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REVIEW

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Review on the "Biological Applications of Okra Polysaccharides and Prospective Research"

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Abstract

Background: Vegetables with edible parts like flowers, fruits, stems, leaves, fibers, roots, and seeds are rich sources of essential vitamins, minerals, and trace elements with various medical functions. Many diseases such as osteoporosis, diabetes, high cholesterol, obesity, heart diseases, and stroke are caused by poor, healthy lifestyle or nutrition. Therefore, generation of new biological functions from vegetables will increase the interests of scientific research and applications.

Main body: Okra is an edible vegetable which contains vitamins, fiber, carbohydrates, protein, and minerals. The bioactive compounds of okra possess various biological activities such as anti-inflammation, antibacterial, anticancer, and antifungal. Polysaccharides from vegetables or medicinal plants are important large molecules with various biological applications. In this review, we will focus on the biological properties and nanoparticle uses of polysaccharides isolated from okra and the extraction methods of polysaccharides.

Conclusion: This review will enhance the scientific research findings of okra polysaccharides and recommend future prospective of polysaccharides for biological uses.

Keywords: Antioxidant, Antibacterial, Extraction methods, Edible vegetables, Nanoparticles of polysaccharides, Okra polysaccharide

Background

Edible plants are one of the important sources of proteins, carbohydrates, vitamins, amino acids, minerals, and lipids that enhance the immune system, bones, muscles, and other parts of the human body to fight diseases [1, 2]. Edible vegetables have common benefits for the human body and animals due to the chemical components of primary metabolism, which depends on the type of soil, used water, and environment changes [3, 4].

Okra is one of the delicious edible vegetable in North America, West Africa, South Asia, and Arab countries; it has few common names like lady fingers (English-speaking countries), Bamya (common name in Iraq), and father of musk (some Arabic countries) [5]. Okra belongs to the Malvaceae family, genus Abelmoschus, species Esculentus and contains edible green seeds, pods, and fibers (Fig. 1) [6].

Fresh okra contains energy, 90% water, 7% carbohydrates, 2% protein, fibers (contains alpha-cellulose, hemicellulose, lignin, pectin, fat, and wax matter), some important soluble vitamins in water and fat, and minerals like calcium, iron, magnesium, phosphorus, potassium, and zinc [7, 8]. Therefore, okra is an important edible vegetable for human health. Okra mucilage is used in industrial as turbidity from wastewater [9, 10], and also under investigations as biodegradable food packaging [11, 12]. The biological studies of okra bioactive compounds were investigated as antioxidant, neuroprotective, anti-diabetic, anti-hyperlipidemia, and anti-fatigue activities [13]. Okra polysaccharides have not yet pharmacology

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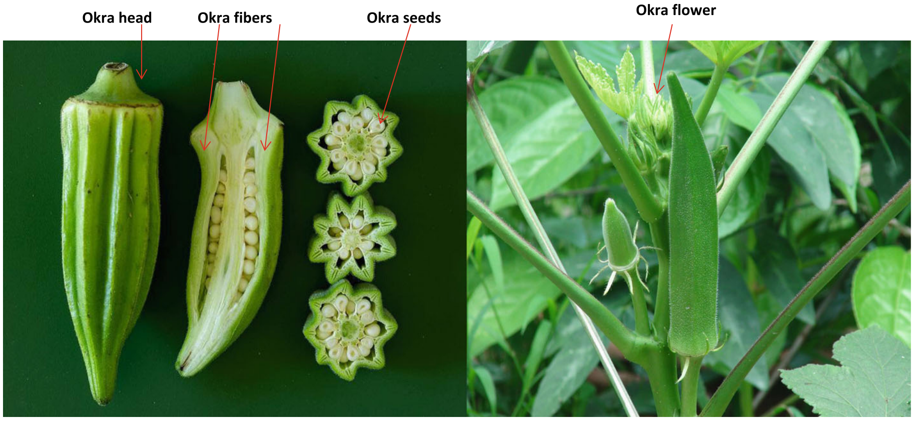

Fig. 1 Okra vegetable

extensively been investigated. In this review, we will present the extraction methods, chemical structure, nanoparticles, and the biological activities of polysaccharides extracted from okra vegetable, which presents a wide understanding of okra polysaccharides' importance and further uses.

Okra polysaccharide (OP)

Isolation and purification of polysaccharides from plants depend on the extraction methods and purification solutions, which may keep or break down the structure of polysaccharides and may reduce the biological properties. Okra polysaccharides have been isolated and identified. Liu et al. used hot water method for extraction and isolation of okra polysaccharides; it consisted of the main four monosaccharides (arabinose, galactose, rhamnose, and galacturonic acid). The isolated polysaccharides showed good hyperglycemia activity (Fig. 2) [14].

Chandra et al. extracted polysaccharides from the okra head waste which contains a high ratio of mucilage and found it to lower thermal degradation properties [15]. Kunli et al. used ultrasound-assisted extraction method to extract polysaccharides from okra vegetable which contains monosaccharides (glucose, mannose, galactose, arabinose, xylose, fructose, and rhamnose). It exhibited high antioxidant activity versus superoxide radicals and DPPH, and weak antioxidant activity versus hydroxyl radicals was revealed [16]. Xi et al. used hot water method to isolate polysaccharides from various five cultivated okra in China. The polysaccharide structure consists of similar monosaccharides (rhamnose, galacturonic acid, galactose, and arabinose); they suggested that the identified polysaccharides could be used as functional food ingredients for industrial application prospects [17]. Huricha et al. used macerated method and identified three fractions from okra polysaccharides with different molecular weight (600, 990, and 1300 kDa) and two groups of monosaccharide composition (group 1 galactose, rhamnose, galacturonic acid, and glucuronic acid; and group 2, galactose, rhamnose, galacturonic acid, glucuronic acid, and glucose). They found that those okra polysaccharides may potentially serve as novel immunomodulators supported by future studies [18]. Qin et al. used three extraction methods to evaluate the efficiency of okra polysaccharide extract; the three extraction methods were hot water extraction (HWE), pressurized water extraction (PWE), and microwave-assisted extraction (MAE). They found that the method PWE was a good extraction technique for okra polysaccharide with high biological activity for industrial applications [19]. Xi et al. used an ultrasonic method to extract okra polysaccharides (obtained pectic polysaccharides, composed of rhamnose, galacturonic acid, and galactose) which promised to be a potential functional food and pharmaceutical industries [20].

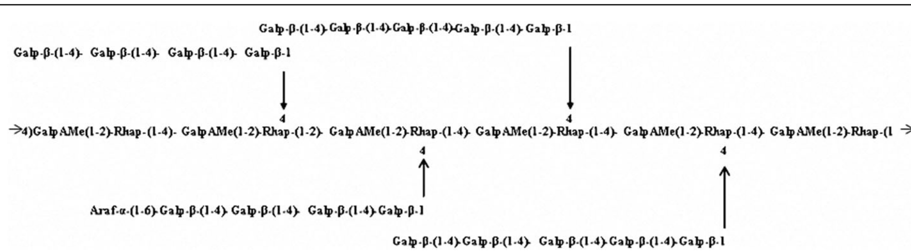

Fig. 2 An example of the chemical structure of polysaccharides isolated from okra vegetable via hot water extraction method

Table 1 showed the type of extraction method and structure analysis of okra polysaccharides. Ultrasound extraction method of okra polysaccharides showed only two similar monosaccharides (galactose and rhamnose). These differences in monosaccharide types cause variations in the biological activities, therefore, needed extensive applications to compare and target the function of structure on the efficiency of okra polysaccharides.

Antioxidant and biological activities of OP

Natural antioxidant plays a role in our life because it can keep and protect the human health rather than an industrial antioxidant. Several studies showed the antioxidant activity of okra chemical components and related to the phenolic and flavonoid contents in okra seeds, flowers, and fruits [21–24]. Gemede et al. found that okra pod mucilage is a good source as a natural antioxidant [25]. Okra polysaccharides have been investigated for its antioxidant activity; Kunli et al. found that okra polysaccharides extracted by the ultrasound method exhibited significant in vitro antioxidant activity [16]. Weijie et al. extracted polysaccharides from okra flowers using the hot water extraction method. The composition of isolated polysaccharides was [2)-α-D-Rhap-(1 → 4)-α-D-GalpA-(1 → 2,4)-α-D-Rhap-(1 → 4)-α-D-GalpA-(1] with a branch of terminal T-α-D-Galp pointed at C4 of 1,2,4-α-D-Rhap), and it was found that it exhibited a significant antioxidant activity and could be used in nutritional food and material application [26].

There are several biological applications of okra polysaccharides. Wang et al. found that those okra polysaccharides extracted by the cold water extraction method exhibited antioxidant, α-amylase, and α-glucosidase inhibitory activities in vitro [27]. Li et al. found that the neutral saccharide side chains of the OP could induce different secondary conformation change of gelatin during complex coacervation [28]. Gao et al. used fractions of okra polysaccharides, as anti-fatigue and observed it may be the main anti-fatigue remedy among *A. esculentus* substances [29]. Wahyuningsih et al. found that crude okra polysaccharides could play a role in enhancing the immune response, including phagocytic activity, spleen index, splenocytes proliferation, and control immune responses through cytokine production [30]. Liu et al. found that polysaccharides isolated from okra named (rhamnogalacturonan) possess hypoglycemic activity and are responsible for the hypoglycemia function in OP [31]. Fan et al. those okra polysaccharides possess therapeutic functions on metabolic diseases by the inhibition of LXR and PPAR signaling [32]. Deters et al. found that pectin-like polysaccharides reduced the proliferation significantly, but improved the cell viability [33]. Table 2 summarized the historical research of OP.

Anticancer properties of OP

Anticancer properties of okra extracts have been little investigated [35, 36]. Thus, the anticancer activity of polysaccharides isolated from okra has not yet been reported, and this point will enhance to explore the

Table 1 The differences between okra polysaccharide chemical compositions based on the type of extraction methods

Hot water (Ref. 14)	Ultrasound (Ref. 16)	Ultrasonic (Ref. 20)	Macerated (Ref. 18)	
Arabinose	Glucose	Galactose	Glucose	Galactose
Galactose	Mannose	Galacturonic acid	Galactose	Galacturonic acid
Galacturonic acid	Fructose	Rhamnose	Galacturonic acid	Rhamnose
Rhamnose	Rhamnose		Rhamnose	Glucuronic acid
	Galactose		Glucuronic acid	
	Arabinose			
	Xylose			

*Red color indicates the similar monosaccharides in the extraction methods

Table 2 The biological applications of OP

No	OP activity	Reference
1	Exhibited good DPPH radical-scavenging ability	[26]
2	Exhibited antioxidant, α-amylase, and α-glucosidase inhibitory activities in vitro	[27]
3	Induce different secondary conformation changes of gelatin during complex coacervation	[28]
4	Responsible for the hypoglycemic activity	[31]
5	Anti-fatigue	[29]
6	Enhancing immune response including phagocytic activity, spleen index, splenocytes proliferation, and control immune responses through cytokine production	[30]
7	Synthesized ZnO nanofilms contains okra mucilage, showed high antibacterial activity against *S. aureus* than *E. coli*	[34]
8	Exhibited significant in vitro antioxidant activity	[16]
9	Possess therapeutic functions on metabolic diseases by the inhibition of LXR and PPAR signaling	[32]
10	Reduced the proliferation significantly but improved the cell viability	[33]

anticancer properties of okra polysaccharides using different extraction methods.

Nanoparticles of OP

Gold nanoparticles of aqueous extract of okra have been synthesized and exhibited antibacterial activity against *Bacillus subtilis*, *Bacillus cereus*, *E. coli*, *Micrococcus luteus*, and *P. aeruginosa* and act as an effective antifungal agent [37, 38]. Silver nanoparticles of the okra aqueous extract have been synthesized by Jassim et al. and showed different antibacterial and enzyme activities [39]. Hamid et al. synthesized ZnO nanostructure film that contains okra mucilage that showed high antibacterial activity against *S. aureus* than *E. coli* [34]. Agi et al. used cost-effective and easier method to synthesize cellulose nanoparticles from okra mucilage using an ultrasonic method [40]. Bhavani et al. used okra extract to synthesize $ZnAl_2O_4$ nano-catalysts and found that microwave method is better than conventional heating in conversion of alcohol to carbonyl group [41]. Thus, further investigation of gold or silver or other metal nanoparticles of okra polysaccharides is of importance in discovering new biological functions and mechanism of actions.

Conclusion

Okra is an important vegetable for human health because of its functional bioactive compounds as antioxidant. A polysaccharide of okra had some biological functions such as anti-fatigue, hypoglycemia, and phagocytic activities. Therefore, needed extensive studies of the biological research to identify the anticancer and antimicrobial properties of okra polysaccharide and nanoparticles forms to target the main purposes of polysaccharide uses, and develop its functions in the medical applications.

Abbreviations

PI3K: Phosphoinositide 3-kinase; AKT: Protein kinase B; GSK3β: Glycogen synthase kinase 3 beta; Nrf2: Nuclear factor erythroid 2-related factor 2; LXR: Liver X receptor; PPAR: Peroxisome proliferator-activated receptors; DPPH: 2,2-diphenyl-1-picrylhydrazyl

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Authors' contributions

AA is the main contributor in designing and writing the review article. MH searched for nanoparticles of OP researches. KH searched for the related researches of OP. HT selected the subject of review article. All authors have read and approved the manuscript.

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Competing interests

The authors declare that they have no competing interests.

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