg) and D1. Rabbits require 0.6–0.9% dietary potassium (24). The potassium values for all the diets in this study, were within the range recommended for rabbits. Therefore, in urbanized rabbit production system where forages are scarcely used, there should be no deficiency of potassium in the animals.

Phosphorus content of D5 (0.539 mg/kg) was the highest (p<0.001), followed by that of D4 (0.526 mg/kg), while D3 (0.521 mg/kg) had the least. However, D3 phosphorus value was not different (p>0.001) from that of D1 (0.522 mg/kg), while D4 phosphorus value was also not different (p>0.001) from that of D1. Phosphorus values for all the diets were higher than those required for all classes of rabbits except fatteners, lactating and breeding does (24). Therefore, it would be necessary to boost the phosphorus content of these diets when feeding those classes of rabbits. This is necessary because deficiency of phosphorus will affect bone formation in the breeding animals, especially does.

D5 (0.346 mg/kg) recorded the highest content (p<0.001) for magnesium, followed by D4 (0.331 mg/kg), while D2 (0.321 mg/kg) had the least. But, the magnesium content of D2 was not different (p>0.001) from that of D3 (0.324 mg/kg). Also, magnesium value for D4, was not different (p>0.001) from that of D1 (0.328 mg/kg). Magnesium contents for all the diets were more than 0.03–0.04% required by all classes of rabbits (24). D5 was top for all the macro-minerals while D2 was the least, implying that using D2 may not be fed to rabbits, except the macro-minerals contents are improved by dietary inclusion. This will be necessary to prevent deficiency diseases resulting from lack of magnesium especially for immunity and breeding (20).

***Micro-mineral contents of concentrate diets used as rabbit feed by smallholder farmers***

Micro-mineral contents of concentrate diets used as rabbit feed by smallholder farmers in Greater Port Harcourt City are shown in Table 3. Results indicate significant differences (p<0.001) among treatment means for all the assessed micro-minerals (iron, copper, zinc, manganese and selenium).

**Table 3:** Micro-minerals content of concentrate diets used as rabbit feed by smallholder farmers in Greater Port Harcourt City

| | Concentrate feeds | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Minerals** | D1 | D2 | D3 | D4 | D5 | SEM | *p*-value | *LOS* |
| Iron (mg/kg) | $46.75^{e}$ | $47.57^{d}$ | $47.88^{c}$ | $47.96^{b}$ | $48.15^{a}$ | 0.13 | 0.000 | *** |
| Copper (mg/kg) | $5.37^{c}$ | $5.41^{c}$ | $5.46^{b}$ | $5.49^{ab}$ | $5.53^{a}$ | 0.02 | 0.000 | *** |
| Zinc (mg/kg) | $60.52^{e}$ | $61.26^{d}$ | $61.38^{c}$ | $61.53^{b}$ | $61.87^{a}$ | 0.12 | 0.000 | *** |
| Manganese (mg/kg) | $4.54^{d}$ | $4.48^{e}$ | $4.67^{c}$ | $4.86^{a}$ | $4.79^{b}$ | 0.04 | 0.000 | *** |
| Selenium (mg/kg) | $0.076^{d}$ | $0.079^{cd}$ | $0.086^{ab}$ | $0.089^{a}$ | $0.082^{bc}$ | 0.001 | 0.000 | *** |

*$^{a,b,c,d}$ Means in the same row with different superscripts are significantly different (p<0.001); SEM=Standard Error of Mean; LOS=Level of significance*

D5 (48.15 mg/kg) had the highest iron content (p<0.001), while D1 (46.75 mg/kg) had the least. The iron contents of the feeds were comparable to those required for rabbits, except, lactating and breeding does (24), implying that, feeding any of these diets to those classes of rabbits would require dietary supplementation with iron. This is important because iron deficiency could cause impaired fertility, anemia, loss of hair and dermatitis in young growing rabbits (26).

Copper content of D5 (5.53 mg/kg) was the highest (p<0.001), but not different (p>0.001) from D4 (5.49 mg/kg). D1 (5.37 mg/kg) had the least copper content, which was not different (p>0.001) from that of D2 (5.41 mg/kg). Also, copper content of D4 was not different (p>0.001) from that of D3 (5.46 mg/kg). Reports by (27) show that copper is essential to animals for foetal growth to early post-natal development, bone development, and inflammatory processes of the body. The copper contents of all feeds were comparable to 5 ppm required by all classes of rabbits. Hence, deficiency of copper in the animals will be rare, if they are fed these diets alone.

Zinc value inD5 (61.87 mg/kg) was the highest (p<0.001) among treatment means, while that of D1 (60.52 mg/kg) was the least. Zinc values for all the concentrates feed exceeded the requirement for growing rabbits, but, were lower than requirements for lactating, pregnant, breeding and fattening animals. Zinc is required for cell division, DNA synthesis and stability, and cellular differentiation (28). These physiological processes could be impacted negatively, if actively reproducing rabbits are not properly supplemented with zinc, when fed these diets.

D4 (4.86 mg/kg) recorded the highest manganese content (p<0.001), while D2 (4.48 mg/kg) recorded the lowest. Manganese is a co-enzyme in amino acid metabolism and cartilage formation (25). The manganese contents of the diets were higher than those needed by all classes of rabbits except growing, breeding and fattening ones (24). Feeding those diets to these groups of rabbits will require supplementation with manganese to prevent consequences of deficiency.

D4 (0.089 mg/kg) had the highest ($p<0.001$) selenium content, which was not different ($p>0.001$) from that of D3 (0.086 mg/kg). D1 recorded the lowest selenium content, which was also not different from that of D2 (0.079 mg/kg). Likewise, selenium content of D3 was not different ($p>0.001$) from that of D5 (0.082 mg/kg), while that of D2 was also not different ($p>0.001$) from that of D5. The range for selenium was lower than the values required for growing rabbits (29). Deficiency of selenium in growing rabbits can cause stress, leading to higher cortisol levels in systemic circulation, immunological suppression, and increased risk of diseases. Supplementation with dietary selenium will be necessary for such animals (25), to prevent the problems associated with deficiency.

***Fiber fractions of concentrate diets used as rabbit feed by smallholder farmers***

Table 4 shows the fiber fractions in concentrates used as rabbit feed by smallholder farmers in Greater Port Harcourt City. Results indicate significant differences ($p<0.001$) among treatment means for all fiber fractions assessed; neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), hemicellulose and cellulose.

**Table 4:** Fiber fractions of concentrate diets used as rabbit feed by smallholder farmers in Greater Port Harcourt City

| | Concentrate feeds | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Fractions** (% DM) | D1 | D2 | D3 | D4 | D5 | SEM | *p*-value | *LOS* |
| Neutral detergent fiber | $31.27^{e}$ | $34.05^{d}$ | $35.20^{c}$ | $38.76^{b}$ | $44.87^{a}$ | 1.25 | 0.000 | *** |
| Acid detergent fiber | $19.66^{e}$ | $21.06^{d}$ | $27.16^{c}$ | $31.31^{b}$ | $33.05^{a}$ | 1.43 | 0.000 | *** |
| Acid detergent lignin | $3.51^{d}$ | $3.68^{c}$ | $3.24^{e}$ | $6.85^{b}$ | $7.13^{a}$ | 0.46 | 0.000 | *** |
| Hemicellulose | $11.61^{c}$ | $13.00^{a}$ | $8.04^{d}$ | $7.46^{e}$ | $11.83^{b}$ | 0.59 | 0.000 | *** |
| Cellulose | $16.16^{e}$ | $17.38^{d}$ | $23.92^{c}$ | $24.46^{b}$ | $25.92^{a}$ | 1.07 | 0.000 | *** |

*[a,b,c,d,e] Means in the same row with different superscripts are significantly different ($p<0.001$); SEM=Standard Error of Mean; DM=dry matter; LOS=Level of significance*

D5 had the highest ($p<0.001$) NDF (44.87%) and ADF (33.05%) values, while D1 had the least ($p<0.001$) values for NDF (31.27%) and ADF (19.66%). Fiber fractions, especially ADF, NDF and lignin (non-digestible fiber) are needed to prevent digestive troubles in growing rabbit as their deficiency could cause serious digestive problems, diarrhoea and mortality (30). Also, ADF values intake of more than 25% might make the animal unable to take enough energy needed for proper growth. In this study, NDF values were comparable to the recommended 300g/kg, while ADF values were also comparable to or higher than recommended 170g/kg (31). Therefore, supplementing with fiber fraction ADF, should be cautious.

The ADL contents of the concentrate feeds was highest ($p<0.001$) in D5 (7.13%), but least in D3 (3.24%). ADL values for D5 and D4 were higher than recommended, while those of other feeds were lower (31, 32). Crude fiber contains 20–90% of lignin (ADL) in most rabbit diets (20). Though crude fiber in D1, D2 and D3 were lower than recommended levels, there may be no serious digestive problems in the rabbits, except they are fed only concentrates; which is rare in smallholder rabbit systems in Nigeria.

D2 (13 %) recorded the highest (p<0.001) content for hemicellulose while D4 (7.46%) had the least. Cellulose content in the concentrates was highest (p<0.001) for D5 (25.92%) and lowest for D1 (16.16%). The values of cellulose and hemicellulose were comparable to ranges of 15–18% dry matter for cellulose and 25–35% dry matter for hemicellulose (33). Except hemicellulose, D5 recorded the highest (p<0.001) content for all the determined fiber fractions. On the whole, D5, followed by D4 had the best fiber fractions profile, while D1 had the worst.

### *Anti-nutritional factors content of concentrate diets used as rabbit feed by smallholder farmers*

Table 5 shows anti-nutritional factor contents in concentrate feeds used as rabbit feed by smallholder farmers in Greater Port Harcourt City. Results show significant differences (p<0.001) in treatment means for all anti-nutritional factors (trypsin inhibitors, tannins, phytates, oxalates, saponins and alkaloids).

**Table 5:** Anti-nutritional factors content of concentrate diets used as rabbit feed by smallholder farmers in Greater Port Harcourt City

| | Concentrate feeds | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Anti-nutrients** | D1 | D2 | D3 | D4 | D5 | SEM | *p*-value | *LOS* |
| Trypsin inhibitors (mg/g) | 2.58$^{a}$ | 2.31$^{c}$ | 2.37$^{b}$ | 2.19$^{e}$ | 2.25$^{d}$ | 0.04 | 0.000 | *** |
| Tannins (%) | 0.0046$^{a}$ | 0.0039$^{b}$ | 0.0040$^{b}$ | 0.0030$^{c}$ | 0.0037$^{bc}$ | 0.0001 | 0.000 | *** |
| Phytates (%) | 0.386$^{d}$ | 0.392$^{c}$ | 0.398$^{b}$ | 0.402$^{b}$ | 0.409$^{a}$ | 0.002 | 0.000 | *** |
| Oxalates (%) | 0.269$^{d}$ | 0.288$^{ab}$ | 0.292$^{a}$ | 0.281$^{c}$ | 0.285$^{bc}$ | 0.002 | 0.000 | *** |
| Saponins (%) | 0.367$^{d}$ | 0.382$^{c}$ | 0.386$^{c}$ | 0.402$^{a}$ | 0.392$^{b}$ | 0.003 | 0.000 | *** |
| Alkaloids (%) | 0.596$^{a}$ | 0.575$^{b}$ | 0.579$^{b}$ | 0.543$^{d}$ | 0.558$^{c}$ | 0.005 | 0.000 | *** |

$^{abc}$ Means in the same row with different superscripts are significantly different (p<0.001); SEM=Standard Error of Mean; LOS=Level of significance

D1 (2.58 mg/g) had the highest (p<0.001) trypsin inhibitors activity, while D4 (2.19 mg/g) had the least. Tannins were most abundant (p<0.001) in D1 (0.0046 %) and least in D4 (0.0030 %). But D2 tannin content was not different (p>0.001) from that of D5 (0.0037 %). Also, D5 tannin content was not different (p>0.001) from those of D3(0.0040 %) and D2 (0.0039 %). D5 (0.409 %) had the highest (p<0.001) phytate content, followed by D4 (0.402 %), while that of D1 (0.386 %) was the least. Nevertheless, the phytate content of D4 was not different (p>0.001) from that of D3 (0.398 %). The highest (p<0.001) oxalate content was in D3 (0.292 %). This was not different (p>0.001) from the value observed for D2 (0.288 %). However, the value for D2 was also not different (p>0.001) from that of D5 (0.285 %), which was also not different (p>0.001) from that of D4 (0.281 %). D4 (0.402 %) had the highest content (p<0.001) of saponins, while that of D1 (0.367 %) was the least. Saponin content of D3 (0.386 %) was not different (p>0.001) from that of D2 (0.382 %). The highest value (p<0.001) of alkaloids was observed in D1 (0.596 %), while the least was in D4 (0.543 %). Nevertheless, alkaloid content of D3 (0.579 %) was not different (p>0.001) from that of D2 (0.575 %).

All the anti-nutrients in the five diets recorded low values. They would likely not have significant effect on the animals. The low values may be due to the processing (milling, fermentation, soaking, drying, cooking and puffing) of the different feedstuff used in formulating the feeds. The feed processing techniques reduce the anti-nutritional factors, increase protein digestibility and improve the biological value of feeds and feeding stuffs (34, 35). Also, according to (36), toxic level of all these anti-nutritional factors have not been established for rabbit diets, though.

## Conclusion and Application

This research evaluated the nutrients and anti-nutrients in concentrate feeds fed rabbits by smallholder farmers in GPHC. We conclude that:

1. Proximate components, except crude fiber, were sufficient for all classes of rabbits
2. Calcium, phosphorus, iron, zinc and manganese contents were insufficient for actively reproducing rabbits, while potassium, magnesium, copper, hemicellulose, cellulose, ADF and NDF were sufficient for all rabbits
3. Only D4 and D5 may meet the ADL requirements for rabbits.
4. Anti-nutrient contents were lower than may cause problems for the animals.
5. D5, followed by D4 may be recommended as sole feed for rabbits, but may need supplementation with crude fiber, while D1 showed the least promise as rabbit feed.
6. Rabbits fed concentrate diets meant for poultry may either not produce to their full potential or consume more nutrients than required.
7. More rabbit-specific commercial concentrate feeds, that meet the nutrient requirements of rabbits for optimum growth, are needed in the Nigerian rabbit feed market.

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