J Herbmed Pharmacol. 2022; 11(1): 20-34.

http://www.herbmedpharmacol.com doi: 10.34172/jhp.2022.03

Journal of Herbmed Pharmacology

Potential medicinal, nutritive and antiviral food plants: Africa's plausible answer to the low COVID-19 mortality

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ARTICLE INFO

Article Type:
Review

Article History:
Received: 25 June 2021
Accepted: 5 August 2021

Keywords:
Coronavirus
Immunomodulatory
Medicinal plants
Morbidity
Nutrients
Phytochemicals

ABSTRACT

The surge in severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) has put the scientific community on overdrive to come up with a cure and/or possible vaccine to curtail the menace this virus has caused. Considering the morbidity rate from the Coronavirus and the World Health Organization (WHO) recommendations for healthy living, this review examined and documented the possible options of plant-based immune boosters for attaining wellness and protect against infections caused by viruses. This review documented 106 plants consumed largely in Africa as food or medicine after assessing over 172 articles from notable search engines. These plants were reported for antiviral activities and immune boosters for attaining wellness and immunomodulation, a key protective feature against infections caused by viruses. The documented plants contain several immune-modulating compounds like vitamins, flavonoids, phenols, macro, and micronutrients, which might be the possible reason for the current leverage on the mortality rate associated with the COVID-19 pandemic in the African continent. The study, therefore, concluded that medicinal/food plants are able to enhance healthy living and medicinal plants are a significant source of phytomedicinal content for the management of viral-induced diseases such as COVID-19.

Implication for health policy/practice/research/medical education:
This review provides a comprehensive perception into the possible reasons of low mortality in coronavirus incidences in Africa and offers an insight into the pharmacological tendencies of the documented plants for immune booster drugs in the pharmaceutical industries.

Please cite this paper as: Raimi IO, Musyoki AM, Olatunji OA, Jimoh MO, Dube WV, Olowoyo JO. Potential medicinal, nutritive and antiviral food plants: Africa's plausible answer to the low COVID-19 mortality. J Herbmed Pharmacol. 2022;11(1):20-34. doi: 10.34172/jhp.2022.03.

Introduction

The year 2020 will be remembered as an exceptional year globally due to the incidence of the coronavirus pandemic, which has caused the loss of many lives. Coronaviruses from the family Coronaviridae are described as rounded, single-stranded RNA viruses, which affect the respiratory and digestive systems of animals and humans (1). Previous outbreaks of human coronavirus infections did not cause mortality or morbidity as severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). World Health Organization (WHO) (2) has categorized COVID-19 as a pandemic because of its devastating effect on global health, lifestyle, and economy (3). Despite the increasing incidence globally, the WHO data showed lower rates of infection and mortality from COVID-19 in the African continent compared to America and Europe (4).

With the associated mortality due to COVID-19, there is a global concern on the appropriate medication and management (2,3). The search is still on; however, some documented evidence from the literature has suggested plant-based drugs and medications based on their antimicrobial activities (5,6). Africa's reliance on medicinal

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plants as foods and additives is well documented in the literature (7). Several studies have reported that plant extracts can be used in treating viral infections (5,8,9) with no exception to the Coronavirus infection. While a lot of precautionary measures such as good respiratory hygiene, hand washing, and nose masking have been suggested for the general populace to combat the spread of COVID-19 (2,3), one of the best measures identified by scientists for alleviating the chance of survival and recovery from COVID-19 is the maintenance of a healthy immune system and safe food consumption (1).

Regarding the supply of nutrients and improvement in the immune system, nutrients derived from medicinal and food plants have played a significant role in modulating the body's immune system to actively mitigate and prevent several infectious diseases in humans (10). However, not a lot of documentation of the various plants with immunomodulatory properties, antiviral activities, and nutritional qualities as consumed, especially in Africa, is available in the literature. African countries' reliance on herbs and vegetables for hunger satisfaction and health maintenance has evolved through ancestral ages but recently getting desired attention in health management practices (11,12).

Diets have been alluded to play a crucial function in hindering pathogenesis and mitigation of communicable diseases (13). WHO reported a nexus between poor diets, irregular feeding, and unhealthy meal intake to an exponential rise in disease incidence on the global scale (2). In recent times, macronutrients and micronutrients (Ca, Zn, Fe, Se, K, vitamins A, D, E, B1, B2, B3, B6, B12, and C) in lesser or excessive amounts in human diets are sources of disease proliferation which has aggravated the global disease burden (14). In some instances, as reported in the literature, consumption of processed food may be linked to health challenges such as obesity, cardiovascular diseases, and high blood pressure, among other microbial causative diseases (15). These are all currently associated with poor prognosis following SARS-CoV-2 infection.

Studies have posited that nutrients derived from fruits, vegetables, and medicinal plants are viable and proven sources of antioxidants, which supply the body with the necessary immune modulation to ward off diseases in humans and prevent the viral attacks (16). It has been reported that the consumption of fruits and vegetables from natural sources could help enhance healthy living by serving as anti-carcinogenic, antihypertensive, antioxidant, anti-inflammatory, anti-allergic, cardioprotective, and antimicrobial remedies (17). Abdulwaliyu et al (18) reported that nutrients from human diets remain the requisite precursor for cellular and physiological functions in humans. For example, *Beta vulgaris* L., a commonly consumed vegetable in many homes, is among the globally cultivated vegetable for food and also for its ability to chelate and neutralize free radicals and decompose peroxides when consumed (19,20).

This review aims to examine literature and document some commonly consumed medicinal and food plants that enhance the immune system and support wellness in humans, especially those with antiviral activities, to provide a number of the plants in one single document for further scientific exploration. This review documents the nutritional and phytochemicals contents and antiviral properties of plant species, together with information on the parts that are mainly consumed.

Methods

Information regarding the role of plants/diets in health management with specific reference to the African nations were retrieved from search engines like Google Scholar, ScienceDirect, Web of Science, and a host of others. Keywords such as "African plants with antiviral properties", "plants with beneficial/nutritive contents", "nutritive plants/diets", "plants with beneficial/nutritive contents in Africa", and "indigenous African diets" were used in searching the literature electronically. The final keywords used after general screening were "nutritive plants/diets and antiviral activities in Africa". ScienceDirect search produced 3108 with 306 review articles and 1341 research articles, while the web of science produced 1535 articles comprising research and review articles, and lastly, Google scholar yielded a total of 60 articles in both review and research articles (Figure 1). The articles were further pruned to contain only those articles that were written in the English language only and have the relevant immunomodulatory properties information. Plants without immunomodulatory properties, nutritional properties, and largely not edible were excluded from the selection. Taxonomic validation of the documented plant was carried using The Plant List online database (21,22).

Exclusion and inclusion criteria

Literature excluded for this current review included thesis, Encyclopedia, book chapters, conference abstracts, book reviews, and others (Figure 1). Articles excluded from this current report were those not written in English language and those with incomplete information on the plants, such as unfit for human consumption, no immunomodulatory properties, and no antiviral activities. A total of 172 articles comprising review and research articles were used for the present review (Figure 1).

Result and Discussion

Incidence of COVID 19 across the world

According to the data from the WHO as of 30th June 2020, showed lower rates of COVID infection and mortality in the African continent as compared to America and Europe (Figure 2) (4).

Food plants as medicine

Plants have proven to be an excellent and unarguable source of nutrients and medicines. A large number of

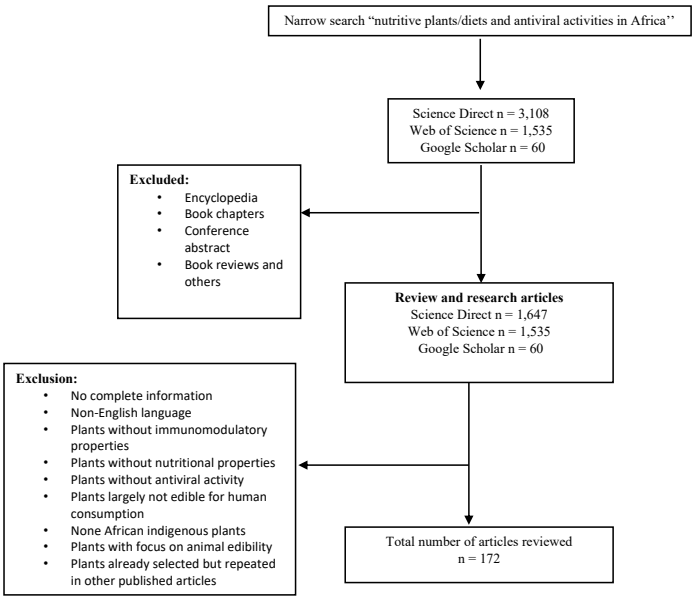

Figure 1. Flow diagram showing the screening criteria throughout the review process.

plants, such as *Amaranthus species* L., *Annona muricata* L., *Annona senegalensis* Pers., *Vernonia amygdalina* Del., *Carica papaya* L., *Garcinia kola* Heckel., *Ocimum gratissimum* L., *Allium sativum* L., *Piper nigrum* L., *Cola nitida* (Vent.) Schott et Endl., *Zingiber officinale* Roscoe, and *Curcuma longa* L., recorded in this study (Table 1), have been confirmed to contain compounds such as proteins, vitamins, minerals, amino acids, γ-tocopherols, terpenoid (Table 2). Similarly, the plants recorded in this study have antioxidants and antiviral properties, which help reduce the risk of chronic diseases (6,23), perhaps, one of the reasons plant-based medicines may be considered beneficial in the prevention and treatment of diseases. Several plants can provide both medicinal and nutritive values (24).

WHO, on several occasions, has advised plants consumption and encouraged research to unravel most of the nutrients present in the plants used as diet (2,25). According to Tahir ul Qamar et al (8), apart from the role of plants as hunger quenchers, they also serve as free radical scavengers, which may help combat chronic communicable diseases. Maggini et al (26) also alluded to the significant role that vitamins, micro-and macro-nutrients from plants play in the coordination of physiological and conferment of immunity against diseases in humans. Similarly, the bio-active compounds and phytochemicals, especially antioxidants found in the plants, have significantly helped humans against diseases (9).

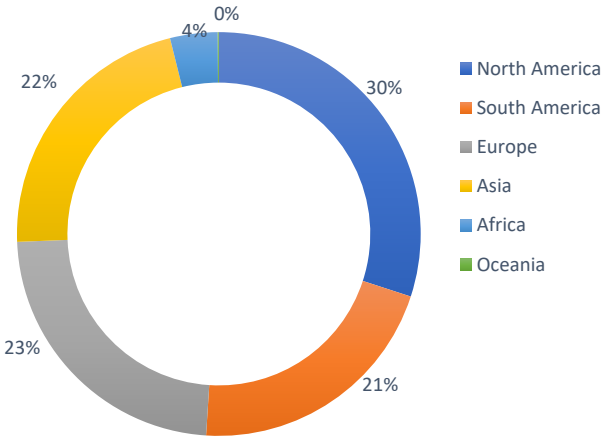

Figure 2. Positive cases of COVID-19 recorded by WHO (as of 30th June 8:43 am GMT+1) (4).

Plant-derived pharmacological properties for maintaining good health

A total of 106 plants were documented to have nutritional and phytochemical contents and antiviral activities against different viruses and can improve the overall body immune system (Table 2). This review found that 58 of the total number of plants reported possessed vitamins (A, B1, B2, B3, B6, B9, C, K, and E), and 51 possessed phenolic compounds. The most important plants with numerous

Table 1. Estimated infection and mortality rate of COVID-19 pandemic from inception up until the 30th June 2020

Continent	Infection rate %	Mortality rate%
North America	0.85	5.36
South America	0.33	3.82
Europe	0.33	7.85
Asia	0.05	2.47
Africa	0.03	2.50
Oceania	0.02	1.33

Table 2. African plants with nutritional and immunomodulatory properties that confer body immune system

Scientific Names	Common/English name	Family	Consumption part	Nutritional contents, Phytochemicals, Macro and Microelements	References
Andrographis paniculata (Burm. f.) Nees	Green chiretta	Acanthaceae*	Leaves	Moisture content, carbohydrate, vitamins, diterpenoids, flavonoids, polyphenols	(49)
Hygrophila schulli M.R.Almeida & S.M.Almeida		Acanthaceae*	Leaves	Moisture, protein, fat, fibre, ash, carbohydrate, sodium, potassium, magnesium, calcium, iron, zinc, copper, ascorbic acid, flavonoids, phenols	(25)
Amaranthus species L.		Amaranthaceae*	Leaves	Moisture, protein, ash, carbohydrates, soluble dietary fiber, insoluble dietary fiber, total dietary fibrer, minerals (Zn, Fe, Cu, Ca, P, Na, K, Mn), myristic acid, palmitic acid, stearic acid, behenic acid, palmitoleic acid, oleic acid, linoleic acid, arachidonic acid	(50)
Spinacia oleracea L.	Spinach	Amaranthaceae*	Leaves	Protein, carbohydrate, fat, dietary fiber, vitamins (A, C, K), Minerals (Na, Ca, Fe, K), Carotenoids, β-carotene, lutein, zeaxanthin, phenolic compounds	(51)
Beta vulgaris L.	Red beetroots	Amaranthaceae*	Bulbs	Total phenol, sugar, organic acid contents, antioxidant activity, and mineral components (Na, Cu, Fe, Zn, Mn, P, K, Mg)	(52)
Harpephyllum caffrum Bernh.	Wild plum	Anacardiaceae*	Fruits, leaves	Calcium, iron, magnesium, flavonoids, phenols	(53)
Sclerocarya birrea (A.Rich.) Hochst.	Marula	Anacardiaceae*	Fruits	Calcium, iron, magnesium, potassium, phosphorus, vitamin C, flavonoids, phenols	(54,55)
Searsia leptodictya (Diels) T.S.Yi, A.J.Mill. & J.Wen		Anacardiaceae*	Fruits, leaves	Flavonoids, calcium, iron, magnesium, potassium, phosphorus, vitamin C, phenols	(56)
Mangifera indica L.	Mango	Anacardiaceae*	Fruits, leaves, barks	Sugars, carbohydrates, fats, vitamins, minerals, dietary fibers, antioxidants, tannins, polyphenols, pigments, Flavor compounds	(57,58)
Lannea edulis (Sond.) Engl.		Anacardiaceae*	Fruits, leaves	Alkaloids, cardiac glycosides, flavonoids, polyphenols, saponins, steroids, tannins, calcium, iron, phosphorus	(58)
Lannea schweinfurthii Engl.		Anacardiaceae*	Roots, leaves, Stem barks	Flavonoids, polyphenols, saponins, steroids	(59)
Annona senegalensis Pers.	Wild custard apple	Annonaceae*	Roots, leaves, fruits, stem barks	Protein, crude fiber, minerals (Fe, Mg, K, P), vitamin C, flavonoids, alkaloids, phenols	(58,60)
Annona muricata L.	Graviola, Soursop	Annonaceae*	Stem barks, fruits, leaves, roots	Protein, carbohydrate, fiber, moisture content, fats, minerals (Fe, Mg, K, P), vitamin C, alkaloids, phenols, flavonoids	(61)
Carissa macrocarpa (Eckl.) A.DC.	Natal plum	Apocynaceae*	Fruits, leaves	Calcium, iron, magnesium, potassium, phosphorus and vitamin C, phenols, flavonoids	(53)
Carissa edulis Vahl		Apocynaceae*	Fruits, leaves	Phenolics, flavonoids, quinic acid, protocatechuoyl-hexose, neochlorogenic acid, chlorogenic acid, cryptochlorogenic acid, and vitamin C	(58)
Phoenix reclinata Jacq	Wild date palm	Arecaceae*	Fruits	Crude protein, crude fiber, moisture, carbohydrate, ash, crude fat, vitamin C, minerals (Na, K, Fe, Zn, Ca, Mg), flavonoids, phenols	(62)
Vernonia amygdalina Del.	Bitter leaf	Asteraceae*	Leaves, stem, roots	Carbohydrate, protein, fibre, ash, fat, moisture, dry matter, alkaloids, tannins, saponins, anthocyanins, starch, reducing sugar, flavonoids, minerals (Mg, Ca, Cu, Fe, Pb)	(6,63)
Blumea lacera (Burm. f.) DC.		Asteraceae*	Leaves	Moisture, protein, fat, fibre, ash, carbohydrate, sodium, potassium, magnesium, calcium, iron, zinc, copper, ascorbic acid, flavonoids, phenols	(25)

Table 2. Continued

Scientific Names	Common/English name	Family	Consumption part	Nutritional contents, Phytochemicals, Macro and Microelements	References
Berberis aristata Roxb.	Indian barberry	Berberidaceae*	Fruits, leaves	Moisture, protein, fat, fibre, ash, carbohydrate, minerals (Na, K, Mg, Ca, Fe, Zn, Cu), ascorbic acid, karachine, palmatine chloride, tetrahydropalmatine, pseudopalmatine chloride, oxyberberine, taxilamine, pakistanine, 1-omethylpakistamine, oxycanthine, aromoline, quercetin, meratin, rutin, chlorogenic acid, (E)-caffeic acid, columbamine, and jatrorrhizine	(25)
Opuntia ficus-indica (L.) Mill.		Cactaceae*	Fruits, stem	Protein, Ash, Crude fat, Crude fibre, Calorific value, Sugars, Carbohydrates, Mg, Na, K, Ca, Mn, Fe, Zn, Phenols	(58)
Carica papaya L.	Paw-paw	Caricaceae*	Fruits, leaves	Crude protein, ash, fibers, vitamin E, K, C, thiamin, riboflavin, pyridoxine, α-carotene, β-carotene, lycopene, β-cryptoxanthin, zeaxanthin, total provitamin A, lutein, total carotenoids, total polyphenols folate, Mg, Na, K, Ca, Mn, Fe, Zn	(58,64)
Salacia kraussii (Harv.) Harv.		Celastraceae*	Fruits	Calcium, iron, magnesium, potassium, phosphorus, phenols, flavonoids	(55,65)
Parinari curatellifolia Benth.		Chrysobalanaceae*	Fruits	Crude protein, crude fat, dry matter, ash, crude fiber, minerals (Ca, Fe, Mg, K, P), vitamin C, alkaloids, terpenoids, anthraquinone glycosides	(58,66)
Parinari capensis Harv.		Chrysobalanaceae*	Rhizomes, leaves	Minerals (Ca, Fe, Mg, K, P), vitamin C, flavonoids, phenols	(58,67)
Garcinia livingstonei T. Anderson	African mangosteen	Clusiaceae*	Fruits	Carbohydrate, crude protein, crude fat, crude fiber, ash, minerals (Ca, Fe, Mg, K, P), phenols, alkaloids, flavonoids	(68)
Garcinia kola Heckel	Bitter Kola/Africa wonder nut	Clusiaceae*	Fruits	Crude fat, crude protein, moisture content, ash, carbohydrate, crude fiber, minerals (K, Ca, Mg, Fe, Zn, Mn, and P), Alkaloid, tannin, saponin, flavonoid, phenol content, caffeine, threobromine	(69)
Acanthosicyos horridus Welw. ex Hook.f.	Nara	Cucurbitaceae*	Fruits, leaves	Crude fat, crude protein, moisture content, ash, carbohydrate, crude fiber, α-tocopherol, β-tocopherol, stigmasterol, fatty acid, β-sitosterol, phosphorus	(70)
Citrullus lanatus (Thunb.) Matsum. & Nakai	Tsamma, Water melon, pig melon	Cucurbitaceae*	Fruits, seeds	α-Tocopherol, β-tocopherol, stigmasterol, iron, magnesium, potassium, phosphorus, flavonoids, phenols	(70)
Coccinia sessilifolia (Sond.) Cogn	Red gherkin	Cucurbitaceae*	Fruits	Calcium, iron, magnesium, potassium, phosphorus and vitamin C, flavonoids, phenols	(71)
Cucumis metuliferus E.Mey. ex Naudin	Jelly melon	Cucurbitaceae*	Fruits, seeds	Calcium, iron, magnesium, phosphorus, flavonoids, phenols	(72)
Cucumis myriocarpus Naud.	Paddymelon	Cucurbitaceae*	Fruits, seeds	Calcium, iron, magnesium, potassium, phosphorus	(73)
Telfairia occidentalis Hook. f. – oysternut	Pumpkin	Cucurbitaceae*	Leaves, seeds	Protein, crude fiber, vitamins, minerals (Fe, Na, K, Ca, P, Mg), phenols, riboflavin, thiamine, nicotinamide, ascorbic acid	(74)
Euclea crispa (Thunb.) Gürke	Motlhakola swifi	Ebenaceae*	Twigs, fruits	Alkaloids, cardiac glycosides, flavonoids, polyphenols, saponins, steroids, and tannins; calcium, iron, phosphorus	(58,59)
Euclea divinorum Hiern	Motlhakolane (Ditlhakolane)	Ebenaceae*	Leaves, roots, fruits	Saponins, steroids, and tannins, calcium, iron, phosphorus	(58,59)
Diospyros mespiliformis Hochst. ex A.DC.	Motsoma (Ditsoma)	Ebenaceae*	Fruits, leaves, barks, roots	Crude fat, crude protein, carbohydrate, ash, calcium, potassium, sodium, iron, and zinc	(58)
Diospyros kaki Thunb.	Persimmon fruit	Ebenaceae*	Fruits	Tannins, licocoumarone, licoflavonol, glyasperin D, 18 β-glycyrrhetinic acids, Luteolin, Vitexin	(75)

Table 2. Continued

Scientific Names	Common/English name	Family	Consumption part	Nutritional contents, Phytochemicals, Macro and Microelements	References
Uapaca kirkiana Mull.Arg.	Sugar plum	Euphorbiaceae*	Fruits, leaves	Calcium, iron, magnesium, potassium, phosphorus	(76)
Cordyla Africana Lour.	Wild mango	Fabaceae*	Fruits	Carbohydrates, fats, vitamins, minerals (Na, K, Ca, Mg, P), dietary fibers, antioxidants, tannins, vitamin C	(77)
Piliostigma thonningii (Schumach.) Milne-Redh.	Mokgoropo (Dikgoropo)	Fabaceae*	Fruits, seeds	Saponins, tannins, flavonoids, volatile oil, glycosides, terpenes, balsams	(58)
Sesbania sesban L. Merr		Fabaceae*	Leaves, seeds, and barks	Moisture, protein, fat, fibre, ash, carbohydrate, sodium, potassium, magnesium, calcium, iron, zinc, copper, ascorbic acid	(25)
Vigna subterranean (L.) Verdc.	Bambara groundnut	Fabaceae*	Fruits	Carbohydrate, protein, fat, fiber, ash and mineral, phenolic compounds	(78)
Arachis hypogea L	Groundnut, Goober or Monkey nut	Fabaceae*	Fruits	Carbohydrate, protein, fat, vitamins, amino acids, minerals	(79)
Vigna unguiculata L. Walp	Cowpea, Black-eyed pea	Fabaceae*	Fruits, leaves	Dietary fiber, carbohydrate, protein, fat, vitamins, amino acids, minerals (Fe, Zn, Mn, B)	(80)
Erythrina variegata L.		Fabaceae*	Fruits	Moisture, protein, fat, fibre, ash, carbohydrate, sodium, Potassium, magnesium, calcium, iron, zinc, copper, ascorbic acid, tannins	(81)
Dovyalis caffra (Hook.f. & Harv.) Sim	Kei-apple	Flacourtiaceae*	Fruits, leaves	Calcium, iron, magnesium, potassium, phosphorus and vitamin C, flavonoids, phenols	(77)
Flacourtia indica (Burm.f.) Merr.	Governor's plum	Flacourtiaceae*	Fruits	Calcium, iron, magnesium, potassium, phosphorus and vitamin C	(76)
Hydnora africana Thunb.	Jakkalskos	Hydnoraceae*	Fruits, seeds	Calcium, iron, magnesium, potassium, phosphorus	(82)
Prunella vulgaris L.		Lamiaceae*	Leaves, flowers	Vitamin C, vitamin k, thiamine, tannins	(83)
Ocimum basilicum L.		Lamiaceae*	Leaves	Carotene, vitamins A, B6, C, calcium, potassium, phosphorus, magnesium, iron, flavonoids, antioxidants	(83)
Ocimum gratissimum L.	Scent leaf, Mints	Lamiaceae*	Leaves	Protein, carbohydrate, moisture, fat, crude fibre, ash, dry matter, saponin, tannin, flavonoids, minerals (Mg, Ca, Cu, Fe, Pb)	(6)
Persea americana Mill.	Avocado	Lauraceae*	Fruits	Protein, Carbohydrate, fiber, sugar, tannin, phytic acid, alkaloid, saponin, oxalate, sodium, calcium potassium, magnesium, zinc, vitamin C, E	(58,84)
Cinnamomum verum	Cinnamon	Lauraceae*	Seeds, leaves, barks	Vanillic acid, caffeic acid, gallic acid, protocatechuic acid, p-coumaric acid, ferulic acid	(85)
Allium sativum L.	Garlic	Liliaceae*	Bulbs, fruits, leaves	Carbohydrates, ash, fats, proteins, mineral contents (K, Na, Ca, Mg, Mn, Fe, Zn), oxalic acid, malic acid, pyruvic acid, and citric acid	(49,86)
Allium cepa L.	Onions	Liliaceae*	Bulbs, leaves	Carbohydrates, ash, fats, proteins, mineral contents (Na, K, P, Ca, Fe, Mg, Mn), hydrocyanic acid, total oxalate, soluble oxalate, phytic acid, cyanogenic glycoside	(87)
Strychnos spinosa Lam.	Green monkey apple, Moshala (Mashala)	Loganiaceae*	Leaves, fruits	Carbohydrate, protein, fiber, fat, energy, calcium, iron, magnesium, potassium, phosphorus, copper, vitamin C, zinc, and iron	(58,88)
Strychnos madagascariensis Poir.	Mogwagwa (Magwagwa)	Loganiaceae*	Fruits, leaves, Seeds	Carbohydrate, protein, fiber, fat, energy, calcium, iron, magnesium, potassium	(58,88)
Punica granatum L.	Pomegranate, Mogranata (Magranata)	Lythraceae*	Fruits, leaves, Seeds	Moisture, protein, fat, ash, fiber, carbohydrate, phenols, Ca, K, Na, P, Fe, Zn, Mn, Cu, Se	(58)

Table 2. Continued

Scientific Names	Common/English name	Family	Consumption part	Nutritional contents, Phytochemicals, Macro and Microelements	References
Azanza garckeana (F. Hoffm) Exell & Hillc.	Snot apple	Malvaceae*	Fruits, seeds	Protein, fiber, carbohydrate, ash, calcium, iron, magnesium, potassium, phosphorus, vitamin C, amino acids	(89)
Grewia flavescens Juss	Donkey berry, Mopharatshena (Dipharatshena)	Malvaceae*	Fruits, leaves	Crude fiber, ash, carbohydrate, protein, lipids, reducing sugar, amino acids, tannins, potassium, iron	(58)
Trichilia dregeana Sond.	Cape Mahogany, Mogotlho	Meliaceae*	Fruits, leaves	Fatty acids such as palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, galantamine, cycloart-23-ene-3,25-dio, Vitamins	(90)
Azadirachta indica A. Juss.	Neem	Meliaceae*	Leaves, stem, seed oil, bark	Carbohydrates, protein, flavonoids, sterols, minerals (Ca and P), vitamin C, carotene, aspartic acid, alanine, proline, glutamine, fatty acids, glutamic acid, tyrosine, arginine, Methionion, phenylalanine, histidine, aminocaproic acid, and isoleucine	(91)
Carpobrotus edulis (L.) N.E. Br.	Sour fig	Mesembryanthemaceae*	Stem, fruits	Carbohydrates, protein, lipids, moisture, vitamin C, minerals (Ca, Mg, Fe, Mn, Zn, Cu, Cr, Co, Se, Ni)	(77)
Ficus sycomorus L.	Sycamore fig	Moraceae*	Fruits	Calcium, iron, magnesium, potassium, phosphorus and vitamin C	(89)
Morus alba L.	Mulberry	Moraceae*	Fruits, leaves	Protein, fiber, sugar, phenolics, flavonoids, isoquercitrin	(92)
Ficus sur Forssk.	Mogo (Mago)	Moraceae*	Fruits	Carbohydrate, tannins, alkaloids, flavonoids, phenols, steroids, cardenolides, quinones, Magnesium, Iron, Potassium, Manganese	(93)
Ficus thonningii Blume	Mokumo	Moraceae*	Fruits	Proteins, fats, carbohydrates, fibres, nitrogen, phosphorus, potassium, magnesium, and calcium	(58)
Musa acuminata Colla	Banana	Musaceae*	Fruits	Minerals, vitamins, protein, moisture, calcium, phosphorus, magnesium, sodium, manganese, zinc, iron, and copper	(58)
Syzygium guineense (Willd.) DC.	Pear	Myrtaceae*	Fruits	Proteins, alkaloids, coumarins, lipids, saponins, vitamin A, potassium, calcium, fats, total polyphenols	(77,89)
Syzygium cordatum Hochst.ex C.Krauss.	Motlho wa tlhaga (Ditlho tsa tlhaga)	Myrtaceae*	Fruits	Calcium, iron, magnesium, potassium, phosphorus and vitamin C, flavonoids, phenols	(58)
Psidium guajava L.	Guava, Mongaba (Mangaba)	Myrtaceae*	Fruits, leaves	Proteins, fats, carbohydrate, phosphorous, calcium, iron, potassium, sodium, phenols, flavonoids	(58,94)
Syzygium cumini (L.) Skeels	Black plum, Jambolan, Motlho (Ditlho)	Myrtaceae*	Fruits	Carbohydrate, dietary fiber, fat, protein, thiamine (B1), riboflavin (B2), niacin (B3), vitamin B6, vitamin C, calcium, iron, magnesium, phosphorus, potassium, sodium	(58,95)
Ximenia americana L.	Blue sour plum	Olacaceae*	Fruits, seeds	Starch, protein, reducing sugar, dietary fiber, fat, protein, calcium, iron and magnesium, flavonoids, phenols	(58,96)
Ximenia caffra Sond.	Motjhidi (Ditjhidi)	Olacaceae*	Fruits, seeds	Protein, potassium, vitamin C, fatty acids, polyphenols	(58,97)
Passiflora edulis Sims	Passion fruit, Mograndela (Magrandela)	Passifloraceae*	Fruits	Fructose, dextrose, maltose, anhydrous lactose, protein, dietary fiber, lipid, ash, sodium, magnesium, calcium, potassium	(58,98)
Antidesma venosum J.J.Sm.	Motilwane	Phyllanthaceae*	Fruits, leaves	Proteins, fiber, vitamins, minerals	(58)

Table 2. Continued

Scientific Names	Common/English name	Family	Consumption part	Nutritional contents, Phytochemicals, Macro and Microelements	References
Flueggea virosa (Roxb. ex Willd.) Royle	White berry-bush, Motlhalabu (Ditlhalabu)/ Motlhakawume (Ditlhakawume)	Phyllanthaceae*	Leaves, fruits	Alkaloids, triterpenoids, resins, steroids, cardiac glycosides, bergenin, menisdaurin, and anthraquinones	(58)
Bridelia micrantha (Hochst.) Baill.	Motsere (Ditsere)	Phyllanthaceae*	Fruits, leaves, stem barks, roots	Carbohydrates, ash contents, flavonoids, polyphenols, saponins, sterols, alkaloids, triterpenes, tannins	(58,99)
Piper nigrum L.	Black Pepper	Piperaceae*	Fruits, leaves, seeds	Ash, protein, carbohydrates, fibre, fat, moisture contents, minerals (Ca, Fe, Mg, Zn), vitamins (B1, B2, B3, C), flavonoid, alkaloid, tannins, oxalate, hydrogen cyanide	(100)
Saccharum officinarum L.	Sugarcane	Poaceae*	Stem	Vitamin B2, vitamin B1, vitamin C, vitamin B6, iron, phosphorus, calcium, fumaric acid, succinic acid, citric acid, and malic acid	(101)
Berchemia discolor (Klotzsch) Hemsl.	Mogokgoma (Digokgoma)	Rhamnaceae*	Fruits, seeds	Total carbohydrates, crude protein, crude lipid, moisture, and total ash contents calcium, iron, magnesium, potassium, phosphorus and vitamin C	(58)
Ziziphus mucronata Willd.	Buffalo-thorn	Rhamnaceae*	Fruits	Calcium, iron, magnesium, potassium, phosphorus	(102)
Berchemia zeyheri (Sond.) Grubov	Moneyi (Dineyi)	Rhamnaceae*	Fruits	Alkaloids, cardiac glycosides, flavonoids, polyphenols, saponins, steroids, and tannins; calcium, iron, phosphorus	(58,59)
Ziziphus zeyheriana Sond.	Mothalo fasane/Mokgalo fasane	Rhamnaceae*	Fruits	Alkaloids, cardiac glycosides, flavonoids, polyphenols, saponins, steroids, and tannins; calcium, iron, phosphorus	(58,59)
Prunus persica (L.) Batsch	Nectarine, Mopeta (Mapeta) Moperekisi (Mapereriki)	Rosaceae*	Fruits, seeds	Beta carotene, vitamin A, vitamin C, minerals, crude fiber contents, flavonoids, phenols	(58)
Prunus domestica L.	Plum, Mopremo (Mapremo)	Rosaceae*	Fruits, seeds	Ascorbic acid, vitamin E, beta-carotene, total polyphenols, phenolic acids, flavonols	(58)
Fragaria ananassa	Strawberry	Rosaceae*	Fruits	Anthocyanins, ellagitannins, flavonols, phenolic acids, lutein, zeaxanthin, beta carotene, vitamin A, C, E	(103)
Eriobotrya japonica (Thunb.) Lindl.	Loquats, Motlho wa sekgowa (Ditlho wa sekgowa)	Rosaceae*	Fruits, seeds, leaves	Energy, protein, total fat (lipid), ash, carbohydrate, total dietary fiber, calcium, iron, magnesium, phosphorus, potassium, sodium, zinc, copper, manganese, selenium, vitamins A, B1, B2, B3, B6, B9, amino acids	(58,104)
Vangueria infausta Burch.	Wild medlar	Rubiaceae*	Fruits	Crude protein, crude fiber, ash, carbohydrate, glucose, manganese, magnesium, nitrogen, sodium, phosphorus, tannin, triterpenoid, iridoid lactone, vitamin C, calcium, iron, magnesium, potassium, phosphorus	(55,105)
Vangueria madagascariensis Vahl.	Mmilofasane (Mabilofasane)	Rubiaceae*	Fruits	Crude protein, crude fiber, ash, carbohydrate, glucose, manganese, magnesium, nitrogen, sodium, phosphorus, tannin, vitamin C	(58,105)
Serissa japonica Thunb.	Snowrose	Rubiaceae*	Leaves	Flavonoids	(83)
Citrus sinensis (L.) Osbeck	Monamona (Manamona)	Rutaceae*	Fruits, leaves	Glucose, fructose, sucrose, phosphorus, calcium, magnesium, zinc, copper, vitamin C	(58)
Citrus reticulata Blanco	Tangerine	Rutaceae*	Fruits, leaves	Glucose, fructose, sucrose, vitamin C	(58)

Table 2. Continued

Scientific Names	Common/English name	Family	Consumption part	Nutritional contents, Phytochemicals, Macro and Microelements	References
Citrus limon (L.) Osbeck	Lemon	Rutaceae*	Fruits, leaves	Glucose, fructose, sucrose, vitamin C, minerals (K, Ca, Mn, Fe, Zn, Cu), flavonoids, phenols, amino acids	(58,106)
Pappea capensis Eckl. & Zeyh.	Jacket-plum	Sapindaceae*	Fruits	Iron, Vitamin C, Lipids, Proteins, Ash, Total dietary fiber	(77)
Litchi chinensis Sonn.	Lychee, Motlhatjwa (Ditlhatjwa)	Sapindaceae*	Fruits	Lipids, proteins, ash, total dietary fiber, flavonoids, carotenoids, polyphenols, vitamin C	(58,107)
Englerophytum magalismontanum (Sond.) T.D. Penn.	Stamvrug, Motlhatjwa wa tlhaga (Ditlhatjwa tsa tlhaga)	Sapotaceae*	Fruits, leaves	Minerals (K, Na, Ca, Mg), vitamin C, caespitin, phenols, flavonoids	(58,108)
Mimusops zeyheri Sond.	Transvaal red milkwood	Sapotaceae*	Fruits	Calcium, Phosphorus, Magnesium, Flavonoids	(58)
Manilkara mochisia (Bak.) Dubard.	Lowveld milkberry	Sapotaceae*	Leaves	Vitamins	(77)
Solanum nigrum Linn.	Black nightshade	Solanaceae*	Fruits, Leaves	Protein, ash, carbohydrate, crude fiber, oil, vitamins, thiamine, riboflavin, niacin, phenols, flavonoids	(49)
Solanum retroflexum Dunal	Nightshade	Solanaceae*	Fruits, Leaves	Calcium, iron, magnesium, potassium, phosphorus, vitamin C, tannin, oxalate, phytate contents, neochlorogenic, chlorogenic, caffeoylmalic acid, kaempferol O-rhamnosyl hexoside, rutin	(109)
Halleria lucida L.	White olive	Scrophulariaceae*	Fruits, Leaves	Vitamin C, phenols, flavonoids	(77)
Cola nitida (Vent.) Schott et Endl.	Kola nut	Sterculiaceae*	Fruits	Crude fat, crude protein, moisture content, ash, carbohydrate, crude fiber, minerals (K, Ca, Mg, Fe, Zn, Mn, and P), alkaloid, tannin, saponin, flavonoid, phenol content, caffeine, threobromine	(69,110)
Vitis vinifera L.	Wine grapes, Motiribe (Ditiribe)	Vitaceae*	Fruits	Protein, fat, ash, carbohydrate, linoleic acid, oleic acid, palmitic acid, tocopherols, α, β and γ-tocopherols and α and γ-tocotrienols and amino acids	(58)
Zingiber officinale Roscoe	Ginger	Zingiberaceae*	Bulbs, leaves	Carbohydrate, moisture, ash, protein, fat, insoluble fibre, soluble fibre, calcium, phosphorous, iron, zinc, copper, chromium, manganese, vitamin C, total carotenoids, thiamine, riboflavin, niacin, essential oil	(49)
Curcuma longa L.	Tumeric	Zingiberaceae*	Rhizomes, leaves	Carbohydrate, moisture, ash, protein, fat, dry matter, alkaloid, saponin, tannin, sterol hydrogen cyanide, flavonoids, phenols, vitamins (niacin, riboflavin, thiamine), minerals (Ca, P, K, Fe)	(111)
Aframomum melegueta K. Schum.	Alligator pepper	Zingiberaceae*	Fruits	Crude fat, crude protein, moisture content, ash, carbohydrate, crude fiber, minerals (K, Ca, Mg, Fe, Zn, Mn, and P), alkaloid, tannin, saponin, flavonoid, phenol content, caffeine, threobromine	(69,110)

pharmacological properties were *Spinacia oleracea*, *Telfairia occidentalis*, *Mangifera indica*, *Andrographis paniculata*, and *Zingiber officinale* conferring several benefits on humans against both communicable and non-communicable diseases (Figure 3). Although simple flavonoids are rare in plants, 48 of the total number of plants reported in this review possessed flavonoids (Figure 3). Flavonoids are mostly considered as non-nutrients but are important to the human diet because of their high antioxidant activities (27), and their effectiveness in scavenging reactive oxygen species, which are comprised of singlet oxygen and other free radicals (6).

Sorghum, which is among the most important staple meals consumed in most African homes prepared with different condiments such as ginger and garlic, has flavonoids, among other antioxidants. It has immunomodulatory potential for the treatment of various ailments (28). There are various reports in the literature about the importance and benefits of phenolic compounds (29-31). Lin et al (31) reported that plants remain the main source of phenolics, and they are centralized in the vacuole either singly or in association with carbohydrates such as glucose, galactose, mannose, and rutinose. Phenolics are secondary metabolites that emanate from the shikimic acid of plants (32). They are synthesized in plants through the glucose to pentose phosphate pathway and later converted to glucose-6-phosphate (31). Phenolic compounds contain different categories of compounds ranging from simple flavonoids to complex flavonoids, phenolic acids and anthocyanins (30).

Major classes of phenolic compounds included hydroxybenzoic acids, simple phenols, hydroxycinnamic acids, flavonoids (flavonols, flavones, flavanones, isoflavones, and anthocyanins), chalcones, aurones (hispidol), hydroxycoumarins, lignans, hydroxystilbenes, and polyflavans (proanthocyanidins and prodeoxyanthocyanidins). Among the principal functions of phenolic compounds are their antimicrobial activities, which benefit healthy living as they can protect against free radicals and retard the progress of some chronic diseases (6,33). The presence of free radicals has been associated with the development of diseases and conditions such as cancer, diabetes, neurodegenerative, aging-related, and cardiovascular diseases. However, phenolics and flavonoids have helped in preventing and improving these human health conditions that could be life-threatening (34). Several studies have enumerated and reported the immunomodulatory effects of phenolic compounds, which partly can further be attributed to the presence of polyphenols in plants (35,36).

Antiviral food plants

Plants reported to have antiviral activity either in folk medicine (traditionally) or *in vitro* studies are captured in Table 2. Tan et al (37) reported that zerumbone and curcuminoids are among the bioactive molecules present in the rhizomes and leaves of *Zingiber officinale* and responsible for the immunomodulatory functions of the plant. Similarly, in the study of Chang et al (38) in Taiwan where fresh ginger was tested against the human respiratory syncytial virus, the result showed that *Zingiber officinale* consumed as spices in most of the world is a natural combatant against human respiratory syncytial virus found in the human respiratory tract cell lining. The efficacy of *Aframomum melegueta* from the same family as *Zingiber officinale* as an antiviral agent was reported by Ojo et al (5) in their study on the antiviral properties of Nigerian plants. *Aframomum melegueta* inhibited viruses from the genus Flavivirus and Morbillivirus that cause yellow fever and measles, respectively even at a lower minimum inhibitory concentration of less than 250 µg/mL (5).

Ellagic acid (a strong polyphenol) from *Annona muricata* reduced the low squamous intraepithelial lesion related to human cervical papillomavirus (HPV) (39). *Allium sativum*, *Vitis vinifera*, *Cola nitida*, *Piper nigrum*, *Solanum retroflexum* respectively from the families Zingiberaceae, Vitaceae, Sterculiaceae, Piperaceae, and Solanaceae have

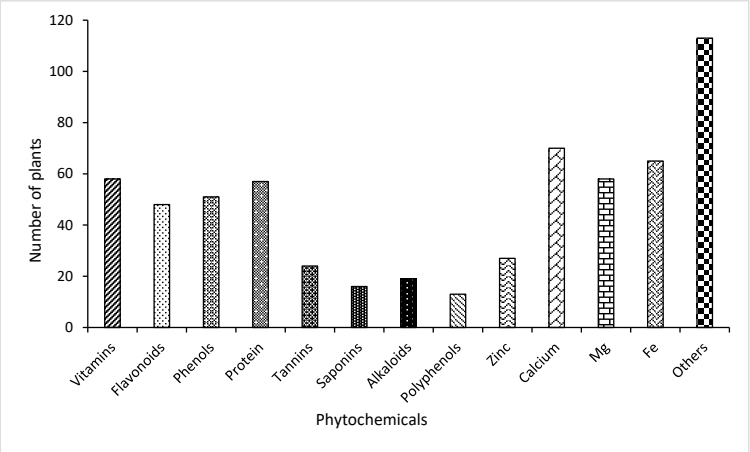

Figure 3. Number of plants and their key nutritional, phytochemicals, macro and micro contents.

all been reported as antiviral agents against viruses such as *Herpes simplex* Virus type 1 & 2, Parainfluenza virus type 3, Human Rhinovirus type 2, Influenza virus, Respiratory Syncytial virus (40-42). Fabaceae was the predominant family in the present study (Figure 4) and this may be due to the global dominance among the largest terrestrial plants (12). Another reason for its predominance among the plant families in the present study may be due to its legume fruit-producing trait and ability to fix nitrogen, as well as economically and medicinally important relevance (43).

Other useful pharmacological properties incidences and mortality from COVID-19 infections

Fifty-eight of the total food/medicinal plants documented in this review have vitamins that are essential micronutrients required by the human in small quantities for efficient metabolism (14). According to Godswill et al (14), vitamins are imbued with various biochemical activities; thirteen categories of vitamins are essential by man for proper physiological and metabolic functions. They include: vitamin A, which comprises all-trans-retinyl-esters, all-trans-retinol, and all-trans-beta-carotene as well as other provitamins A carotenoids, vitamin B1 (thiamine), vitamin B2 (riboflavin), vitamin B3 (niacin), vitamin B5 (pantothenic acid), vitamin B6 (pyridoxine), vitamin B7 (biotin), vitamin B9 (folic acid or folate), vitamin B12 (cobalamins), vitamin C (ascorbic acid), vitamin D (calciferous), vitamin E (tocopherols and tocotrienols), and lastly vitamin K (quinones).

Vitamin C (ascorbic acid) supports cellular membrane integrity (23), and can avert the formation of disease-causing N-nitroso compounds (44). In this review, the fruit of *Carica papaya (*Paw-paw) and the leaf of *V. amygdalina* (Bitter leaf), among other plants, are documented to possess ascorbic acid contributing to a better body immune system. Besides, both humans and organisms require inorganic elements known as "minerals" for their physical, chemical, physiological, and metabolic activities (45).

Plants are the major source of minerals for human use (46). Minerals are among the four groups of essential nutrients, others include vitamins, essential amino acids, and essential fatty acids (47). They are called essential nutrients because they cannot be synthesized in the body and, therefore, must be taken through foods or, in rare cases, supplements. The majority of the plant documented in this review possessed mineral elements like Zn, Ca, Mg, Fe (Table 2, Figure 3). Zinc, Fe, and Mg are necessary for the formation of antioxidants. The presence of these micronutrients in food plants could make them a good source of antiviral agents and should be considered as a possible antiviral agent in food product preparation and drug formulations (48). All the plants documented in this review have nutritional, immunomodulatory, and antiviral properties, and they are consumed fresh or processed by a large population in the African continent for hunger satisfaction or medicinal purposes. Hence, they might be the likely reason for the current low incidences and mortality rate of COVID-19.

Conclusion

This review highlights the importance of plants as a source of nutrients, antiviral, and undoubtedly the provider of immunomodulatory properties through their bioactive compounds, antioxidant activities, metabolites, and amino acid contents, which may explain the low mortality associated with COVID-19 in Africa. This paper also suggests the inclusion of more food plants with antiviral properties in human diets for healthy living. The

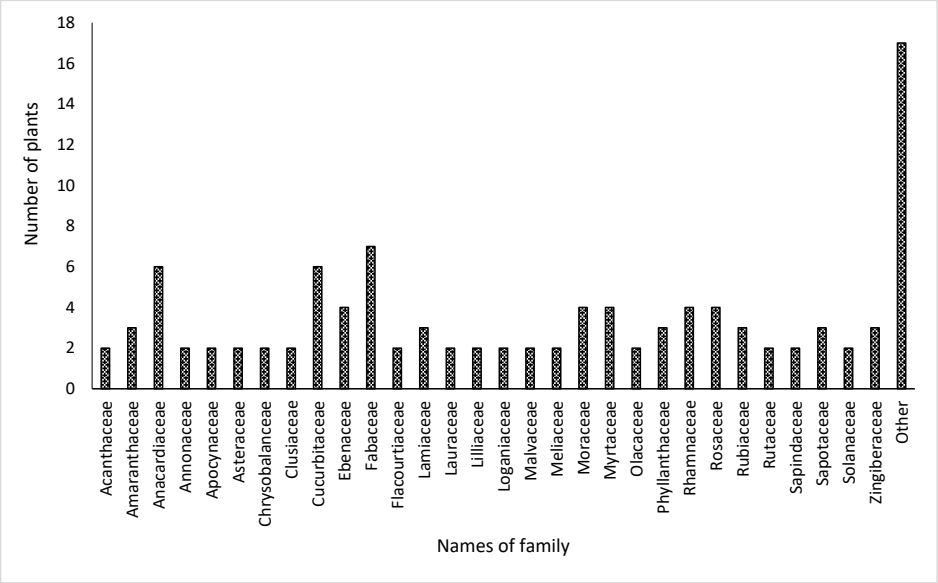

Figure 4. Number of the most common plant families documented to possess antiviral properties.

data presented in this review could assist in identifying plants needed for the development of pharmaceutical formulations. However, further study is required to substantiate and isolate the different nutrients derivable from these plants and find their usage in the food and pharmaceutical industries.

Acknowledgments

This work was supported by the Department of Biology and Microbiological Pathology, Sefako Makgatho Health Sciences University. The authors gratefully appreciate the scholars whose works were cited in this review while equally apologizing to authors whose works might have been inadvertently missed.

Authors' contributions

All the authors (RIO, MAM, OOA, JMO, DWV, OJO) took part in the conceptualization of the work. OOA, JMO, DWV, and RIO retrieved and curated the data. The format analysis and the methodology design were done by DWV. The manuscript was prepared by RIO and JMO, while OOA reviewed and edited the manuscript before submission to MAM and OJO. Both MAM and OJO checked the manuscript draft and approved it. The final formatting was through Mendeley software and the formatting was done by RIO and JMO. All authors read the manuscript's final draft, consented, and confirmed the publication of the final version.

Conflict of interests

No potential conflict of interest was reported by the authors.

Ethical considerations

The authors have carefully observed all ethical issues. Authors painstakingly observed ethical issues such as plagiarism, data falsification, misconduct, and data manipulation, double publication, or redundancy related to the manuscript.

Funding/Support

This work received no funding from any external or internal source.

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