REVIEW ARTICLE

A review on medicinal properties and nutritional security of Okra

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There has been a recent paradigm shift away from traditional medicine and toward relatively safer phytotherapies. This discrepancy is important for the treatment of various chronic disorders. Okra (*Abelmoschus esculentus* L.) is a popular vegetable crop with great nutritional value and therapeutic effects, making it a potential option for use in a variety of nutraceutical products. The okra fruit's mucilage, seeds and pods are all rich in particular essential bioactive components that give it its medicinal qualities. The potential therapeutic effects of okra's phytochemicals on a number of chronic illnesses, such as type 2 diabetes, heart disease and digestive issues, have been studied. Their antifatigue, liver detoxifying, antimicrobial and chemo preventive qualities have also been investigated. Most people agree that okra is a cheap, easily accessible vegetable crop with a variety of nutritional benefits and possible health benefits. Despite a plethora of studies on okra's medical benefits and possible nutraceutical relevance, research on its pharmacokinetics and bioavailability has been lacking, which has hindered its broad use in the nutraceutical industry. This study compiles the research on the bioactive ingredients of okra and its possible application as a nutraceutical. It will also lay the groundwork for future research into the pharmacokinetics and bioavailability of okra in advance of its possible commercial manufacturing for use as a remedy for various chronic illnesses.

Key Words: *Antidiabetic; Cardio protective; Functional foods; Nutraceuticals; Okra; Phytotherapy*

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) a member of the Malvaceae family, is also referred to as lady's finger in many regions of the world where it is grown. Okra is also known by the following common names: Gombo, bamia, okra, quimgombo, lai long ma, and jain et al., [1]. It is believed that okra originated in or around Ethiopia, where it was widely cultivated by Egyptians in the 12th century. It then extended to North Africa and the remainder of the Middle East [2,3]. Growing yearly, okra is a common crop for gardens and farms, mostly in tropical and subtropical regions of the world. It is a popular food crop that is well-known for its flavor all over the world. The young green pods of okra are usually consumed as vegetables, but the extract from the pods can also be used to soups and sauces to make them more viscous [4,5]. Another important application of okra fruit is its extensive use in the pickle business. Because of their numerous health benefits and long shelf lives, polysaccharides, which are found in okra, are used in baked goods and sweetened frozen foods like ice cream [6]. Tiny, soft, hairy structures cover the anatomical surfaces of the fruits, stem and leaves of okra. The ability of okra plants to flower is perennial, although it is highly dependent on a range of biotic and abiotic factors. Okra has hairy coverings on both the upper and below surfaces of its leaves, which are polymorphous and petioles that are around 15 cm long. Blooms of okra are easily recognized by their somewhat yellowish color with a red center. The capsule or pod, that contains the edible part of okra is pentagonal, pyramidal-oblong and ranges in length from 15 to 20 cm. Okra pods have been used historically for food, as an aphrodisiac as an astringent and as a hunger stimulant. Additionally, okra pods have been proposed as a treatment for urinary tract issues, diarrhea and gonorrhea [7].

It has also been demonstrated that extracts from young okra pods have moisturizing and diuretic properties and that the plant's seeds contain fungicidal and anticancer properties [8]. Due to the presence of several important bioactive compounds and their associated bioactivities, okra has recently been used for its nutritional benefits as well as its nutraceutical and medicinal qualities. This study examines the nutritional value of okra, talks about the possible therapeutic applications of its bioactive ingredients and considers the vegetable's potential for use in the production of functional foods and nutraceuticals. The potential health advantages of okra-based nutraceuticals and their use are among the main topics of this review, as are the medicinal applications of *Abelmoschus esculentus* as a nutraceutical plant.

LITERATURE REVIEW

Okra's nutritious and bioactive ingredients

It can be argued that okra is a more effective nutritious element than a staple crop. Small enterprises in Hunan, China and Surajbala Exports Private Limited, New Delhi, India, have utilized okra seeds to extract oil. Additionally, one of the most important variables in assessing a food's nutritional value is its lipid content. The lipid composition of different food types varies in terms of the quantity of lipids such as diacylglycerols, triacylglycerols, polar lipids and free fatty acids. Among these elements that are crucial in determining the durability and nutritional worth of different food types are fatty acids. Triacylglycerols are biomolecules made up of both unsaturated and saturated fatty acids, with only minor variations in the number of associated acyl group repeats, the number of double bonds repeated and their locations. Importantly, these lipids are destined to serve as energy stores by nature [9]. Prior to this, Savello et al., [10] found that the okra plant's seeds are a significant source of oil, making up 20 to 40% of the total composition depending on the extraction method. Linoleic acid, a well-known Polyunsaturated Fatty Acid (PUFA) representative, makes up the majority (47.3%) of the oil in okra seeds. Additional important nutritional components required for human growth are the amino acids and their polymers or proteins [11,12]. Okra seeds are said to have a different protein composition than grains and pulses because the balance of unique amino acids, particularly lysine and tryptophan has been added to the protein components. Due to their high content of essential amino acids, okra seeds are an essential component of the human diet [13]. Okra also provides a possible excess of carbohydrates and vitamins, two other important nutritional components. In addition to being popular for their excellent nutritional value, okra pods can be eaten raw or cooked [14]. Table 1 lists the nutritional benefits of each edible portion of the okra plant (per 100 g serving).

Additionally, okra provides an abundance of nutrients that are necessary for maintaining good cellular balance. There is proof that the parts of plants that are edible have different amounts of calcium (Ca), phosphorus (P) and iron (Fe)-84, 90 and 1.20 mg, respectively. It also includes beta-carotene, riboflavin and vitamin B complex in approximate amounts of 185 g, 0.08 mg and 0.04 mg, respectively. The extra vitamins that are present in okra plants are listed in Table 2.

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TABLE 1

The nutritional makeup of 100 g of raw okra. USDA (United States Department of Agriculture) SR-21 data was provided

S. No.	Dietary constituents	Amount per serving	% Daily value
1	Total calories	130 kJ	2
2	Total carbohydrates	7 g	2
3	Total protein	2.0 g	4
4	Dietary fiber	3.2 g	13
5	Starch	0.3 g	-
6	Sugar	1.2 g	-
7	Total fat	0.1 g	-
8	Trans-fat	-	-
9	Saturated fat	0.0 g	0
10	Cholesterol	0.0 mg	0
11	Total omega-3 fatty acids	0.001 g	-
12	Total omega-6 fatty acids	0.026 g	-
13	Phytosterols	0.024 g	-

TABLE 2

Mineral content of 100 g of okra per serving. Information obtained from USDA (United States Department of Agriculture) SR-21

S. No.	Minerals	Amount per serving	% Daily value
1	Potassium	303 mg	9
2	Calcium	81.0 mg	8
3	Phosphorus	63.0 mg	6
4	Magnesium	57.0 mg	14
5	Copper	0.1 mg	5
6	Selenium	0.7 µg	1
7	Manganese	1.0 mg	50
8	Zinc	0.6 mg	4
9	Sodium	8.0 mg	0
10	Iron	0.8 mg	4

Carbohydrates make up the majority of the mucilage produced by the okra plant [15]. Additionally, the early pods of okra plants contain 11% amino acids and polysaccharides (Mw 170,000). Additionally, the main components of okra pods are 22% rhamnose, 25 and 27% galactose and 27% galacturonic acid, respectively. Okra pods are also eaten in dried form in several regions of the world, particularly in West Africa, after being combined with other ingredients. However, the lack of carotene or retinol (vitamin A) in a dried form is a significant nutritional disadvantage of such eating [16]. Additionally, viscous dietary fiber found in fresh okra pods has been shown to lower cholesterol levels. The highest nutritional contents were found in okra pods that had just been matured for seven days, according to earlier studies [17].

The pharmacological properties and possible uses of biomolecules derived from okra

Antidiabetic efficacy: All communities Worldwide have seen a sharp increase in the prevalence of metabolic diseases, particularly diabetes. Diabetes is caused by a multitude of reasons, but the most common side effects have been identified as oxidative imbalance and inflammatory responses [18,19]. Obesity and high lipid profiles have lately been associated with type 2 diabetes patients. Okra plant pieces have a well-documented history of lowering blood sugar levels. It has been demonstrated that okra mucilage and pod extracts, in both ethanolic and aqueous forms, lower blood glucose levels in mice with diabetes induced by alloxan [20]. Diabetes Nephropathy (DN) is a frequent consequence of diabetes that poses a major risk to human health and is predicted to increasingly be the root cause of cardiovascular events and end-stage renal disease [21].

In therapeutic settings, the Chinese single plant drug Huangkui Capsule (HKC) is used to treat inflammatory diseases such as membranous nephropathy, DN, chronic glomerulonephritis and Chronic Kidney Disease (CKD). It is made from Abelmoschus manihot's dried blooms. It is a proprietary drug approved in 1999 for use in treating diabetes-related problems by the Chinese State Food and Drug Administration (Z19990040) [22]. Diabetic rats that ate okra peel and seed powder had significantly decreased blood glucose levels and gained weight [23]. They demonstrated that okra could prevent diabetes for the first time. Majd et al., [24] also noted that okra powder could reduce the expression of the Peroxisome Proliferator-Activated Receptors (PPARs) gene in the pancreas of diabetic rats, hence enhancing glucose homeostasis and reducing cell damage in diabetic patients. It's also interesting to note that neither boiling nor baking affected the fruit's or seed's capacity to control blood sugar levels in rats with type 2 diabetes. This might be the result of okra's ability to retain a constant amount of total viscous dietary fiber even when heated [25].

In Long Evans rats, aqueous okra plant pod extracts administered in combination with metformin likewise resulted in hypoglycemia. The enzyme known as the catalyst amylase is thought to be essential for supplying the body with the glucose it needs to function because it breaks down polysaccharides. In the past, it has also been demonstrated that water-soluble seed and peel extracts from the okra plant block the activities of glucosease and amylase [26]. Furthermore, it was discovered that the okra plant's early seeds were caused by oligomeric proanthocyanidins, which also inhibited -glucosidase and -amylase. Additional research into the anti-diabetic properties of the okra plant suggests that rhamnogalacturonan may also have mediated the antidiabetic activity [27].

Antioxidant's potency: Nearly every nation on the planet consumes okra pods, the okra plant's immature fruits, as vegetables. Previous studies have

shown that immature okra pods have antioxidant activity [28]. To shed more light on this, a recent study discovered that the high percentage of polyphenols (29.5%) in the seeds of immature pods could be the reason for the okra pod's potent antioxidant properties. For flavonoids in the ingested matrix to be absorbed, food or drink must pass through the gastrointestinal lumen and enter the circulatory system. Since almost all flavonoids found in plants are glycosides, absorption requires the removal of the attached sugar following meals [29]. By reducing Malondialdehyde (MDA) levels and raising Superoxide Dismutase (SOD) and Glutathione Peroxidase (GSH-Px) levels, these polyphenols from immature okra pods perform antioxidant activity [30]. According to Gonzales et al., [31] there are currently about 8000 distinct types of flavonoids, a large class of secondary plant metabolites that can form as aglycones or conjugates with glycosides and acyl groups. Of the principal phenolic compounds found in okra fruits, quercetin-3-O-gentiobioside was the most common. Other components included rutin, a derivative of quercetin, protocatechuic acid, a derivative of catechin and quercetin-3-O-glucoside (isoquercitrin). One important component of the antioxidant capability is quercetin-3-O-gentiobioside. It also has inhibitory effects on digestive enzymes like lipase, glucosidase and amylase [32].

Effect against cancer: Even with advancements in drug development, the second greatest cause of death worldwide-cancer-still requires the creation of novel drugs derived from plants. There is an immediate need for new anticancer drugs because cancer cells are growing resistant to the drugs that are now available, including taxanes and vinca alkaloids [33]. According to the National Cancer Institute, the term "cancer" refers to a broad class of malignancies that are characterized by unregulated growth, which is supported by a number of regulatory and functional changes that ensure systemic dispersion throughout the body. Even while the scientific community has made incredible strides in understanding the mechanics underlying such a crippling disease, there is still a need for an efficient treatment method free of side effects. The primary therapeutic management technique for such potentially fatal methods should be the expanding research of a chemo preventive approach utilizing natural substances derived from plants in diverse sources. Plant chemicals have caught the interest of numerous researchers worldwide because of their unique toxicity against cancer cells [34]. Okra blossoms are reported to have significantly higher concentrations of flavonoids and phenols than the pods, peel, leaves and seeds [35]. Okra extracts has strong anticancer properties due to their ability to trigger tumor apoptosis, increase macrophage activity and reduce tumor growth. Through NF-B activation, Zheng et al., [36] demonstrated that okra flower polysaccharides could promote RAW264.7 cell's phagocytosis and the release of cytokines including Nitric Oxide (NO) and Tumor Necrosis Factor (TNF). However, a study discovered that okra pectin Rhamnogalacturonan-I (RG-I) might interact with galactose agglutinin-3 to prevent B16F10 cells from proliferating, stop the cell cycle in the G2/M phase and trigger cell death [37]. M phase and interact with galactose agglutinin-3 to cause cell death. In addition, Monte et al., [38] showed that treatment of human breast cancer cells (MCF7) with okra lectin boosted the expression of pro-apoptotic genes and the Bax/Bcl-2 ratio (Bax is a pro-apoptotic regulator while Bcl-2 protein is anti-apoptotic). These results offered support for the investigation and application of okra extracts as supplemental anticancer agents.

Additionally, epidemiological studies have demonstrated that eating foods high in phenolic compounds on a regular basis can lower the risks of cardiovascular illnesses and several malignancies [39]. Three mechanisms exist for flavonoids to exert their anticancer effects: antioxidant action, stimulation of anticancer cytokine release and suppression of cancer cell proliferation. Okra is high in polyphenols and flavonoids, as has been said and regular consumption may lower the chance of developing some cancers.

Okra can be utilized as a raw ingredient to create healthy foods that are helpful in reducing the symptoms of various chronic conditions. For instance, flavonoids derived from the okra flower can substitute antibiotics at a specific concentration and okra seed is a rich source of protein for creating functional foods [40]. Okra's edible functional value offers promising long-term development prospects [41]. However, there hasn't been enough study done on the active components and their mechanisms of action in okra.

Immunomodulatory capabilities: The immune system serves as a clear-cut barrier of defense against harmful internal or external intervening factors. Protecting the body from infectious diseases requires the functioning of the immune system. Its two main causes are innate and acquired immunological responses. The most important feature of innate immunity is its lack of specific identification. This type of immune system responds to all infections, regardless of their type. Innate immunity comprises both immune and nonimmune components, whereas acquired immunity only consists of immunological components. Phytochemicals are the widely distributed secondary metabolites present in fruits and vegetables. Humans have evolved to gather and use these phytochemicals for their own benefit, despite the fact that they are essential for plant growth and maintenance but have little nutritional value [42].

Furthermore, it has been observed that the complex immune system is impacted by the biologically potent components of *A. esculentus*. Mice injected with lectin from okra at low dosages (0.01, 0.1 and 1 mg/kg) have shown significant inflammatory effects. In Wistar rats with acute gastric mucosal injury, okra extract given orally in ethanol recently decreased inflammation [43]. Research has demonstrated that the presence of polysaccharides in an aqueous okra extract raises the quantity of haemoglobin, increases the expression of Major Histocompatibility Complex Class II (MHC II) and CD80/89 in rat bone marrow hematopoietic cells and decreases endocytosis. Furthermore, according to Ortac et al., [44] the aqueous extracts decrease interleukin-10, an anti-inflammatory cytokine, while concurrently increasing the expression of interleukin-12 and interferon. Macrophages are integral components of innate immunity and are required for the appropriate operation of the innate immune systems. Chen et al., [45] assessed the Immunomodulatory qualities of okra polysaccharides on macrophage cell lines. They discovered that following treatment, these polysaccharides raised the levels of cytokines and tumour necrosis factor in RAW264.7 cells, as well as the synthesis of Nitric Oxide (NO) and the expression of Inducible No Synthase (INOS) [46].

Antimicrobial efficacy: Okra antibacterial properties are primarily due to the oil or flavones in the seeds. According to Petropoulos et al., [47], okra seed extracts had stronger fungicidal activities than ketoconazole and had noticeable antibacterial effects. Okra seeds contain a lot of oil, as was already mentioned and it is conceivable that this oil is what gives the seeds their antibacterial properties. A different study found that fresh water okra pod extract had stronger antibacterial properties than freeze-dried extract, which may be related to the latter's decreased solubility. The investigation also demonstrated that the lipid fraction of okra extract, as opposed to the protein and polysaccharide fractions, was associated to its antibacterial activity. Some fatty acids (linoleic acid, palmitoleic acid, oleic acid, linolenic acid and arachidonic acid) can inhibit enyl-carrier protein reductase, which is required for bacterial fatty acid synthesis. Long-chain unsaturated fatty acids can also prevent bacteria from synthesising fatty acids [48]. Because okra seeds are so high in unsaturated and saturated fatty acids, the majority of which are long-chain fatty acids, okra has an antimicrobial effect.

Some plant's antibacterial properties can be linked to their secondary metabolites, like alkaloids, flavonoids and terpenoids, in addition to their oils. According to Solomon et al., [41], the antibacterial and antifungal activities of the chemical isolated from the ethyl acetate portion of the okra flower were nearly identical to those of normal chloramphenicol and fluconazole, respectively. Flavonoids were the primary active ingredients in okra flower extracts and since they could interact with bacterial cell walls to create complexes, they may also have antibacterial properties [49].

DISCUSSION

Potential benefits of okra as dietary supplements and nutraceuticals

The therapeutic benefits of plant-based compounds are relied upon by almost two-thirds of the world's population (7.8 billion), mostly due to their widespread availability, affordability and safety, as well as ingrained consumer beliefs [50]. According to Ashraf et al., [51], Hippocrates famously remarked, "Let food be thy medicine and medicine be thy food", emphasizing the value of food and its therapeutic and nutritional advantages in the management, treatment, and prevention of illness. By combining the terms "nutrition" and "pharmaceutical", Defelice later created the term "nutritraceutical", which is defined as a food or food component that not only offers health benefits but also aids in the prevention or treatment of a number of illnesses [52]. Importantly, nutraceuticals have been created in a way that could help or make it easier to maintain human health without causing any harm because of how they naturally arise.

Nutraceuticals derived from plants, animals or live microorganisms have a lot of potential to be used by scientific communities, food researchers and

the food-processing industry to develop novel foods or food components that will meet people's future needs for staying healthy without causing any negative side effects. Nutraceutical products are currently in high demand because to their therapeutic benefits for various conditions such as diabetes, hypertension, arthritis, inflammatory bowel disease, the common cold, dyslipidemia, heart disease and cancer. Nutraceutical supplements may also extend life by delaying the aging process, protecting the body's integrity, and ensuring regular, smooth functioning [53].

However, this exceptional, inexpensive vegetable crop's potential for medicinal or nutraceutical benefits is still not being completely utilised. Therefore, the use of an inexpensive, readily available vegetable crop like okra in a nutraceutical composition is urgently needed. Therefore, nutritional supplements made from okra may be crucial for both health improvement and disease treatment. Therefore, *A. esculentus*, a vegetable that can be eaten, might be a good source of nutraceuticals because it has both compounds that are nutritionally active and sources of diverse physiological benefits. Few nations have a history of using okra in folk medicine for a variety of medicinal objectives, including diuretic, antiulcerogenic and gastro protective. The worldwide population is now at risk for a number of chronic diseases due to recent urbanization, lifestyle, dietary and other changes. Okra is a cheap and easily accessible vegetable that has the potential to grow in importance as a nutraceutical for populations worldwide, regardless of a country's level of development. Okra-based nutraceuticals in particular could evolve into the perfect source of nourishment for those suffering from hunger in less developed nations. The therapeutic potential of okra as a nutraceutical, however, has not been specifically examined in the researches that are currently available in the literature.

Creation and formulation of nutraceuticals based on okra

Most people consider nutraceuticals to be food or food ingredients with additional health benefits. Because of its inherent nutritional content and additional bioactive ingredients that promote health, okra-based nutraceuticals are popular health foods [54]. Many attempts are being made to enhance the well-known hypoglycemic effects of okra fruit by varying the ratios of the peels and seeds of Ex-maradi Okra fruit (10:90, 20:80, 30:70, 40:60, 50:50% and so on). The *in vitro* effectiveness of these formulations as antioxidants and anti-diabetic agents is then investigated. According to recent research, seeds and peels at a ratio of 10% to 90% are the most effective at demonstrating significant *in vitro* anti-diabetic and antioxidant effects.

Because it showed significant hypoglycemic and hypolipidemic activity in alloxan models of diabetes (rodents), the nutraceutical formulation of peel and Ex-maradi okra seeds in the ratio (10:90) was then suggested as being appropriate for further improvements for the formulation of okra-based nutraceutical interventions in diabetes mellitus. Conversely, it has also been discovered that the polysaccharides in okra inhibit the proliferation of human cancer cells [55]. This implies that they might be applied as nutraceutical formulations with anticancer properties. However, a person's genetic predisposition and lifestyle decisions, such as smoking and frequent drinking, also play a significant role in their susceptibility for any given disease. As a result, different people may respond differently to nutraceuticals. Nutraceutical consumption (within the permitted range of suggested dietary intakes) may help a person prevent disease and preserve general health. As a result, okra can be considered a noteworthy vegetable crop for nutraceutical applications due to the numerous therapeutic applications of its various parts, such as the fruit, seed, pulp and mucilage.

Global okra production and possible nutraceutical market

Okra, a common vegetable crop, is inexpensive and widely consumed locally as a staple food in low-income countries. Due to its nutritional and physiological advantages, okra is becoming more and more popular these days. A wide range of okra products can be purchased on online marketplaces. A recent projection by Market Research Future states that the global market for okra seeds might bring in USD 352.7 million in sales and rise at a compound annual growth rate of 9.8% between 2018 and 2023 (M.R. Future, Seeds Market Research Report, 2020). Global trade in okra seeds is dominated by North America, Europe and Asia-Pacific, with the remaining countries following. With regard to its share of the okra market in 2018, the Asia-Pacific region was recognized the most (63.77%). The market for nutraceuticals based on okra is projected to be valued 222.9 million USD by the end of 2023. Small-scale growers have a major part of the blame for the downfall of the Asia-Pacific okra market.

The leading nations for producing okra seeds are Pakistan, Malaysia, India and the Philippines, per research [56]. India, along with the other countries mentioned above, has been the World's leading producer of okra as of late. Since 2018, these trailing countries have accounted for 33.0% of the global okra market. This better expansion within the local market is attributed to enhanced farming and the development of Genetically Modified (GM) seeds. The okra market appears to be expanding in part because the area is open to hybrid and disorder-resistant seeds. Africa is currently predicted to hold a dominant share of the global market for okra seed consumption. Owing to the availability of more fertile agricultural land around the country, it holds roughly 69% of the territory market share. However, in 2017 North America accounted for just 2.2% of the world market for okra, while Europe accounted for just 1.0%. Furthermore, Mexico is acknowledged as one of the top producers of okra in North America because of its widespread domestic okra farming [57].

CONCLUSION

The qualities of the many edible okra components that are covered in this review highlight the nutritive value of okra as well as its potential as a nutraceutical to improve human health. Okra is an inexpensive and efficient natural source that contains a wide range of bioactive phytochemicals, such as proteins, carbs, fatty acids, vitamins, fiber and minerals, which are essential for human health. Scientific studies have examined okra's potential health benefits for a number of chronic disorders, but more research is still needed in a few areas, such as its pharmacokinetics and bioavailability as well as the exact processes by which it treats different illnesses. The intricate etiologies of diseases and other elements that contribute to the diseases may have contributed to the development of such a knowledge gap. Okra's nutritional composition makes it a promising tool for mitigating the problem of malnutrition in underdeveloped countries worldwide. Because okra is inexpensive and widely accessible, it would be beneficial to develop nutraceuticals based on it. Consequently, the focus of future study should be on utilizing okra's components to make nutraceuticals, functional meals, or medications.

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