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Research Article

Physicochemical Characterizations of Leaf Meals Derived from Tropical Plants as Possible Nutraceuticals in Animal Production

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Abstract

Background and Objective: The leaves of many tropical plants are habitually given to animals as fodder without adequate knowledge of the nutritional and pharmacological compositions that generate their desirable effects. The objective of this study was to evaluate the phytochemical characteristics of leaf meals of *Garcinia kola*, *Gongronema latifolium* and *Mucuna pruriens* as candidate nutraceuticals in animal production. **Materials and Methods:** They were collected from surrounding farmlands and bushes at Ihiagwa, Owerri west Local Government Area (LGA) of Imo state, Nigeria. The leaf meals were subjected to physicochemical characterization to determine their bulk density (BD), water holding capacity (WHC), specific gravity (SG), proximate composition, metabolizable energy, fibre fractions, minerals and secondary metabolite concentrations. **Results:** The *G. latifolium* had higher bulk density than *M. pruriens* and *G. kola*, while *G. kola* had higher water holding capacity (WHC) value. The *G. latifolium* yielded highest crude protein, crude fat, total ash and metabolizable energy values, while for crude fiber contents of *M. pruriens* yielded the highest. **Conclusion:** It is therefore, concluded that *G. latifolium*, *G. kola* and *M. pruriens* are endowed with essential nutrients and bioactive substances.

Key words: *Garcinia kola*, *Gongronema latifolium*, *Mucuna pruriens*, leaf meal, nutraceuticals

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Worldwide, tens of thousands of species of higher plants and several hundreds of lower plants are currently used by humans for a wide diversity of purpose as food, fuel, fibre, oil, herbs spices, industrial crops as well as forage and fodder for domesticated animals. In the tropics alone, it has been estimated that 25,000-30,000 plants are in use and up to 25,000 have been used in traditional medicine[1]. Generally, some of these plants, especially the edible ones are eaten habitually without any knowledge of their pharmacological effects. However, plants derived substances have increasingly attracted interest owing to their importance in food, industrial and pharmacological preparations[2].

The World Health Organization (WHO) estimated that 80% of the world's inhabitants rely on traditional medicine for their healthcare. Many medicinal plants have proved successful in the treatment of various alignments leading to mass screening of their therapeutic components. Specifically, there are emerging industrial benefits of many of these plants, especially for chemical production. New initiatives in livestock and pharmaceutical industry are thus seeking to promote the use of plant materials that have combined nutritional and medicine properties[3]. The search for nutritional compounds derived from plants and rich in anti-oxidants, anti-cancer and anti-microbial properties is increasing due to their importance in controlling many related chronic disorders such as cancer and cardiovascular diseases. Anti-oxidant is used in the treatment and prevention of diseases because they scavenge excess free radicals in the body. Cancer is currently a leading cause of death and growing evidence relates its occurrence to oxidative damage of DNA, protein and lipids in the body. It has been estimated that two-third of anti-cancer drugs approved worldwide up to 1994 were derived from plant sources. Similarly, many medical plants have been screened extensively for their anti-microbial potential worldwide[1,4]. Bacterial resistance to conventional antimicrobial preparations[5] has also given credence to such studies of herbals remedies as alternatives to conventional drugs[6,7]. It is thus established that the additive synergistic and nutritional effects of plants materials are be beneficial in livestock production[3,8].

South-eastern agro-ecological zone of Nigeria is endowed with rich plant diversity possessing nutritional and medicinal properties. It is therefore necessary to evaluate such plants for possible utilization in animal production as feed or medicinal materials. Although many studies have been carried out to ascertain the nutritional value of some of these plants, especially the leaf meals[8-10], little attention has been paid to their pharmacological benefits to animals, which could augment their nutritional effects on livestock performance[7,11]. For example, plants exhibiting high anti-oxidant activities have been established to enhance physiological parameter, especially of small laboratory animals[11].

Examples of plants that have received research attention at our station include for their nutraceutical properties, *Garcinia kola*[12] *Mucuna pruriens*[13] and *Gongronema latifolium*[8]. *Garcinia kola* has been shown to contain complex mixtures of polyphenolic compounds such as tannins[14], bioflavonoids, xanthenes, benzophenone, kola flavonoids[15] all of which have antimicrobial activities.

The *Gongronema latifolium* commonly called "Utazi" and "Arokeke" in the southeast and southwest geopolitical zones of Nigeria, respectively is a tropical rain forest plant primarily used as a vegetable spice and also in traditional folk medicine. The *G. latifolium* has been shown to be nutritionally high in minerals, vitamins and proteins[8] and as a medicinal plant, it is used in the treatment of many diseases such as diabetes and hypertension[16,17]. It enhances the immune system and is used in the treatment of stomach problems such as typhoid fever, dysentery, malaria, worm, cough among others[16,18]. Phytochemical evaluation of its leaf, stem and root has revealed the presence of saponins, tannins, alkaloids flavonoids triterpenes and cardiac glycosides. Recent studies at our situation have also shown its activity against common livestock pathogens such as *Salmonella* spp. and *E. coli* among others[8].

Mucuna puriens (L.) is a plants of the Fabaceae family[19] found in tropical regions and used for various purpose in traditional medicine in several countries. In India and West Africa for example, its extract is effective in the treatment of snake bite[20]. It is also used as a uterine stimulant and aphrodisiac[21]. The legume is currently not highly in used as human food or animal feed, probably because it contains several anti-nutritional factors include hemagglutinins, protease inhibitors (like trypsin inhibitor), cyanogens, tannins, dopamine, L-Dopa, antivitamins, lipoxygenase, nicotine, phytates, goitrogens and serotonin[13]. The presence of these anti-nutritional factors in a feedstuff confers toxicity action to its seeds when used as feedstuff and therefore needs to be eliminated through further processing[22].

More studies however needed to generate the reference biochemical data on plant parts in developing countries like Nigeria in order to select indigenous plants of nutraceutical importance thereby providing clues on which product development could be focused on a particular therapeutic action in animal production[1,23]. The objective of this study was to evaluate the phytochemical characteristics of leaf meals derived from three indigenous plant of southeastern Nigeria, *Garcinia kola*, *Gongronema Latifolium* and *Mucuna pruriens* as candidate nutraceuticals in animal production.

MATERIALS AND METHODS

Study area: The selected plants were collected from the same location in the surrounding farmlands and bushes of Ihiagwa in Owerri, Owerri west Local government Imo state. Imo state is located in the south eastern region of Nigeria. The state is located with latitude 4°45°N and 7°15°N and longitude 6°50°E and 7°25°E[24]. It has common boundaries with Abia state on the east, Anambra State to the north, Delta state to the west and Rivers state to the south. The study was done during the months of March to August, 2017.

The vegetation is typically rain forest with two seasons (the rainy and dry seasons). The period of rainy season is from the month of April-October, while dry season runs through November-March. People in the rural and semi-urban areas are predominantly farmers they also cultivate crops like cassava, plantain, vegetables among others[25]. Imo state is a typical rain forest zone and harbors many typical rain forest plants including bitter kola and is high in conservation. In marshy, swamps, canals, creeks and tributaries of rivers such as Otamiri that flows through the study area.

Experimental design and sample collection: The bitter kola (*Garcinia kola*), velvet bean (*Mucuna pruriens*) and utazi leaves (*Gongronema latifolium*) used in the study were obtained from surrounding farmlands and bushes of Ihiagwa Owerri West L.G.A of Imo state, Nigeria. Portions of leafs were collected and spread evenly on trays and dried at room temperature for 7 days so as to preserve its natural green colour. In each case samples were collected from three different plants in other to obtain three different samples of the same plant the experiment designs as therefore completely randomized block design (CBRD).

Sample analysis: The samples were dried at room temperature for 7 days and thereafter, packed in cellophane bags, labeled and transported to the laboratory for analysis. The leaf samples were analyzed for physical, proximate, mineral and fibre fractions at the Chemical Laboratory of the School of Agriculture Laboratory, Federal University of Technology Owerri (FUTO), Nigeria.

The methods described by Makinde and Sonaiya[26] and modified by Omede[27] were used to determine the bulk density (BD) and water holding capacity (WHC) values. Specific gravity (SG) was calculated as ratio of the BD of known mass of the experimental sample to the density of water for the sample[27]. The proximate analysis was carried out to determine the moisture content (MC), Crude protein (CP), Ether extract (EE), Crude fibre (CF), Nitrogen free extract (NFE), Total ash (TA) and Gross and Metabolizable energy according to the methods of AOAC[28]. All the proximate values were reported in percentages. The calorific measurements of samples for gross energy analysis were done with Cal 2K, C1.7 bomb calorimeter. The gross energy was determined according to AOAC[28] using the digital CAL-2K Isothermal Automatic Bomb Calorimeter.

The fibre fractions such as neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), cellulose and hemicellulose (HEM) were determined according to a standard methods[28]. Mineral composition analysis (micro and macro-element) was performed with an Atomic Absorption Spectrophotometer (AAS), Bulk scientific, model 210 VGB to determine the following minerals; Ca, K, Na, P, Mg, Mn, Fe, Cu, Zn, Co, Cr, Pb and Ni according to the methods of AOAC[28] using the Atomic Absorption Spectrophotometer (Bulk Scientific, 205).

The phytochemical analyses were carried out at JAAGEE Nigeria Limited Demonstration, Application and Research Laboratory Ibadan, Nigeria and the percentage proportions of the respective anti-nutritional factors notably alkaloids, phenols, carotenoids, anti-oxidants, flavonoids and terpenoids, tannins, phytate/phytic acid, trypsin inhibitor, oxalates, saponins and cyanogens were evaluated using elaborate laboratory procedures as described by Harbone[29] and Sofowora[30].

Statistical analysis: Data generated were subjected to descriptive statistics such as means, standard deviation (SD) and coefficient of variation (CV) to establish the reference values of the different parameters analyzed[31]. Scoring of the candidacy of the leaf meals as possible alternative feed raw materials for livestock feeding trial was based on their crude protein, ash, metabolizable energy, NDF, copper, iron, anti-oxidants, trypsin inhibitor and cyanide contents[32,33]. The parameters were selected as important representative components of the physicochemical properties of the study materials in order to arrive at a functional and practical score for candidacy selection based on this scoring protocol.

RESULTS

Physical characteristics of sampled leaf meals: Table 1 shows the physical characteristics of the leaf meals of selected plants growing Imo state, southeastern Nigeria. *G. latifolium*

Table 1: Physical characteristics of the selected plants from southeastern Nigeria

Parameters	*Gongronema latifolium*	*Mucuna pruriens*	*Garcinia kola*	Mean±SD	Range
Packed bulk density (g mL^{-1})	0.59	0.42	0.41	0.47±0.101	0.41-0.59
Loose bulk density (g mL^{-1})	0.35	0.24	0.35	0.31±0.063	0.24-0.35
Water holding capacity (%)	245.45	250.00	440.00	311.82±111.03	250.00-440.00

Table 2: Proximate and ME compositions of the leafs of selected plants from southeastern Nigeria

Parameters	*Gongronema latifolium*	*Mucuna pruriens*	*Garcinia kola*	Mean±SD	Range
Moisture (%)	4.00	3.60	4.80	4.13±0.61	3.60-4.80
Dry matter (%)	96.00	96.40	95.20	95.87±0.61	95.20-96.40
Crude protein (%)	24.46	20.73	14.22	19.80±5.18	14.22-24.40
Crude fat (%)	6.32	1.35	3.77	3.78±2.44	1.35-6.32
Crude fiber (%)	15.39	35.39	32.37	27.72±10.78	15.39-35.39
Total ash (%)	12.21	6.56	5.33	8.03±2.12	5.33-12.21
NFE (%)	37.62	32.37	39.59	36.53±3.73	32.73-39.59
ME (Kcal kg^{-1})	2937.50	2275.70	2525.02	2578.74±335.14	2275.70-2937.50

Table 3: Fibre partition of the leafs of selected plants from southeastern Nigeria

Parameters (%)	*Gongronema latifolium*	*Mucuna pruriens*	*Garcinia kola*	Mean±SD	Range
NDF	43.13	58.86	44.42	48.80±8.73	43.13-58.86
ADF	32.57	40.68	38.12	37.12±4.15	32.57-40.68
ADL	12.07	11.34	18.22	13.88±3.78	11.34-18.22
Cellulose	20.50	29.34	19.90	23.25±5.29	19.90-29.34
Hemicelluloses	10.5	18.18	6.30	11.66±6.02	6.30-18.18

Table 4: Macro-minerals compositions of the leafs of selected plants from southeastern Nigeria

Parameters	*Gongronema latifolium*	*Mucuna pruriens*	*Garcinia kola*	Mean±SD	Range
Ca (mg kg^{-1})	15556.72	8648.17	9774.56	11326.48±3706.53	8648.17-15556.72
P (mg kg^{-1})	3202.65	2915.59	1614.16	2577.47±846.50	1614.16-3202.65
Mg (mg kg^{-1})	5631.18	2282.76	3046.44	3653.46±1754.80	2282.76-5631.18
K (mg kg^{-1})	26301.60	16287.19	7041.57	16543.45±2632.57	7041.57-26301.60
Na (mg kg^{-1})	1502.50	1786.64	800.77	1363.30±507.46	800.77-1786.64
Ca/P ratio	0.486	2.97	6.06	3.71±2.79	0.486-6.056
Na/K ratio	0.5813	0.4725	0.114	0.58±0.47	0.114-0.5813

recorded the highest packaged bulk density, while *M. pruriens* and *G. kola* had similar values. The *G. latifolium* and *G. kola* also recorded the highest and similar loose bulk density. The *G. kola* had higher water holding capacity (WHC) value than those of the *M. pruriens* and *G. latifolium*.

Proximate and metabolizable energy compositions: Table 2 shows the proximate and metabolizable energy compositions of the leaf meals of the selected plants from southeastern Nigeria. The crude protein content of *G. latifolium* and *M. pruriens* were higher than that of *G. kola*. *G. latifolium* and *G. kola* yielded relatively high crude fat contents, while the crude fiber contents of *M. pruriens* were also high. Total ash content was high in *G. latifolium* than in *M. pruriens* and *G. kola*.

Fibre fractions of the sampled leaves: Table 3 shows the fiber partition of leaf meals of the selected plants. The *M. pruriens* recorded the highest NDF, while *G. kola* and *G. latifolium* had lower values. Again, *G. kola* recorded the highest ADL value, while *G. latifolium* and *M. pruriens* recorded lower and similar values. However, *M. pruriens* recorded the highest cellulose values, while *G. latifolium* and *G. kola* had lower and similar values. Again, *M. pruriens* recorded a hemicellulose value, which was much higher than the values recorded by *G. latifolium* and *G. kola*.

Macro minerals compositions of sampled leaves: Table 4 shows the macro-mineral compositions of the leave of the selected plants from southeastern Nigeria. The *G. latifolium* recorded the highest Ca values followed by *G. kola* and *M. pruriens*. All the plants were rich in phosphorus. *G. latifolium* however recorded the highest Mg and K, while *M. pruriens* recorded the highest Na values.

Micro-minerals compositions of sampled leaves: Table 5 shows the micro-mineral composition of leafs of selected plants from southern Nigeria. The *G. kola* and *G. latifolium* recorded the highest Mn values, while *M. pruriens* recorded a low value. The *G. kola* recorded the highest Cu followed by *M. pruriens* and *G. kola*. *G. latifolium* recorded the highest values Zn values followed by *M. pruriens* and *G. kola*. All

Table 5: Micro-minerals composition of leafs of selected plants

Parameters (mg kg^{-1})	*Gongronema latifolium*	*Mucuna pruriens*	*Garcinia kola*	Mean±SD	Range
Mn	240.88	25.21	302.06	189.38±145.43	25.21-302.06
Fe	383.81	213.66	459.68	352.38±125.98	213.66-459.68
Cu	19.49	28.45	65.38	37.77±24.32	19.49-65.38
Zn	75.46	53.41	23.37	50.75±26.15	23.37-75.46
Co	0.00	0.00	0.00	0.00	0.00-0.00
Cr	24.49	53.41	9.94	29.28±22.13	9.94-53.41
Pb	0.00	0.00	0.00	0.00	0.00-0.00
Ni	1.50	3.99	0.00	1.83±2.02	0.00-3.99

Table 6: Medicinal phytochemical contents of the selected plants

Parameters	*Gongronema latifolium*	*Mucuna pruriens*	*Garcinia kola*	Mean±SD	Range
Carotenoids (mg kg^{-1})	116.76	119.32	115.64	117.24±1.87	115.64-119.32
Terpenoids (mg kg^{-1})	266.25	270.00	250.00	2620.08±10.63	250.00-270.00
Anti-oxidants (mg kg^{-1})	329.70	516.70	544.70	463.70±116.89	329.70-544.70
Phenol (mg kg^{-1})	5500.00	6800.00	6400.00	6233.33±665.83	5500.00-6800
Flavonoids (mg kg^{-1})	1872.00	1454.40	1800.00	1708.80±223.24	1454.40-1872.00
Alkaloids (%)	2.23	2.83	1.83	2.15±0.73	1.83-2.83

Table 7: Anti-nutrient composition of selected leaf plant from southeastern Nigeria

Parameters (mg kg^{-1})	*Gongronema latifolium*	*Mucuna pruriens*	*Garcinia kola*	Mean±SD	Range
Tannin	3600.00	2400.00	2200.00	2733.33±757.19	2200.00-3600.00
Phytate	0.52	0.50	0.502	0.51±0.01	0.50-0.52
TI	1550.00	910.00	930.00	1130.00±363.87	910.00-1550.00
Oxalate	6380.00	5060.00	3850.00	5096.66±1265.40	3850.00-6380.00
Saponin	1.50	2.38	2.38	2.09±0.51	1.50-2.38
Cyanide	0.06	0.02	0.05	0.04±0.02	0.02-0.06

TI: Trypsin inhibitor

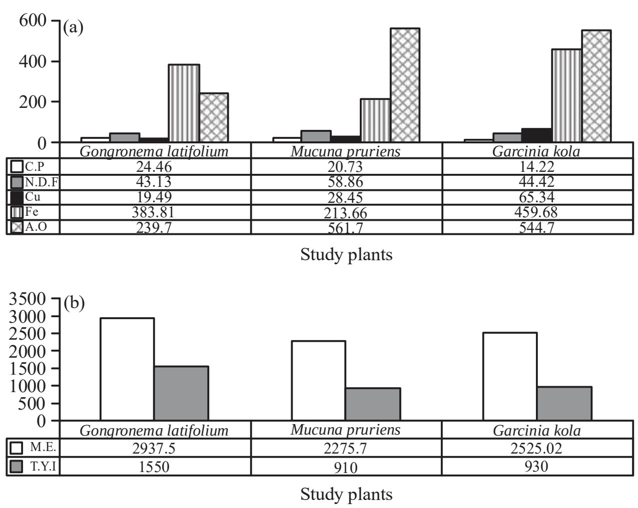

Fig. 1(a-b): Comparison of the mineral richness of the different leaf meals

the selected leaf plants showed no traces of Co in them. *M. pruriens* recorded the highest Cr values, while *G. kola* recorded the lowest values. Zero traces of Pb were recorded in the selected plants. The *M. pruriens* and *G. latifolium* recorded Ni values of 3.99 and 1.50 mg kg^{-1}, respectively, while no traces of Ni were recorded in *G. kola.*

Medicinal phytochemical contents of sampled leaves: Table 6 shows the medicinal phytochemical content of selected leaf plants from southeastern Nigeria. The *M. pruriens* and *G. latifolium* recorded the highest carotenoids values. *M. pruriens* had the highest terpenoid value, while *G. kola* recorded the lowest values. *G. kola* on the other hand recorded the highest total anti-oxidant values, followed by *M. pruriens* and *G. latifolium*. *M. pruriens* recorded the highest phenol and alkaloid values.

Anti-nutrients: Table 7 shows the anti-nutrient compositions of the selected plant leaves from southeastern Nigeria. *G. latifolium* recorded the highest values of tannin followed with *M. pruriens* and *G. kola*. *G. latifolium* had the highest phytate, oxalate and trypsin inhibitor value, while *M. pruriens* and *G. kola* had lower values. The three plants had low trace amounts of cyanide.

Alternative feed raw materials score: Figure 1 showed the scoring of the candidacy of the dried leaf meals as possible alternative feed raw materials for monogastric feeding trials. The scoring was based on the crude protein, metabolizable energy, copper, iron, anti-oxidants and trypsin inhibitor contents of the leaf meals. These parameters were selected

Table 8: Numerical scoring of the study plants

Parameters	*Gongronema latifolium*	*Mucuna pruriens*	*Garcinia kola*
CP	1	2	3
NDF	3	1	2
CU	3	2	1
FE	2	3	1
AO	3	1	2
ME	1	3	2
TY1	3	1	2
	16	13	13

as important representative components of the physicochemical properties of the study materials, in order to arrive at a functional and practical score for candidacy selection based on this scoring protocol. It was determined that *M. pruriens* and *G. kola* leaf meals are superior to *G. latifolium* (Fig. 1). Again on a score of 1-3 across the appraisal parameters, where 1 is the most positive score and 3 is the most negative, values of 13, 13 and 16 were computed for *G. kola*, *M. pruriens* and *G. latifolium,* respectively (Table 8).

DISCUSSION

Usually feedstuffs have nutritional, toxicological and microbial characteristics[34]. The nutritional characteristics could be divided into the biophysical and biochemical components that determine nutrient uptake and availability, respectively[35]. Information on the proximate composition and sometimes the toxicology of novel feedstuffs has been used routinely in determining the suitability of such feedstuffs in poultry feeding, especially during animal feeding trials. Limited information however exists on the biophysical and other characteristics of such novel feedstuffs[35]. Since the nutritional characteristics of a finished ration is an aggregation of the proximate, physical and toxicological characteristics of the individual ingredients used in compounding the ration, proper understanding of all these component characteristics in all the raw materials used in formulating a ration is imperative. Such information could be used in developing protocols for determining the candidacy of a suspected novel feed stuff that could be employed in subsequent animal feeding trials.

The *G. latifolium* and *G. kola* recorded the highest loose bulk density of 0.35 g mL^{-1} each and these values are similar to the values obtained by Omede[27] for *Microdesmis puberula* leaf meals produced in the same study area. The water holding capacity (WHC) value of *G. kola* at 440% was much higher than those of the two plants and this result indicated that *G. kola* dry leaf meal will absorb more water than the others when included in the diets of monogastrics. Omede *et al.*[25] has shown that information on macro biophysical properties of novel feedstuffs such as their bulk density and WHC could be used together with proximate and toxicological information to determine the nutritional and intake potentials of novel feedstuffs even before a feeding trial. Implication of this is that level of inclusion of each these leaf meals in final feed formulation will be influenced by these variations in physical characteristics and would influence the ceiling of inclusion. However, the physical characteristics of all groups of feed raw materials used in Nigeria are not known indicating that currently there are no standards on this vital issue for feed manufacturers[36]. It is known that the performance of any compounded feed is a summary of the individual contributions from the different raw materials used in producing such feed. This according to Omede *et al.*[37,38] makes it imperative to consider the quality of feed raw materials not only in terms of their chemical but also of physical quality in the formulation of commercial feeds.

The dry matter values were high at the range of 95.20-96.40 indicating that the materials were very dry and could be stored for extended periods without fungal contamination. The crude protein content of *G. latifolium* and *M. pruriens* were as high, indicating that they could form rich protein sources for monogastric feeding[32,39]. The lower crude fiber content of *G. latifolium* (15.39%) may be reflecting it knows value human in food preparations and recent trials in poultry and rabbits[8,40]. The Nitrogen free extract which is a reflection of the carbohydrate content of a feed stuff ranged from the 32.37% recorded for *M. pruriens* to the 39.51% recorded in *G. kola* indicating that these leaf meals may be high in gross energy. The ME value of *G. latifolium* at 2937.50 kcal kg^{-1} was quite high for a leaf meal and compares favorably with values obtained for grains by products[41]. The ME value of *G. kola* was also high at 2525.02 kcal kg^{-1} indicating that these leaf meals can replace substantial portions of energy and protein ingredients in the diet of monogastrics[42].

The mean values of NDF, ADF, ADC, cellulose and hemicelluloses for the three plants were high indicating that on equal weight basis a cocktail of the leaf meals will yield such values on an analysis. However, yield better digestible fibre[9]. Again, the mean values of different macro-minerals reflect probable values derivable from a cocktail of the three leaf meals. Chromium is a known strong metallic antioxidant that processes up to 7^{+} anions. Therefore, the relatively high Cr (53.41 mg kg^{-1}) content *M. pruriens* points to its possible value as a source of strong antioxidant extract.

The carotenoids content of many leaf meals are useful in producing yellow the color of yolk and shank when such leaf meals are fed to laying hens and broilers[42]. These values are relatively high and show that the analyzed leaf meals have potent antioxidant functions which could be beneficial in the improvement of nutrient utilization, cellular integrity and antimicrobial activities[43]. Specifically, amongst all diet, antioxidants rich diets have recently gained special importance for growth, survival and maintenance of productive and reproductive health of the animal. The three plants studied were rich in phenolic compounds which include tannins which are also phenols. However, since phenols may also have anti-oxidant functions. It is expected that this high phenolic content of the leaf meals contributed to the rich anti-oxidant values recorded in the present study. Furthermore, many tropical medicinal plants have before shown to be rich in polyphenolic compounds[44]. The *G. latifolium* recorded the highest flavonoid content of the leaf meals. This again should again be seen as beneficial attributes since several studies have reported the beneficial effects of flavonoids as aromatase inhibitors and among many other animal reproduction and functions[35]. Many flavonoids are also known to function as beneficial antioxidants since they consist of the largest group of phenolics[45]. Again, the total alkaloid content of the leaf meals was high confirming the use of *G. latifolium* and *M. pruriens* leaf extracts in indigenous medicines, especially as antimicrobial substances[8] and blood profile enhancement[39] as well as uterine stimulant and aphrodisiacs[21].

Tannin, even though an anti-nutrient that has astringent properties has also been shown to be a strong botanical antioxidant that has found value in the management of coccidial infections of poultry[43]. However, the high values recorded in the leaf meals may require some form of treatment before they could be used in animal feeding. Alternatively, extracts from the leaf meals could be fed to animals as supplements, thus, reducing the quantity of tannins consumed. The present low phytate values of these plants indicate that most of the phosphorus found in the leaf meals is in their freely available state as also reported by Okoli *et al.*[9] similar for 7 tropical browses from the same study area.

The level of trypsin inhibitors recorded in the leaf meals, especially in *G. latifolium* may present a strong draw back in the effective utilization of these leaf meals in monogastric animals feeding, since they may compromise protein digestion. However, heat treatment has been shown to effectively minimize the untoward effects of trypsin inhibitors on protein digestion[42]. The oxalate values of the leaf meals were high, especially for *G. latifolium* and may explain why it is use as spices in indigenous foods and not as full vegetable condiment in the preparation of foods[18,46]. However, all the plants showed low trace amounts of cyanide at 0.06, 0.05 and 0.02 mg kg^{-1}. Saponins even though an anti-nutrient has also been shown to exhibit strong antioxidant effects and because of this has been found useful in the treatment of protozoan infections such as poultry coccidiosis[43,47].

It was determined that *M. pruriens* and *G. kola* leaf meals are superior to *G. latifolium* (Fig. 1). Again on a score of 1-3 across the appraisal parameters, where 1 is the most positive score and 3 is the most negative, values of 13, 13 and 16 were computed for *G. kola*, *M. pruriens* and *G. latifolium* respectively (Table 8) indicating that *G. kola* and *M. pruriens* may serve as better alternatives raw materials leaf meals for monogastric animal feeding trails. Similar candidate alternative feed raw material scores were developed by Okoli *et al.*[32] based on indigenous use ranking and crude protein contents of 93 browse plants identified in southeastern Nigeria. Therefore, the present study is an attempt at developing more detailed laboratory protocols for selecting such candidate alternative feed raw materials for monogastric animal feeding trials.

CONCLUSION

The study has shown that apart from their medicinal attributes, *G. latifolium*, *G. kola* and *M. pruriens* have promising animal feed benefits in terms of crude protein, soluble fibres, micro and macro-minerals. Based on the developed scoring technique, *G. kola* and *M. pruriens* with scores of 13 each may be regarded as better plants for monogastrics feeding trial. It is recommended that further research be carried out on not just these three selected leaf meals but also on all leaf meals intended for use as alternative raw materials for animals feeding trials in the study environment.

SIGNIFICANCE STATEMENT

The study has shown that the leaf meals of *Gongronema latifolium*, *Garcinia kola* and *Mucuna pruriens* plants are abundant in essential nutrients and pharmacological active compounds hence proving their suitability in animal production. The information provided on the nutritional and pharmacological composition of *G. latifolium*, *G. kola* and *M. pruriens* leaf meals may be employed in developing protocols for investigating the candidacy of other novel leaf meals for use in animal feeding and medications. This study also demonstrated that *G. kola* can replace substantial portions of conventional energy and protein concentrates in the rations of monogastrics. The high chromium content in *M. pruriens* and high concentration of alkaloids in *G. latifolium* and *M. pruriens* as demonstrated in this study makes it an important raw material with the potential for industrial application and commercialization.

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