Review Article

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Nutritional and chemical composition of black velvet tamarind (*Dialium guineense* Willd) and its influence on animal production: A review

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Abstract: The world population is expected to double by 2050, creating a greater demand for animal protein sources. This calls for an increase in the supply of animal-derived foods in order to avoid food scarcity in the future. Non-ruminants, which would have been a panacea to this increased demand for animal-derived foods, have suffered from the rising costs of feed ingredient world-wide. The increase in the prices of conventional feedstuffs have attracted the attention of researchers on the potentials of lesser-known tropical medicinal plants like *Dialium guineense* Willd (black velvet tamarind) as a feed resource for non-ruminants. The increase in prices of conventional feedstuffs have attracted the attention of researchers on the potentials of lesser-known tropical medicinal plants. One such lesser-known tropical plant that can be used in chicken and livestock production is black velvet tamarind. The plant is found in many parts of the world. It belongs to the family Fabaceae, has high forage yield, resistant to drought and insects, and does not require annual cultivation. The whole seed is moderate in crude protein and fibre but high in carbohydrates. The leaf, on the other hand, is low in carbohydrate, moderate in crude protein, and high in ash. *D. guineense* stem bark and fruit are excellent source of essential oils, and rich source of dietary fibre, minerals, and vitamins for monogastrics. The plant is endowed with beneficial phytochemicals such as alkaloids, tannins, phenols, flavonoids which may serve as natural alternatives to in-feed antibiotics. *D. guineense* has beneficial pharmacological effects including antioxidant and antimicrobial properties. The purpose of this study was to review the body of knowledge on the nutritional and chemical composition of *D. guineense* and its impact in animal production.

Keywords: black velvet tamarind, chemical composition, antioxidant, antimicrobial, animal production

1 Introduction

Animal production plays an important role in the socio-economic wellbeing of smallholder farmers in developing nations and is one of the sources of protein for the teeming human population. However, animal products are still considered as luxury by the majority of people in developing countries. This is largely due to the high cost of products, which is controlled mainly by the high cost of feed, and this has burdened researchers on how to find cheaper feed ingredients to reduce cost of feed. Availability of several close substitute feedstuff could ameliorate the high cost of feed for animals by reducing the problem of scarcity. Alternative cheaper and available feedstuff is the only means of reducing the production cost of animal products, and this could be achieved through the use of lesser-known tropical medicinal plants. Tropical medicinal plants are abundant in nutrients and beneficial phytochemicals, making it suitable as feed [1–5]. Black velvet tamarind (*Dialium guineense* Willd) is a medicinal plant widely grown in many West African countries. It is also believed to have nutraceutical health benefits due to its richness in beneficial phytochemicals [6]. Given the benefits of medicinal plants in animal production, the objectives of this review are to (i) provide information on

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the proximate and nutritional composition of different parts of black velvet tamarind to maximise their potential as feed; (ii) to summarize the phytochemical and pharmacological properties found in the different parts of black velvet tamarind, and (iii) to discuss the origin, botany, and taxonomy of black velvet tamarind.

2 Literature search and study selection

Five online databases (Scopus, PubMed, Web of Science, Google scholar, and Google search engine) were searched for published studies that evaluated the nutritional and chemical composition of black velvet tamarind and its influence on animal production. Literature search was not restricted by date and the search terms used were origin, taxonomy, botanical description, proximate composition, nutrient values, phytochemistry and pharmacological properties, and farm animals. Authors also searched the reference lists of retrieved papers for related studies. Papers included in the study met the following conditions: (i) described the origin, taxonomy, botany, and uses of black velvet tamarind, (ii) assessed the proximate, nutrient, phytochemical, and pharmacological properties of different parts of black velvet tamarind, and (iii) evaluated the effect of different parts of black velvet tamarind plants on the performance indices of farm animals. The requirements for inclusion in the dataset were satisfied by 32 studies out of the 183 papers retrieved from the search performed on the five online databases. Eighty-five publications were excluded after reading the titles and abstracts because they were duplicates across two or more databases. Sixty-three articles were also excluded from the study for being reported in small laboratory animal models. Three studies published in language other than English were also excluded.

3 Origin, taxonomical, and botanical description of *Dialium guineense* Willd

Black velvet tamarind is a leguminous plant in the Fabaceae family and Caesalpinioideae sub-family. The taxonomic positions of black velvet tamarind are as follows:

Kingdom: Plantae
Clade: Tracheophytes
Clade: Angiosperms
Clade: Eudicots
Clade: Rosids
Order: Fabales
Family: Fabaceae
Genus: *Dialium*
Species: *guineense*

The tree grows up to 30 m height. *D. guineense* Willd is a woody plant that thrives well in the rainforest region of West Africa [6]. *D. guineense* Willd has a densely hairy leafy crown, smooth grey bark, and whitish flowers that bear the thick black fruits. Each fruit has a single hard, flat, round, brown seed measuring 7–8 mm long and 3 mm thick. The seeds are shiny and coated with a small layer of starch.

4 Uses of *Dialium guineense* Willd

The barks, leaves, and fruits of *D. guineense* Willd are utilised in traditional medicines [6,7]. Several parts of the plant are used in folk medicine to cure fever, prenatal pains, and oedema; the fruit is used to treat diarrhoea [7]. The stem bark is used for the treatment of cough, toothache, and bronchitis [7]. The pulp is edible and may be eaten raw or soaked in water and consumed as a beverage. The bitter leaves are ingredients in a Ghanaian dish called domoda. Its wood is hard and is used for construction, firewood, and charcoal production. The spermatogenic and anti-ulcerogenic effect of the *D. guineense* leaf meal in animal models has been reported [8,9]. There are claims among women in south-eastern Nigeria that black velvet tamarind fruit pulps improve lactation.

5 Chemical composition of *D. guineense*

5.1 Proximate composition

Proximate analysis results are widely used in nutritional assessment and in the industry for quick evaluation of the nutrient value of plant materials. While such analyses may not give the true pictures of the nutrient content of the test material, they do provide clues for further analysis. Velvet tamarind has received a lot of attention in animal production because of its numerous nutritional benefits [10,11]. The results of the nutrient content of *D. guineense* leaves and stem barks as reported by several authors are summarized in Tables 1 and 2. The chemical composition indicates that *D. guineense* leaves and stem

Table 1: Proximate composition of *D. guineense* leaves

Nutrients (%)	Leaves*	Leaves**	Whole seed***	Pulp***
Gross energy (kJ/g DM)		19.44		
ME (kJ/g DM) *in vitro*		4.97		
Crude protein	12.64–18.72	14.28	17.44	3.94
Ether extract	1.02–1.31		35.33	5.34
Carbohydrates	6.46–9.39		43.90	58.65
Crude fibre	13.34–14.29		13.52	1.05
Total ash	17.86–22.72	7.80	2.55	12.52
NDF		61.65		
ADF		45.14		
Hemicellulose		16.51		
ADL		20.48		
Cellulose		24.66		

Adapted from Awotedu et al. [13]*, Osakwe et al. [12]**, and Osanaiye et al. [14]***; NDF – neutral detergent fibre; ADF – acid detergent fibre; ADL – acid detergent lignin; DM – dry matter.

bark are good sources of essential nutrients [12,13]. Results suggest that *D. guineense* fruit pulp is low in protein and may not serve as a source of protein in animal feed [14]. *D. guineense* leaves and whole seeds are moderate in protein suggesting that it could be a moderate protein supplement for non-ruminant feeding [13,17]. The higher digestible fibre content, on the other hand, suggests that *D. guineense* leaves may be added to feed to aid nutrient digestibility. The total ash content of *D. guineense* leaves and pulp is higher than that of the whole seeds. Most minerals used in animal feed are found in inorganic form which means they may not be readily bioavailable to the animals, owing to mineral antagonism resulting in decreased nutrient absorption [18]. The high ash content of *D. guineense* leaves and pulp, which is a reflection of mineral content of a feedstuff, suggest that this plant may be high in beneficial minerals. As indicated in Table 1, black velvet tamarind, particularly the fruit pulp, is high in complex carbohydrates. The fruit pulp is also rich in vitamins and minerals, as well as carbohydrates [15]. All these properties may have given *D. guineense* its therapeutic potential. In addition, *D. guineense* stem bark has high amounts of B vitamins such as B1 (thiamine), B2 (riboflavin), and B3 (niacin) [15].

Table 2: Vitamin and mineral compositions of *D. guineense* stem bark extracts

Parameter	Extracts	
	Aqueous	Ethanol
Vitamins (mg/100 g)		
B1 (thiamine)	67.71 ± 2.61	95.36 ± 5.00
B2 (riboflavin)	324.75 ± 7.24	532.38 ± 10.00
B3 (niacin)	103.32 ± 4.93	127.56 ± 6.04
B6 (pyridoxine)	2.15 ± 0.31	5.25 ± 0.95
B7 (biotin)	4.38 ± 0.51	7.03 ± 1.20
A	2.07 ± 0.41	2.91 ± 0.50
C	8.13 ± 1.00	12.13 ± 1.20
E	0.04 ± 0.01	0.07 ± 0.02
Minerals (mg/kg)*		
Selenium	38.75 ± 2.01	35.45 ± 1.93
Manganese	9.47 ± 0.53	5.23 ± 0.41
Zinc	5.87 ± 0.06	7.12 ± 0.35
Chromium	0.01 ± 0.00	0.03 ± 0.00
Vanadium	0.02 ± 0.00	0.03 ± 0.00
Calcium	6.54 ± 0.60	8.43 ± 0.70

Source: Abu and Onoagbe [15] and Abu et al. [16]*.

5.2 Nutrient composition and essential oil (EO)

D. guineense pulp is abundant in minerals (Table 3), whereas the seeds and the fruit coats are poor in potassium and sodium, respectively [19]. The mineral content of *D. guineense* pulp reported by Ofosu et al. [19] was higher than the value reported by Adepoju [20], which could be attributed to the difference in the analytical methods and soil types. Similarly, Gnansounou et al. [21] and Osanaiye et al. [14] reported that *D. guineense* pulp is high in micronutrients, particularly iron, magnesium, and calcium. The various parts of *D. guineense* are high in total ash suggesting that the plant is a source of mineral in animal feed. The leaf and fruit pulp of *D. guineense* are high in vitamin C [22], which may explain why it is known as the vitamin C plant. Therefore, the relatively high ascorbic acid content indicates that it could be

Table 3: Mineral characteristics of different parts of *D. guineense*

Elements (µg/g)	Fruit coat	Pulp	Seed
Manganese	88.81	23.40	574.20
Chlorine	203.30	205.40	131.90
Calcium	5428.00	5671.00	5954.00
Sodium	nd	332.95	365.58
Magnesium	874.20	910.10	4401.00
Potassium	5.64	6190.00	nd
Aluminium	136.10	161.40	275.40
Vanadium	0.42	0.46	1.19

Adapted from Ofosu et al. [19]; nd – not detected.

Table 4: EOs collected from *D. guineense*

Plant part	Weight of sample (g)	Weight of EO (g)	% Yield of EO	Physical examination
Leaf	320	0.2	0.06	Acceptable leafy odour
Stem bark	315	0.3	0.10	Sweet woody odour
Fruit	500	0.3	0.06	Pleasant fruity odour

Source: Moronkola et al. [23].

used as a source of dietary antioxidant. The plant is a source of EOs (Table 4) which may explain why it is used in management of several diseases in traditional medicine [24]. EOs are complex mixtures of hydrocarbons and oxygenated hydrocarbons derived from the isoprenoid pathways, with monoterpenes and sesquiterpenes making up the majority. *D. guineense* EOs are dominated by aliphatic alkanes and aldehyde [25,26]. A study by Essien et al. [24] found that *D. guineense* leaf oil is high in precocene I followed by β-caryophyllene, valencene, and cadalene, whereas Pelissier et al. [26] discovered that the fruit pulp is high in EOs such as nonanal, nonanoic acid, and dodecanoic acid. The presence of high concentrations of precocene I in *D. guineense* leaf oil reinforces the antimicrobial properties of the plant [10].

6 Phytochemical composition

Phytochemical assay is one of ,the steps in the isolation of novel substances with promising bioactivities. The plant is high in organic acids (malic, ascorbic, tartaric and citric) and sugars [22,27,28], which may serve as cheap and readily available eco-friendly feed additives in non-ruminant nutrition. Table 5 indicates that black velvet tamarind contains tannins, alkaloids, saponins, flavonoids, steroids, and cardiac glycosides [15,16,29–32]. Phytochemicals are abundant in *D. guineense* stem bark [33]. Similarly, *D. guineense* leaves are endowed with important phytochemicals [31,34]. The presence of several bioactive compounds in *D. guineense* may be linked to its medicinal properties [35]. Flavonoids present in *D. guineense* have been confirmed to have anti-ulcerogenic and cytoprotective effects [36]. Phenolics are the most abundant group of phytochemicals and are abundant in *D. guineense*, accounting for most of the plant antioxidant activity. The ability of plant to scavenge free radicals increases as its phenol content increases [37]. Abu and Onoagbe [16] and Abu et al. [38] found that *D. guineense* contains high levels of phenols, flavonoids, saponins, and tannins, which may explain why it is used in traditional medicine. Flavonoid is one of the most potent antioxidants found in tropical plants [39]. This finding is consistent with others who reported that tropical medicinal plants are high in phenolics [39]. Jolayemi et al. [40] put the flavonoid content of *D. guineense* fruit pulp at 860.63 mg/100 g which is higher than the value of 305–661 mg/100 g recorded for *Dacryodes edulis* and *Irvingia gabonensis* in Nigeria. Saponins exhibits hypocholesterolemic property by blocking the re-absorption of cholesterol in body, implying that *D. guineense* can be added to animal feed to improve the cholesterol content of the meat, egg, and milk. *D. guineense* may accomplish this by inhibiting the activity of hydroxy methylglutaryl CoA reductase, a key enzyme in cholesterol production. Its stem-extract contains alkaloids which possess several pharmacological effects like antihypertensive, molluscicidal, antiarrhythmic, anticancer, and antimicrobial [20]. Pathogens have negative impact on animal production as well as animal product quality [41–43]. Antibiotics were added to feed to suppress the bacterial activity and improve the performance until the development of antibiotic-resistant bacteria [44–46]. The use of herbal products to tackle this problem is becoming more common [47–50]. The reported antimicrobial activity of *D. guineense* [51] suggests that *D. guineense* could replace antibiotics in animal feed with a minimal chance of development of antimicrobial

Table 5: Phytochemical content and total antioxidant capacity (TAC) of various parts of *D. guineense* plant

Parameters	Concentration (mg/100 g)			
	Pulp	Stem bark	Seed	Leaf
Saponins	0.00	25.82	48.10	0.00
Tannins	0.00	7.59	23.06	0.00
*Condensed tannin (% DM)				5.97
Phenol	13.43	17.34	12.75	15.77
Flavonoids	35.44	47.64	36.60	12.44
Terpenoids	19.07	0.00	21.79	25.68
Cardiac glycoside	22.35	24.02	46.48	0.00
TAC	36.85	26.84	33.15	27.96

Adapted from Oluwole-Banjo [30]; Osakwe et al. [12]*; DM – dry matter.

resistance as well as growth promoters. Abu et al. [52] found that *D. guineense* stem bark is high in saponins and tannins. The use of tannins in the management of coccidal infection in poultry has been demonstrated [39].

7 Pharmacological properties

7.1 Antioxidant activity

Phytochemical constituents are the naturally occurring antioxidant in plants [53] and exhibit redox properties [53,54]. Studies have shown that *D. guineense* leaf extract exhibits *in vitro* antioxidant activity [10,55] and may be used as a source of antioxidants in livestock and chicken diets. Antioxidant-rich diets have gained prominence in animal nutrition because of assumed positive impacts on animal health, growth, and productivity. It is expected that this high levels of phenols and flavonoids in various parts of *D. guineense* plant contributed to the rich antioxidant potentials of the plant. Gideon et al. [55] investigated the *in vitro* antioxidant activity of *D. guineense* leaf and discovered a dose-related increase in 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity when compared to ascorbic and gallic acids. The antioxidant activities of methanolic *D. guineense* pulp, seed, leaf, and stem bark extracts have been reported [30]. The methanolic extracts of black velvet tamarind pulp, seed, leaf, and stem bark show a concentration-dependent increase in DPPH radical scavenging and nitric oxide scavenging activities (Table 6). These findings supported Gideon et al. [55], who reported the antioxidant property of *D. guineense* (Willd) leaf extract. The dose-related increase in DPPH radical scavenging properties of black velvet tamarind plant demonstrates its ability to scavenge free radicals. This might be attributed to the high concentrations of phenolics in black velvet tamarind extracts (Table 6). Similarly, Oluwole-Banjo [30] reported that *D. guineense* pulp, seed, stem bark, and leaf extracts have high total antioxidant capacity which aids in the neutralization and absorption of free radicals as well as quenching singlet and triplet oxygen [56].

7.2 Antimicrobial activity

The principal mechanism of action of natural feed additives is the modulation of gut beneficial microbes by exclusion of pathogens. Previous studies have shown antimicrobial activities of phytochemical constituents from different parts of *D. guineense* [10,55,57]. Besong et al. [10] investigated the antimicrobial activities of leaf extract of *D. guineense* following the methods of Rath et al. [58]. The authors found that gram-positive bacteria were more susceptible to the extracts than fungi and gram-negative bacteria, suggesting that the extract could be used in animal production to manage bacterial infections. In contrast, Nnadi et al. [59] found that *D. guineense* fruit coat extract had stronger effect on gram-negative bacteria than gram-positive. However, the disparity may be attributed to the part of the plant used which has been reported to influence the phytochemical content of plants [10]. *D. guineense* leaf extract has demonstrated broad antimicrobial activity

Table 6: DPPH inhibition and scavenging of nitric oxide by the methanolic extract of *D. guineense* plant

Concentration (µg/mL)	Pulp (%)	Stem bark (%)	Seed (%)	Leaf (%)	Ascorbic acid (%)
DPPH					
20	35.40	39.29	36.31	43.95	46.50
40	40.10	43.25	41.47	49.36	61.40
60	59.70	62.80	65.15	65.65	70.20
80	67.85	69.12	71.06	72.25	74.50
100	71.20	71.96	73.00	77.80	83.25
IC_{50}	50.00	45.00	43.00	35.00	25.00
Nitric oxide					
20	23.77	31.66	39.28	36.20	43.47
40	29.20	44.96	49.80	47.48	54.08
60	47.44	60.34	65.75	58.15	60.15
80	68.35	67.32	70.55	69.51	74.35
100	75.70	78.17	80.52	77.35	85.95
IC_{50}	62.00	50.00	42.00	42.00	34.00

Adapted from Oluwole-Banjo [30]; IC_{50} – half maximal inhibitory concentration.

suggesting their wide application in animal production for the treatment of bacterial infection [55]. In a similar study using stem bark extract, Olajubu et al. [57] found potent action of *D. guineense* stem bark extract against *Salmonella typhi* and *S. aureus*. These reports are in agreement with Besong et al. [10] who found antimicrobial activities of *D. guineense* leaf extract. A recent study by Ololade et al. [60] revealed that methanol *D. guineense* leaf extract had greater antimicrobial activity than gentamicin. The antibacterial activity of *D. guineense* is attributed to the hydrophobicity of its bioactive compounds, which permeate the bacterial cell membrane resulting in disintegration of cell membrane, leakage of ions, and ultimately cell death [61]. Olajubu et al. [57] also found that *Candida albicans* was inhibited by *D. guineense* stem bark extract. Olajubu et al. [57] and Nnadi et al. [59] found that methanol *D. guineense* fruit coat extract had stronger antibacterial property than ethanol *D. guineense* stem bark extract.

8 Impact of adding *Dialium guineense* to animal feed

Research by Iwuji et al. [9] demonstrated that incorporation of *D. guineense* leaf meal (DGLM) at 3 g/kg feed improved the reproductive traits in males when compared to those fed with diet without *D. guineense* leaf meal. This implies that incorporation of up to 30% of *D. guineense* leaf meal in rabbit diet supported spermatogenesis. The diets containing DGLM as a protein supplement enhance the growth performance characteristics in aquatic animals [62]. Studies have shown linear decrease in total volatile fatty acid levels in the rumen when the supplementation levels of *D. guineense* leaves increased from 25 to 50% in sheep diet [15]. The authors also reported that supplementation of *D. guineense* leaves at 25 and 50% in sheep rations reduced ruminal ammonia concentration which they attributed to the high condensed tannin content of the leaf. This suggests that *D. guineense* leaf is not a good protein supplement for small ruminant, despite its high crude protein content. The high condensed tannin content in *D. guineense* leaves [15] implies that it may need some level of treatment before it could be used as a protein supplement in small ruminant feeding.

9 Conclusion

This review showed that *Dialium guineense* leaves and fruits are high in essential nutrients and may be added to livestock feed to boost growth and productivity. The plant is also a rich source of phytochemicals and EOs that are responsible for its high antioxidant and antimicrobial properties. In the light of the ban on the use of antibiotics as growth promoter, the bioactive compounds in various parts of *Dialium guineense* plant could be harnessed and used as eco-friendly growth promoters in animal production. There is scanty information on the effect of *Dialium guineense* on the performance and product quality of livestock and poultry in the literature. Therefore, the use of *D. guineense* leaf, stem bark, and fruits, and their bioactive constituents as natural feedstuffs and additives in livestock and chicken is recommended. In addition, studies on the safety of *Dialium guineense* leaf, stem bark, and fruits as well as the mechanisms of action of *Dialium guineense* are also recommended.

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References

[1] Yasudha K, Archana D, Mutyalamma B, Kishori B. Phytochemical screening, antimicrobial, and antioxidant activities of root and leaf extracts of *Leucas aspera*. Asian J Pharm Clin Res. 2019;12:141–7.

[2] Abdurohaman MY. Phytochemical extraction and screening of bio active compounds from black cumin (*Nigella sativa*) seeds extract. Am J Life Sci. 2015;3:358–64.

[3] Ogbuewu IP, Jiwuba PC, Ezeokeke CT, Uchegbu MC, Okoli IC, Iloeje MU. Evaluation of phytochemical and nutritional composition of ginger rhizome powder. Int J Agric and Rural Dev. 2014;17:1663–70.

[4] Chatoui K, Talbaoui A, Aneb M, Bakri Y, Harhar H, Tabyaoui M. Phytochemical screening, antioxidant and antibacterial activity of *Lepidium sativum* seeds from Morocco. J Mater Environ Sci. 2016;7:2938–46.

[5] Abhishek D, Dipankar C, Nikhil BG, Anupam C, Nripendranath M. Phytochemical analysis, antioxidant and anticancer potential of leaf extracts from edible greater yam, *Dioscorea alata* L., from North-east India. Int J Phytopharmacol. 2014;5:109–19.

[6] Akinpelu AD, Awotorebo TO, Agunbiade OM, Aiyegoro AO, Okoh IA. Anti-vibrio and preliminary phytochemical characteristics of crude methanolic extracts of the leaves of *Dialium guineense* (Willd). J Med Plants Res. 2011;5:2398–404.
[7] Arbonnier M. Trees, shrubs and lianas of West Africa dry zone. 2nd edn. GMBH: Margaraf Publishers; 2004.
[8] Nkanu EE, Ikpi DE, Jeje SO, Beshel JA, Otu GU, Odu PO. Aqueous fruit pulp of *Dalium guineense* protects against gastric acid secretion and decrease pepsin activity in albino wistar rats. Eur J Experntal Biol. 2016;6:28–32.
[9] Iwuji TC, Uzor VC, Kadurumba OE, Okere PC, Egenuka FC. Reproductive characteristics of adult rabbit bucks fed diets containing *Dialium guineense* leaf meal. Nig J Anim Sci. 2020;22:98–105.
[10] Besong EE, Balogun ME, Djobissie SFA, Obu DC, Obimma JN. Medicinal and economic value of *Dialium guineense*. Afri J Biomed Res. 2016;19:163–70.
[11] Florou-Paneri P, Giannenas I, Christaki E, Govaris A, Botsoglou N. Performance of chickens and oxidative stability of the produced meat as affected by feed supplementation with oregano, vitamin C, vitamin E and their combinations. Archive Geflugelkd. 2006;70:232–40.
[12] Osakwe II, Steingaβ H, Drochner W. The feeding value of *Dialium guineense* as a supplement to West African dwarf sheep fed natural grass hay. Der Tropentandwlrt, Beitrage zur tropischen Landwirtschaft und Veterinarmedizin. 1999;5:111–9.
[13] Awotedu OL, Ariwoola OS, Chukwudebe E, Ajekigbe JM. Analytical evaluation of four accessions of *Dialium guineense* (L.) leaves. Int J Sustaina Agric Res. 2020;7:134–42.
[14] Osanaiye FG, Alabi MA, Sunday RM, Olowokere T, Salami ET, Otunla TA, et al. Proximate composition of whole seeds and pulp of African black velvet tamarind (*Dialium guineense*). IOSR J Agric and Vet Sci. 2013;5:2319–72.
[15] Abu OD, Onoagbe IO. Vitamin contents of extracts of *Dialium guineense* stem bark. Biomed J Sci and Tech Res. 2020;30:23263–7.
[16] Abu OD, Onoagbe IO, Obahiagbon O. Analyses of metal and amino acid compositions of aqueous and ethanol stem bark extracts of *Dialium guineense*. Open Access J Biol Sci and Res. 2020;6:1–3.
[17] Atawodi SE, Yakubu OE, Umar IA. Antioxidant and hepatoprotective effects of *Parinari curatellifolia* root. Int J Agric and Biol. 2013;15:523–8.
[18] Soetan KO, Olaiya CO, Oyewole OE. The importance of mineral elements for humans, domestic animals and plants: a review. Afr J Food Sci. 2010;4:200–22.
[19] Ofosu DO, Opata NS, Gyampo O, Odamtten GT. Determination of the elemental composition of the pulp, seed and fruit coat of *Dialium guineense* using instrumental neutron activation analysis. Res J Appld Sci Eng and Tech. 2013;6:3536–9.
[20] Adepoju OT. Proximate composition and micronutrient potentials of three locally available wild fruits in Nigeria. Afr J Agric Res. 2009;4:887–92.
[21] Gnansounou SM, Noudogbessi JP, Yehouenou B, Gbaguidi ANM, Dovonon L, Aina M, et al. Proximate composition and micronutrient potentials of *Dialium guineense* willd growing in Benin. Int Food Res J. 2014;21:1603–7.
[22] Eremosele IC, Eremosele CO, Kuzhkuzha DM. Evaluation of mineral elements and ascorbic acid contents in fruits of some wild plants. Plant Food Nutr. 1991;2:151–4.
[23] Moronkola DO, Kunle OF, Olaoluwa O, Ogukwe C. Chemical compositions of *Dialium guineense* Willd leaf, stem-bark and fruit essential oils. J Complement and Alternat Med Res. 2017;3:1–8.
[24] Essien E, Ogunwande IA, Ogunbinu AO, Flamini G, Cioni PL. Analysis of the essential oil of *Dialium guineense* Willd. J Essent Oil Res. 2007;19:545–7.
[25] Odukoya OA, Houghton PJ, Adelusi A, Omogbai EKI, Sanderson L, Whitfield PJ. Molluscicidal triterpenoid glycoside of *Dialium guineense*. J Nat Prod. 1996;59:632–4.
[26] Pelissier Y, Haddad C, Marion C, Milhau U, Bessiere JM. Volatile constituents of fruit pulp of *Dialium guineense* Willd. (Cesalpinaceae). J Essent Oil Res. 2001;13:103–4.
[27] Okwu DE, Ekeke O. Phytochemical screening and mineral composition of chewing sticks in South Eastern Nigeria. Glob J Pure Appl Sci. 2003;9:235–8.
[28] Ubbaonu CN, Onuegbu NC, Banigo EOI, Uzoma A. Physicochemical changes in velvet tamarind (*Dialium guineense* Willd) during fruit development and ripening. Nig Food J. 2005;23:133–8.
[29] Arogba SS, Ajiboro A, Odukwe IA. Physico-chemical study of Nigerian velvet tamarind (*Dialium guineense*) fruit. J of the Sci of Food and Agric. 2006;66:533–4.
[30] Oluwole-Banjo AK. Phytochemical and antioxidant properties of methanolic extracts of pulp, seed, leaf and stem bark of velvet tamarind (*Dialium guineense*) plant. J Underutilized Legumes. 2019;1:159–68.
[31] David AA, Olaniyi AT, Mayowa AO, Olayinka AA, Anthony OI. Anti-vibro and preliminary phytochemical characteristics of crude methanolic extracts of the leaves of *Dialium guineense* (Willd). J Med Plants Res. 2011;5:2398–404.
[32] Ezeja MI, Omeh YS, Ezeigbo II, Ekechukwu A. Evaluation of the analgesic activity of the methanolic stem bark extract of *Dialium guineense* (Willd). Annals of Med and Hlth Sci Res. 2011;1:55–62.
[33] Gideon IO, Raphael A. Phytochemical analysis and *in vivo* antidiarrheal potentials of *Dialium guineense* (Willd) stem bark extract. J Intercult Ethnopharmacol. 2012;1:105–10.
[34] Ogu GI, Amiebenemo R. Phytochemical analysis and *in vivo* antidiarrheal potentials of *Dialium guineense* willd stem bark extract. J Intercult Ethnopharmacol. 2012;1:105–10.
[35] Raaman N. Phytochemical techniques. New Delhi, India: New India Publishing Agency. 2006;19–24.
[36] Borrelli F, Izzo AA. The plant kingdom as a source of anti-ulcer remedies. Phytother Res. 2000;14:581–91.
[37] Oki T, Masuda M, Furuta S, Nishida Y, Terahara N, Suda I. Involvement of anthocyanins and other phenolic compounds in radical-scavenging activity of purple fleshed sweet potato cultivars. J Food Sci. 2002;67:1752–6.
[38] Abu OD, Onoagbe IO, Obahiagbon O. Qualitative phytochemical screening and proximate analysis of *Dialium guineense* stem bark. IAR J Agri Res Life Sci. 2020;1:108–12.
[39] Okoli IC, Udedibie COI, Achonwa CC, Ogbuewu IP, Anyanwu NJ, Enemor VHA. Physicochemical characterizations of leaf meals derived from tropical plants as possible nutraceuticals in animal production. Asian J Biol Sci. 2019;12:693–701.
[40] Jolayemi OS, Olanrewaju OJ, Ogunwale O. Exploring *in vitro* antioxidants and physicochemical properties of selected 174 under-exploited tropical fruits. Acta Universitatis Cibiniensis Series E: Food Tech. 2020;24:166–74.

[41] AbdEl-Hack ME, El-Saadony MT, Shehata AM, Arif M, Paswan VK, Batiha GE, et al. Approaches to prevent and control Campylobacter spp. colonization in broiler chickens: a review. Environtal Sci and Pollut Res Int. 2021;28:4989–5004.
[42] Swelum AA, Elbestawy AR, El-Saadony MT, Hussein EO, Alhotan R, Suliman GM, et al. Ways to minimize bacterial infections, with special reference to *Escherichia coli*, to cope with the first-week mortality in chicks: an updated overview. Poult Sci. 2021;100:101039.
[43] Yaqoob MU, Abd El-Hack ME, Hassan F, El-Saadony MT, Khafaga AF, Batiha GE, et al. The potential mechanistic insights and future implications for the effect of prebiotics on poultry performance, gut microbiome, and intestinal morphology. Poult Sci. 2021;100:101143.
[44] Alagawany M, Madkour M, El-Saadony MT, Reda FM. *Paenibacillus polymyxa* (LM31) as a new feed additive: Antioxidant and antimicrobial activity and its effects on growth, blood biochemistry, and intestinal bacterial populations of growing Japanese quail. Anim Feed Sci and Tech. 2021b;276:114920.
[45] Alagawany M, El-Saadony MT, Elnesr S, Farahat M, Attia G, Madkour M, et al. Use of lemongrass essential oil as a feed additive in quail's nutrition: its effect on growth, carcass, blood biochemistry, antioxidant and immunological indices, digestive enzymes and intestinal microbiota. Poult Sci. 2021a;100:101172.
[46] Reda FM, El-Saadony MT, El-Rayes TK, Farahat M, Attia G, Alagawany M. Dietary effect of licorice (*Glycyrrhiza glabra*) on quail performance, carcass, blood metabolites and intestinal microbiota. Poult Sci. 2021;100:101266.
[47] Abou-Kassem DE, Mahrose KM, El-Samahy RA, Shafi ME, El-Saadony MT, AbdEl-Hack ME, et al. Influences of dietary herbal blend and feed restriction on growth, carcass characteristics and gut microbiota of growing rabbits. Italian J Anim Sci. 2021;1:896–910.
[48] El-Saadony MT, Zabermawi NM, Zabermawi NM, Burollus MA, Shafi ME, Alagawany M, et al. Nutritional aspects and health benefits of bioactive plant compounds against infectious diseases: a review. Food Rev Int. 2021;19:1–23.
[49] Saad AM, Mohamed AS, Ramadan MF. Storage and heat processing affect flavours of cucumber juice enriched with plant extracts. Int J Vegetable Sci. 2021a;27:277–87.
[50] Saad AM, Mohamed AS, El-Saadony MT, Sitohy MZ. Palatable functional cucumber juices supplemented with polyphenols-rich herbal extracts. LWT Food Sci Tech. 2021b;148:111668.
[51] Osuagwu GGE, Eme CF. The Phytochemical composition and antimicrobial activity of Dialium guineense, Vitex doniana and Dennettia tripetala leaves. Umuahia, Abia state: Department of Plant Science and Biotechnology, Michael Okpara University of Agriculture, Umudike. 2013.
[52] Abu OD, Adeogun EF, Ebhohon SO. Oral LD50 of total saponins and tannins isolated from *Dialium guineense* stem bark. Eur Exp Biol. 2019;9:8–11.
[53] Ogbuewu IP, Aladi NO, Etuk IF, Opara MN, Uchegbu MC, Okoli IC, et al. The relevance of oxygen free radicals and antioxidants in sperm production and function. A review. Res J Vet Sci. 2020;3:138–64.
[54] Agarwal A, Aponte-Mellado A, Premkumar BJ, Shaman A, Gupta S. The effects of oxidative stress on female reproduction: A review. Reprod Biol and Endocrinol. 2012;10:49.
[55] Gideon IO, Joachim E, John ME. Antioxidant and antimicrobial activities of *Dialium guineense* (willd) leaf extract. Pharmaceut and Pharmacol Res. 2013;1:1–7.
[56] Osawa T. Novel natural antioxidants for utilization in food and biological systems. In: Uritani L, Garcia VV, Mendoza EM, editors. Post harvest biochemistry of plant food materials in Tropics 1994. Tokyo, Japan: Japan Scientific Societies Press; 1994. p. 241–51.
[57] Olajubu F, Akpan I, Ojo D, Oluwalana S. Antimicrobial potential of *D. guineense* (Willd) stem bark on some clinical isolates in Nigeria. Int J Appld Basic Med Res. 2012;2:58–62.
[58] Rath CC, Dash SK, Misha RK. Antimicrobial efficacy of Indian essential oils individually and combination. J Essential Oil Bearing Plants. 2002;5:99–107.
[59] Nnadi CO, Udeani TKC, Ugwu LO. Wound-healing and antimicrobial properties of dichloromethane fraction of *Dialium guineense* (Willd) fruit coat. Res Pharmaceut Scs. 2016;11:219–26.
[60] Ololade ZS, Anuoluwa IA, Ishaku P. Phytochemical, pharmacognostic, anti-radical, anti-arthritic and antibacterial potential of the leaf extract of *Dialium guineense*. Res J Appld Sci. 2021;16:192–203.
[61] Burt S. Essential oils: their antibacterial properties and potential applications in foods – a review. Int J Food Microbiol. 2004;94:223–53.
[62] Djissou ASM, Vodounnou JV, Tossavi CE, Toguyeni A, Fiogbe ED. Complete replacement of fish meal by unconventional proteins sources in diet of Oreochromis niloticus (L.,1758) fingerlings: growth performance, feed utilization and body composition. Int J Fisheries and Aquat Stud. 2016;4:242–7.