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NUTRITIVE POTENTIALS OF INDIGENOUS FORBS FOR RABBITS IN PORT HARCOURT

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ABSTRACT
This research examined the nutritive value of indigenous forbs as sole feed for rabbits in Port Harcourt, Rivers State. Thirty-five farms in two Local Government Area were purposively selected for the study. Samples of the forages were obtained for laboratory analyses. Data collected were analyzed using One-way ANOVA, descriptive statistics and Duncan Multiple Range Test in SPSS. Corchorus olitorius, Telfairia occidentalis, Ipomea batatas, Amaranthus spps and Tridax procumbens were identified as rabbit feed by the farmers. DM, CP, EE, CF, ash and NFE values ranged from 89–91.06%, 14.33–21.53%, 3.50–3.87%, 15.67–22.03%, 8.35–11.36% and 38.59–42.24%, respectively. NDF, ADF, ADL, hemicellulose and cellulose in percent DM ranged from 44.96–59.16, 28.79–47.61, 9.11–13.37, 11.55–16.71 and 19.21–34.24, respectively. Methionine, lysine and tryptophan contents (mg/100g protein), ranged from 0.178–0.389, 0.589–0.876 and 0.217–0.328, respectively. Also, trypsin inhibitors (mg/g) ranged from 1.76–4.89, while tannins, phytates, oxalates, saponins and alkaloid values in percent ranged from 0.0032–0.006, 0.436–0.689, 0.268–0.587, 0.354–0.561 and 0.546–0.659, respectively. There were significant differences ($p<0.001$) among forbs for all parameters measured. All forbs were rich in CP, EE, CF, ash, all fiber fractions, sodium, potassium, phosphorus, magnesium, iron, copper, zinc, selenium, lysine (T. occidentalis, I. batatas and Amaranthus spps only), but deficient in NFE, calcium, manganese, phosphorus (only T. procumbens), iron (Amaranthus spps), methionine, tryptophan, lysine (C. olitorius and T. procumbens) and low in all the anti-nutrients. Supplementation of all forbs with alternatives rich energy, calcium, manganese, methionine and tryptophan, phosphorus (only T. procumbens), iron (only Amaranthus spps), lysine (only C. olitorius and T. procumbens) could boost the feeding value of the forbs as sole feed for rabbits. T. occidentalis is recommended as sole feed for high protein-demanding physiological states such as pregnancy, lactation and fast growth. Further research on acceptability, nutrient digestibility and performance of rabbits eating these forbs is required.

Keywords: Nutritive value, anti-nutrients, forages, pseudo-ruminants.

1. INTRODUCTION
Forages are important to rabbit nutrition and can constitute 80% of rabbit diets (Speight, 2017; Lee, 2018). Rabbits, similar to ruminants, consume a wide variety of forages such as herbs, shrubs, grasses, trees foliage and forbs (Wood *et al*., 2015). Among these functional groups of forages, there are wide differences in their nutrient contents (example proteins, fiber, energy and minerals) and palatability (Lee, 2018). For example, leguminous herbs have greater protein

potential than grasses, while digestibility of grasses is better than others (Weller and Cooper, 2001; King *et al*., 2012). The individual nutrients in forages also combine in different proportions among themselves to determine the nutritive value and digestibility, as well as animal growth rate and procreative ability (Lee, 2018). Therefore, knowing the nutritive worth of forages can influence the choice of forages for feeding pseudo-herbivores such as rabbits (Delaby and Peyraud, 2009).

Furthermore, in urban context such as Port Harcourt, there are many landless farmers, who depend on manufactured concentrate pellets or raw feed materials (food by–products and forages). Manufactured feed pellets are usually the most convenient to use but are expensive while, food by-products and forages from vacant spaces are the cheapest. But household food by-products have competitive uses as co-products for other types of food for humans, leaving forages (herbs, shrubs, grasses, browse and forbs) as the major option for livestock feeding in landless settings.

Among the classes of forages consumed by livestock, forbs are one of the most neglected, as feed for rabbits. Yet, they have good and desirable animal feeding qualities. They are rich in protein, which is deficient in wild indigenous grasses (Holechek, 1984), hence, can be used to improve poor quality indigenous grasses (Babayemi, 2007; Kubkomawa *et al.*, 2015). More so, indigenous forbs still thrive when trampled by grazing animals; easily adjust to unfavorable changes to local climate; flourish over the dry season and quickly regrow after bush burning for farmland preparation (Adebayo and Babayemi, 2020). But, the use of forbs as animal feed, like other types of animal feed materials could be hampered by the presence of anti-nutrients in their tissues and the potential harm they could do to the consuming animals (Salem *et al*., 2011; Kumar *et al*., 2017).

Notwithstanding these positive features of forbs, most research on forages, especially in Nigeria, focuses on grasses and browse (Larbi *et al*., 1996; Okoli *et al*., 2003; Amata, 2010; Okukpe and Adeloye, 2011; Gboshe and Ukorebi, 2020; Oji *et al*., 2020), while the focus of most nutritive value evaluations and feeding trials with forbs in Nigeria is ruminant feeding (Kallah *et al*., 2000; Adebayo and Bbabyemi, 2020). The poor research on forbs in the country implies low and incomplete quantification of the nutritive values of forbs in different regions of Nigeria. The result is little information on nutritive value of forbs used as rabbit feed in Nigeria and indeed Port Harcourt. Poor information on these forages means insufficient understanding of the nutritive value of feed resources which primarily causes their poor utilization for improvement of animal nutrition.

Therefore, this research was conceived to investigate the nutritive value and anti-nutrients composition of indigenous forbs in Port Harcourt area of Rivers State. This study of poorly investigated forbs will illuminate their potential for protein, fiber, energy, vitamin and minerals nutrition for rabbits; reveal variations among the forbs and broaden the scope of data on feed materials used as rabbit feeds. Conclusions and recommendations will inform decisions towards improvement of rabbit feeding systems in the study area and, elsewhere in Nigeria.

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2. MATERIALS AND METHODS

2.1 Study location

The research took place in Port Harcourt, Rivers State, Nigeria (see Figure 1) with flat land area spanning 4820 km^2 (Dan-Jumbo *et al*., 2018) placed twenty meters above sea level (Ikechukwu, 2015), sandwiched among latitudes 4°42'N and 4°47'N and longitudes 6°55'E and 7°08'E (Dan-Jumbo, 2018). The demographic estimate of the area by 2019 was 2,130,000 people (Dmographia, 2019) engaged in arable farming, fishing and white-collar jobs. The economy is dependent on petrochemical production.

2.2 Sample collection procedure

The entire rabbit farms in Port Harcourt formed the population of the study, while smallholder rabbit producers in Obio-Akpor and Ikwerre Local Governments constituted the sample population. Twenty and fifteen rabbit farms from Obio-Akpor and Ikwerre, respectively, totaling thirty-five, were purposively picked for the study using the following conditions: (a) the farm currently keeps at least five rabbits (b) Production had be going on for the previous one year and (c) at least forty percent of the respondent's farms are sited in each of the Local Governments. The snowballing technique (i.e. after an interview, an respondent is requested to direct the interviewer to other rabbit farmers) was employed to recruit the respondents due to unavailability of rabbit farmers' database at the Rivers State Agricultural Development Programme office; agency of government responsible for such register. A new respondent is visited for location verification, consent seeking and briefing on the research objectives and benefits to the respondent, upon participation. After the respondent, all the forages presented by any farmer as rabbit feed were sorted into their different groups (grasses, multipurpose trees and forbs). In total, five forbs (*Corchorus olitorius, Telfairia occidentalis, Ipomea batatas*, *Amaranthus spps*, *Tridax procumbens*) were identified, selected, coded, oven-dried and milled for proximate, fiber fractions, mineral elements, amino acids and anti-nutrients analyses. Two hundred grams of each forb were collected for the analyses.

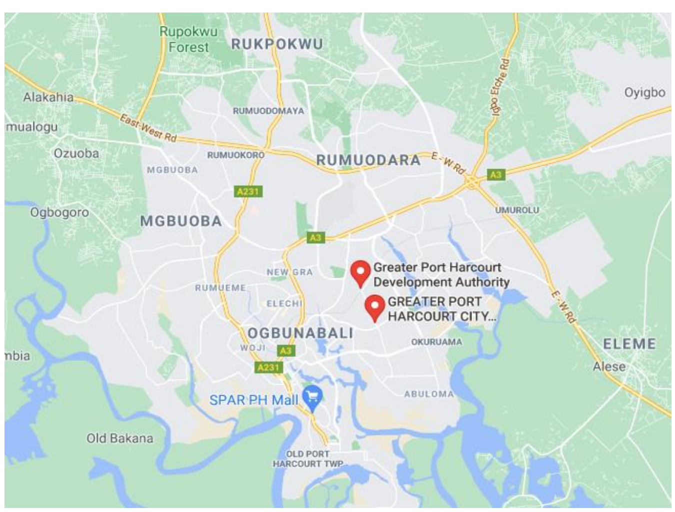

Figure 1: Map showing Port Harcourt in Rivers State

2.3 Proximate composition

The dry matter, crude protein, ether extract, crude fiber, ash and nitrogen free extract were assessed in all samples in triplicates according to (AOAC, 2005). Two grams of a sample were oven-dried at 103ºC for overnight (>4hours) to a constant weight. Dry matter was calculated using the following equation:

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

Where W_o, W_1 and W_3 represented weight of empty crucible, weight of crucible plus sample and weight of crucible plus oven-dried sample, respectively. Semi-micro Kjeldahl techniques (digestion, distillation and titration) were used to determine crude protein by multiplying the resultant percent nitrogen by 6.25. Crude fats were extracted by Soxhlet apparatus procedure and percentage oil was calculated using the following formula:

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

Where W_o and W_1 represent initial weight of dry Soxhlet flask and final weight of oven-dried flask + oil. Two grammes of each sample were scorched in a muffle furnace at 550ºC for 4 hours to assess ash whose percentage was calculated using the following equation:

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

Two grammes of each sample in fiber flask were used to assess crude fiber and percent fiber calculated using the equation:

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

Where W_1 and W_2 represented weight of oven-dried crucible containing residue and weight of cooled crucible containing free of carbonaceous material. Nitrogen free extractives for each sample were calculated by deducting percent moisture, crude protein, crude fat, crude fiber and ash from 100.

2.4 Minerals determination

Ca, K and Na were determined with PFP7 Jenway Digital Flame Photometer and concentration of the minerals was calculated with the following equation:

% Ca or % K or % Na = meter reading x slope x dilution factor,

Where, meter reading x slope x dilution factor = concentration in ppm or mg per kg. Concentration in % = concentration in ppm/10000. P was assessed using vanado-molybdate spectrophotometric procedure with concentration of P expressed as % P calculated by equation:

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

Se, Mg, Cu, Mn, Fe and Zn were assessed using ash digest from Ca and P analyses and Buck 200 Atomic Absorption Spectrophotometer procedure. The meter reading for each mineral was used to determine the concentration of each mineral using the following equation:

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Mineral (ppm) = meter reading x slope x dilution factor,
While % Mineral = ppm÷10000.

2.5 Fiber fractions

NDF, ADF, ADL, hemicellulose and cellulose were determined using standard techniques (Van Soest, 1963). For NDF, one gramme of dried and milled material, neutral detergent solution, decaline and sodium sulphite were used. Percent NDF was calculated with equation:

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

In ADF, one gramme of dried sample, cold sulphuric acid-CTAB solution and decaline were used. % ADF was calculated using equation:

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

Furthermore, % hemicellulose = % NDF – % ADF, while % cellulose was calculated using equation: % cellulose = % ADF – % ADL. To determine ADL, ADF residue was treated with 72 % sulphuric acid and calculated by equation:

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

Where W_1 and W_2 stood for weight of crucible plus acid free residue and residue ash weight plus weight of crucible, respectively.

2.6 Anti-nutritional factors analysis

Determination of phytates used chromatophore reagent as stipulated by (Mohamed *et al*., 1986) while tannins analysis followed the adapted Vanidlin-HCl technique (Zia-Ul-Haq *et al*., 2007). Saponins determination utilized standard methods (Shukla and Thakur, 1986) while oxalates were estimated according to techniques stated by (Tuleun and Patrick, 2007).

2.7 Data analyses

Triplicate data collected per sample were analyzed using SPSS software, version 21.0 (IBM Corp, 2007). Descriptive statistics, Completely Randomized Design Analysis of Variance (means comparisons were done at 1.0% level of significance) and Duncan Multiple Range test for significant means' separation in SPSS were employed for the analyses.

3. RESULTS

3.1 Proximate composition of forbs assayed in Port Harcourt

Table 1 shows the proximate composition of forbs in selected Local Government Areas of Rivers State. There were significant differences (p<0.001) among all the forbs for all the parameters assessed (i.e. dry matter: DM, crude protein: CP, ether extract: EE, crude fiber: CF, ash and nitrogen free extract: DM, CP, EE, CF, ash and NFE values ranged from 91.06% (*T. occidentalis*) to 89.00% (*T. procumbens*), 21.53% (*T. occidentalis*) to 14.33% (*C. olitorius*), 3.87% (T. *occidentalis*) to 3.50% (*C. olitorius*), 22.03% (*C. olitorious*) to 15.67% (*T. occidentalis*), 11.36% (*T. occidentalis*) to 8.35% (*C. olitorious*) and 42.24% (*T. procumbens*) to 38.59% (*I. batatas*), respectively.

Table 1: Proximate composition of forbs in Port Harcourt

Component (%)	**Forbs**					SEM (df=4)	*p*-value
	Corchorus olitorius	*Telfairia occidentalis*	*Ipomea batatas*	*Amaranthus spps*	*Tridax procumbens*		
DM	89.63^{b}	91.06^{a}	89.55^{b}	89.31^{c}	89.00^{d}	0.19	***
CP	14.33^{e}	21.53^{a}	17.93^{b}	16.54^{c}	15.23^{d}	0.67	***
EE	3.50^{d}	3.87^{a}	3.66^{c}	3.58^{cd}	3.75^{b}	0.03	***
CF	22.03^{a}	15.67^{e}	19.36^{c}	19.51^{b}	18.76^{d}	0.54	***
Ash	8.35^{e}	11.36^{a}	10.02^{b}	9.90^{c}	9.04^{d}	0.27	***
NFE	41.43^{b}	38.63^{d}	38.59^{d}	39.80^{c}	42.24^{a}	0.39	***

*$^{a,b,c=}$ Means in the same row with different superscripts are significantly different (p<0.001); SEM=Standard Error of Mean; df=degree of freedom; DM=Dry Matter; CP=Crude Protein; EE=Ether Extract; CF=Crude Fibre; NFE=Nitrogen Free Extract; OM=Organic Matter; GE=Gross Energy. *** = significant at 1% level of significance.*

Telfaria occidentalis had the highest (p<0.001) values for DM, CP, EE and ash, but recorded the least (p<0.001) for CF and NFE. *Corchorus olitorius* recorded the highest (p<0.001) value for CF but least (p<0.001) for CP, EE, and ash. *Telfaria procumbens* had the highest (p<0.001) value for NFE but least (p<0.001) for DM. *Ipomea batatas* had the least (p<0.001) NFE value which was not different (p>0.001) from that of *T. occidentalis*.

3.2 Fiber fractions of forbs assayed in Port Harcourt

Fibre fractions in forbs in Rivers State is presented in Table 4.2. There were significant differences ($p \leq 0.001$) among treatment means for all the fibre fractions examined.

DF, ADF, ADL, hemicellulose and cellulose in percent dry matter ranged from 59.16 (*C. olitorius)* to 44.96 (*T. occidentalis*), 47.61 (*C. olitorius*) to 28.79 (*T. occidentalis*), 13.37 (*C. olitorius*) to 9.11 (*T. procumbens*), 16.71 (*T. procumbens*) to 11.55 (*C. olitorius*) and 34.24 (*C.

olitorius) to 19.21 (*T. occidentalis*), respectively. *Corchorus olitorius* had the highest (p<0.001) values for NDF, ADF, ADL and cellulose but least (p<0.001) hemicellulose value, while *T. procumbens* had the highest (p<0.001) hemicellulose, but least (p<0.001) in ADL. Also, *T. occidentalis* was the least (p<0.001) in NDF, ADF and cellulose.

Table 2: Fiber fractions of forbs in Port Harcourt

Fractions (% DM)	**Forbs**					SEM (df=4)	*p*-value
	Corchorus olitorius	*Telfairia occidentalis*	*Ipomea batatas*	*Amaranthus spps*	*Tridax procumbens*		
NDF	59.16[a]	44.96[e]	56.46[c]	56.66[b]	52.83[d]	1.32	***
ADF	47.61[a]	28.79[e]	42.13[c]	42.57[b]	36.13[d]	1.72	***
ADL	13.37[a]	9.58[d]	11.44[c]	11.60[b]	9.11[e]	0.41	***
Hemicellulose	11.55[e]	16.17[b]	14.33[c]	14.09[d]	16.71[a]	0.49	***
Cellulose	34.24[a]	19.21[e]	30.69[c]	30.97[b]	27.02[d]	1.37	***

*[a,b,c,d,e] Means in the same row with different superscripts are significantly different (p<0.001); SEM=Standard Error of Mean; df=degree of freedom. *** = significant at 1% level of significance.*

3.3 Macro-minerals contents in forbs assayed in Port Harcourt

Table 3 shows the macro-mineral content of forbs in the study area. It indicates that the sodium, calcium, potassium, phosphorus and magnesium contents ranged from 0.469–0.332%, 0.701–0.558%, 1.245–0.917%, 0.608–0.447% and 0.598–0.308%, respectively. There were significant differences (p<0.001) among the forbs for all the minerals. *Telfairia occidentalis* had the highest (p<0.001) values for all the macro-minerals, while *Tridax procumbens* had the least.

Table 3: Macro-minerals content in forbs in Port Harcourt

	Forbs							
Minerals (%)	*Corchorus olitorius*	*Telfairia occidentalis*	*Ipomea batatas*	*Amaranthus spps*	*Tridax procumbens*	Mean	SEM (df=4)	*p*-value
Sodium	0.411[c]	0.469[a]	0.451[b]	0.447[b]	0.332[d]	0.422	0.013	***
Calcium	0.628[d]	0.701[a]	0.692[b]	0.687[c]	0.558[e]	0.653	0.014	***
Potassium	0.975[d]	1.245[a]	1.224[b]	1.216[c]	0.917[e]	1.115	0.037	***
Phosphorus	0.549[d]	0.608[a]	0.591[b]	0.585[c]	0.447[e]	0.556	0.015	***
Magnesium	0.472[d]	0.598[a]	0.498[b]	0.486[c]	0.308[e]	0.472	0.025	***

*[a,b,c,d,e] Means in the same row with different superscripts are significantly different (p<0.001); SEM=Standard Error of Mean; df=degree of freedom. *** = significant at 1% level of significance.*

3.4 Micro-minerals contents in forbs assayed in Port Harcourt

Micro-minerals content of the forbs is presented in Table 4. The iron, copper, zinc, manganese and selenium contents ranged from 56.85–48.05%, 6.51–5.47%, 67.59–61.35%, 5.75–4.53% and 0.132–0.075%, respectively. There were significant differences ($p<0.001$) among the forbs for all the micro-elements. *Ipomea batatas* had the highest ($p<0.001$) iron, zinc, manganese and selenium contents, while *Corchorus olitorius* recorded the highest ($p<0.001$) copper value. More so, *Amaranthus spps* showed the least ($p<0.001$) contents for all these elements. However, the selenium content of *T. occidentalis* was not different ($p>0.001$) from that of *C. olitorius*. Similarly, selenium value of *C. olitorius* was not different ($p>0.001$) from that of *T. procumbens*.

Table 4: Micro-minerals content in forbs in Port Harcourt

	Forbs							
Minerals (%)	*Corchorus olitorius*	*Telfairia occidentalis*	*Ipomea batatas*	*Amaranthus spps*	*Tridax procumbens*	Mean	SEM (df=4)	*p*-value
Iron	55.23^{b}	51.65^{c}	56.85^{a}	48.05^{e}	51.13^{d}	52.58	0.83	***
Copper	6.51^{a}	6.07^{c}	6.41^{b}	5.47^{d}	6.04^{c}	6.10	0.10	***
Zinc	66.92^{b}	66.34^{c}	67.59^{a}	61.35^{e}	66.29^{d}	65.70	0.59	***
Manganese	5.52^{b}	5.39^{c}	5.75^{a}	4.53^{e}	5.28^{d}	5.29	0.11	***
Selenium	0.117^{bc}	0.118^{b}	0.132^{a}	0.075^{d}	0.113^{c}	0.111	0.005	***

*^{a,b,c,d,e} Means in the same row with different superscripts are significantly different (p<0.001); SEM=Standard Error of Mean; df=degree of freedom. *** = significant at 1% level of significance.*

3.5 Amino acids content in the forbs assayed in Port Harcourt

Methionine, lysine and tryptophan content of the forbs is presented in Table 5. The values, in mg/100g protein, ranged from 0.389–0.178, 0.876–0.589 and 0.328–0.217, respectively. There were significant differences (p<0.001) among the forbs for all the amino acids. *Telfairia occidentalis* recorded the highest (p<0.001) values for all the amino acids while *Tridax procumbens* had the least. Nevertheless, there were no differences (p>0.001) between the methionine, lysine and tryptophan values of *Ipomea batatas* and *Amaranthus spps*.

Table 5: Amino acids content in forbs in Port Harcourt

	Forbs							
Amino acids (mg/100g)	*Corchorus olitorius*	*Telfairia occidentalis*	*Ipomea batatas*	*Amaranthus spps*	*Tridax procumbens*	Mean	SEM (df=4)	*p*-value

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Methionine	0.248^{c}	0.389^{a}	0.362^{b}	0.359^{b}	0.178^{d}	0.307	0.210	***
Lysine	0.729^{c}	0.876^{a}	0.851^{b}	0.847^{b}	0.589^{d}	0.778	0.029	***
Tryptophan	0.261^{c}	0.328^{a}	0.313^{b}	0.309^{b}	0.217^{d}	0.286	0.011	***

*^{a,b,c,d} Means in the same row with different superscripts are significantly different (p<0.001); SEM=Standard Error of Mean; df=degree of freedom. *** = significant at 1% level of significance.*

3.6 Anti-nutritional factors in the forbs assayed in Port Harcourt

Table 3 presents the anti-nutritional factors contents in forb in selected Local Government Areas of Rivers State. There were significant differences (p<0.001) among means for all the parameters studied. Results reveal that trypsin inhibitors in mg/g ranged from 4.89 (*T. occidentalis*) to 1.76 (*C. olitorius*), while tannins, phytates, oxalates, saponins and alkaloid values in percent ranged from 0.006 (*T. occidentalis*) to 0.0032 (*C. olitorius*) and 0.689 (*C. olitorious*) to 0.436 (*T. procumbens*), 0.587 (*C. occidentalis*) to 0.268 (*T. procumbens*), 0.561 (*Amaranthus spp*) to 0.354 (*T. occidentalis*) and 0.659 (*T. occidentalis*) to 0.546 (*C. olitorius*), respectively.

Table 6: Anti-nutritional factors in forbs in Port Harcourt

	Forbs						
Anti-nutrients	*Corchorus olitorius*	*Telfairia occidentalis*	*Ipomea batatas*	*Amaranthus spps*	*Tridax procumbens*	SEM (df=4)	*p*-value
Trypsin inhibitors (mg/g)	1.76^{e}	4.89^{a}	3.41^{b}	3.23^{c}	1.94^{d}	0.30	***
Tannins (%)	0.0032^{c}	0.0060^{a}	0.0056^{ab}	0.0052^{b}	0.0034^{c}	0.0003	***
Phytates (%)	0.689^{a}	0.445^{d}	0.574^{c}	0.582^{b}	0.436^{e}	0.025	***
Oxalates (%)	0.587^{a}	0.327^{d}	0.468^{c}	0.475^{b}	0.268^{e}	0.030	***
Saponins (%)	0.381^{c}	0.354^{e}	0.364^{d}	0.561^{a}	0.397^{b}	0.020	***
Alkaloids (%)	0.546^{e}	0.659^{a}	0.627^{b}	0.552^{d}	0.564^{c}	0.012	***

[a,b,c,d] *Means in the same row with different superscripts are significantly different ($p<0.001$); SEM=Standard Error of Mean; df=degree of freedom. *** = significant at 1% level of significance.*

Corchorus olitorius had the highest ($p<0.001$) phytates and oxalates values but least ($p<0.001$) trypsin inhibitors, tannins and alkaloids values. *Telfairia occidentalis* had the highest ($p<0.001$) values for trypsin inhibitors, tannins and alkaloids but least ($p<0.001$) in saponins. Also, *Amaranthus spp.* was the highest ($p<0.001$) in saponins, while *T. procumbens* was the lowest ($p<0.001$) in phytates and oxalates.

However, the least ($p<0.001$) tannin content (*C. olitorius*) was not different ($p>0.001$) from the value recorded for *T. procumbens*. Also, the tannin content of *Amaranthus spp* was not different ($p>0.001$) from that of *Ipomea batatas*, while that of *Ipomea batatas* was also not different ($p>0.001$) from that of *T. occidentalis*.

4. DISCUSSION

The dry matter contents of the forbs were narrowly lower than values reported for non-leguminous forbs (Adebayo and Babayemi, 2020). Differences could be due to the types of forbs and age (i.e. the older the leaves, the less the dry matter) of the leaves (Wallau *et al*., 2018). The species of forbs in this study were different from those reported in literature while the age of the leaves was not considered in the study. The crude protein content of the forbs in this study, was similar to some but lower than others reported in literature (Kallah *et al*., 2000; Adebayo and Babayemi, 2020). The inconsistency could be attributed to agro-ecological differences and plant types. This is because between this study and literature, the types of forbs differ. Also, while the two studies in literature were conducted in rainforest of South-West Nigeria and Savannah of Northern Nigeria, the present study was conducted in the rainforest/mangrove of South-South Nigeria. These three zones have different soils and rainfall which could affect crude protein content (Wallau *et al*., 2018). Generally, rabbits require 12–19% dietary crude protein (Speight, 2017) and 16% for mixed or single feed small scale operations (Lebas, 2013). All the forbs had crude protein values within the required range except *T. occidentalis* which was higher. This agrees with (Lebas, 2013) that when fed sole to rabbits, non-grass forages such as forbs can cover 72–184% of rabbit crude protein requirement. Compared to values obtained for non-leguminous forbs in Oyo State, Nigeria (Adebayo and Babayemi, 2020), the present values were within the normal range. Also, when higher dietary crude protein levels are required, such as pregnancy, lactation and fast growth, *T. occidentalis* could be the best option. Rabbits require 2.5% dietary fat (Lowe, 2010). The fat contents of all the forbs were higher than the required value, indicating that should any of these forages be fed sole to rabbits, the fat requirement of the rabbits would be met. This agrees with (Speight, 2017) that rabbits can satisfy their essential fatty acid requirements by consuming forages alone. A dietary crude fiber of 15% is adequate for rabbits when fed on mixed or sole feed diets (Lebas, 2013). All the forbs had higher fiber values than the recommended dietary crude fiber. Hence, feeding any of these leaves to rabbits as sole forage could satisfy their crude fiber requirements. Compared to figures in literature (Adebayo and Babayemi, 2020), the fiber values obtained in this study were within the range for forbs.

Rabbits at all physiological stages require 4–6.5% dietary ash (MSUBT (2017). All the forbs contained more crude ash than needed for adequate growth and production in rabbits. Hence, should the animals be fed only one of these forages at a time, their ash needs could be satisfied. Compared to literature (Adebayo and Babayemi, 2020), the ash values were within reported ranges. Depending on their physiological state, rabbits require 43–50% NFE in diets, with requirements for nursing and pregnant does at the upper threshold (MSUBT, 2017). None of the forbs may supply enough dietary NFE if fed sole to rabbits. Feeding any of the forbs sole to rabbits would need supplementation with sources rich in energy such as concentrate diets, for energy needs to be satisfied. Compared to literature, the NFE values of the forbs were lower than those reported in literature (Vondraskova *et al*., 2012). Differences could be due to agro-ecological and climatic reasons (Wallau *et al*., 2018).

The NDF content of all the forbs in this study, were within the ranges reported for forbs elsewhere (Kallah *et al*., 2000; Adebayo and Babayemi, 2020). Mixed or single feed for rabbits require 31% NDF (Lebas, 2013). Non-grass forages such as forbs can cover 53–123% dietary NDF required by rabbits (Lebas, 2013). All the forbs contained more than the required dietary NDF, indicating that rabbits can meet their NDF requirements from eating any of these forbs alone. This agrees with reports by (Lebas, 2013) that forbs can satisfy the NDF needs of rabbits when fed as sole feed. Mixed or single feed for rabbits should contain 17% ADF (Lebas, 2013). All the forbs contained more than these ADF values, indicating that rabbits can meet their ADF requirements by consuming any of these forbs alone. Furthermore, compared to literature reports (Kallah *et al*., 2000; Adebayo and Babayemi, 2020), the ADF values in the present study were comparable. Mixed or single feed for rabbits should contain 5% ADL (Lebas, 2013). All the forbs contained more ADL than they should contain, indicating rabbits can satisfy their ADL requirements if fed any of these forbs alone. This agrees with (Lebas, 2013) that non-grass forages such as forbs can cover 99–335% ADL required by rabbits. Compared to literature values, the ADL values for this study were higher. Differences could be due to the type of forb, climate and agro-ecological factors (Wallau *et al*., 2018), which were different among the reported studies and between reported values and those in present study. Generally, hemicellulose levels in forages vary from 100 to 250g/kg DM (McWilliams, 2001), and compared to literature values of a standard forage such as alfalfa (Naydenova and Vasileva, 2015), the hemicellulose values in the present study were higher. Differences could be explained by the type of plant and age of the leaves as posited by (Wallau *et al*., 2018). Rabbits require 10–12% hemicellulose per kilogram feed (Gidenne and Lebas, 2002), meaning that these forbs when fed sole to rabbits, may cover their dietary need for hemicellulose. Cellulose content in forages varies from 100 to 300g/kg DM (McWilliams, 2001). Values obtained for forbs in this study were within reported range and comparable to alfalfa (Naydenova and Vasileva, 2015). Rabbits require 11–13% cellulose per kilogram feed (Gidenne and Lebas, 2002), indicating that when fed sole to rabbits, the animals may cover their dietary need for cellulose.

Compared to literature (Kallah *et al*., 2000) the calcium values were lower; the phosphorus and magnesium values were higher, while the sodium and potassium values were within the reported range. Differences could be attributed to influence of soil and agro-climatic zones (King *et al*., 2012). The literature values were obtained from savanna area of Nigeria, while the present study was conducted in rainforest/mangrove region of the country. Furthermore, the calcium, phosphorus, sodium, potassium and magnesium requirements for rabbits in a mixed feeding regime are 1.10, 0.50, 0.22, 0.60–1.80 and 0.03–0.04%, respectively (TANUVAS, 2012; Lebas, 2013; De Blas and Mateos, 2020). Compared to the recommended values, the sodium, potassium, phosphorus (except phosphorus content of *T. procumbens*) and magnesium contents of all the forbs were high while the calcium contents of all forbs and phosphorus contents of *T. procumbens* only were low. Therefore, supplementation of all the forages with calcium-rich sources and *T. procumbens* with phosphorus-rich feed materials could be helpful in boosting the feeding value of the forbs when used as sole feed for rabbits.

Paralleled to values reported in literature (Kallah *et al*., 2000), iron, manganese, copper and zinc were high and within reported ranges while selenium values were lower. Soil, agro-climatic zones and species of the forb could be responsible for the differences (King *et al*., 2012). Furthermore, the iron, copper, zinc, manganese and selenium values recommended for growing, breeding and fattening rabbits in ppm (i.e. mg/kg) are 50–100, 5.0, 50–70, 8.50 and 0.01–0.15, respectively (TANUVAS, 2012; De Blas and Mateos, 2020). Compared to these required values, those obtained in this study were high for iron (except Amaranthus spps), copper, zinc and selenium but low for manganese. This implies that they may be need to supplement diets with feed materials rich in manganese should any of the forbs be fed sole to rabbits. Also, supplementaion with iron-rich feed materials could be necessary when *Amaranthus spps* if fed sole.

The methionine, lysine and tryptophan requirements of rabbits are 0.60, 0.80 and 1.5–2.0%, respectively (Lebas, 2013; De Blas and Mateos, 2020). Based on these requirements, the methionine and tryptophan contents of all the forages and lysine contents of *C. olitorius* and *T. procumbens* were lower than required, while lysine contents of *T. occidentalis*, *I. batatas* and *Amaranthus spps* were within the required figures. This agrees with (Lebas, 2013) that the lysine content of forages is generally low and insufficient to cover rabbit requirements. This implies that using any of the forbs as sole feed for rabbits might require supplementation with other feed materials rich in methionine and tryptophan. Also, feeding *C. olitorius* and *T. procumbens* to rabbits as sole feed might require supplementation with other feed sources rich in lysine.

The trypsin inhibitors are mostly found in seeds of legumes, especially soybeans (Savage and Morrison, 2003). Most legumes contain less than 50% of trypsin inhibitors of soybeans (Samtiya *et al*., 2020). In soybean trypsin inhibitors could be up to 6mg/g (Erdaw and Beyene, 2018). The trypsin inhibitors content of the forbs in this study, compared to range for soybeans, a reference crop for this anti-nutrient was low. Hence, feeding any of these forbs sole to rabbits might not affect the animals negatively. Feeding 5% dietary tannin to rabbits had no deleterious effects on the animals (Maertens and Struklec, 2006) but feeding rabbits sorghum grains containing a high tannin level (3.5% catechin equivalent) affected rabbit growth and feed conversion ratio, but not at 1.5% catechin equivalent (Al-Mamary *et al*., 2001). All the forbs had tannin contents lower than 1%, indicating the animals are safe from tannin toxicity when fed these forbs sole. Phytate in form of phytic acid is a secondary compound naturally present in all plant derived foods such as seeds of legume, cereals and oilseeds. Phytate content in foods range from 0.1–6% (Gupta *et* *al*., 2015). Compared to this literature values, phytate contents of forbs in this research were low. This could be because most of the phytate is concentrated in the seeds (Samtiya *et al*., 2020). Rabbits can digest 82.1% of phytate phosphorus (Marounek *et al*., 2003). Phytic acid affects bioavailability of minerals and hinders activity of protein enzymes (Samtiya *et al*., 2020). Since the levels were low in the forbs, the forages may be fed sole to rabbits without any issues. About 20-30% of calcium in forage is in the form of calcium oxalate that reduces the availability of calcium to livestock (Varga, 2014). Oxalates occur mainly in the leaves of plants. The oxalate contents of the forbs in this study were comparable to similar forages from Nigeria (Musa and Ogbadoyi, 2014). Feeds containing 3.2% oxalate could be toxic to livestock (Cymbaluk *et al*., 1986). In this study, oxalate values in all the forbs were below the toxic threshold. Saponins are anti-nutritional factors with bitter taste and foaming properties and can reduce feed intake and growth rate in affected animals. The saponin contents of Nigerian forbs reported in literature (Odufuwa *et al*., 2013a), are comparable and agree with values obtained in this present study. Feeding of *Sesbania sesban* containing 0.71% saponins affected chicks' performance (Shqueir *et al*., 1989). Also, dietary alfalfa saponin up to 2% had no effect on rabbits (Cheeke, 1971). Compared this non-toxic level, the saponin content of the forbs would unlikely cause any harm to rabbits when the forbs are fed as sole forage to the animals. Alkaloids are natural compounds mostly derived from amino acids. They interfere with animal nervous system and toxic to man and livestock (Lima, 2022). The alkaloid contents in this study, compared to fresh forbs in literature (Odufuwa *et al*., 2013b) were low, hence, unlikely to cause any negative effects on the rabbits when fed sole.

5. CONCLUSION

All the forbs contained enough DM, CP, EE, CF, ash, fiber fractions (NDF, ADF, ADL, hemicellulose and cellulose), sodium, potassium, phosphorus, magnesium, iron, copper, zinc, selenium, lysine (*T. occidentalis*, *I. batatas* and *Amaranthus spps* only) needed for rabbits in mixed feeding regime, but deficient in NFE, calcium, manganese, phosphorus (only *T. procumbens*), iron (*Amaranthus spps*), methionine, tryptophan, lysine (*C. olitorius* and *T. procumbens*). All the forbs were low in all the anti-nutrients (trypsin inhibitors, tannin, phytate, oxalate, saponin and alkaloid), hence, potentially not harmful to rabbits.

6. RECOMMENDATIONS

To boost the feeding value of the forbs as sole feed for rabbits, there may be need to supplement all the forbs with other feed materials that are rich in energy, calcium, manganese, methionine and tryptophan. Specifically, as sole feed for rabbits, there may be need to supplement *T. procumbens* with phosphorus-rich feed ingredients; *Amaranthus spps* with iron-rich ingredients and; *C. olitorius* and *T. procumbens* with lysine-rich ingredients. Lastly, we recommend that for high protein-demanding physiological states such as pregnancy, lactation and fast growth, *T. occidentalis* could be fed sole to rabbits.

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