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Potential Role of Okra (Abelmoschus esculentus) Mucilage in the Pharmaceutical Fields

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Abstract: Mucilages have shown high demand in food and in other industrial applications such as film coatings, emulsifiers, disintegrants, binders, suspending and gelling agents. They are biodegradable, biocompatible, non-toxic, economical, and easily available. The natural polysaccharides found in plant mucilage have high antioxidant activity and thus prevent cell damage induced by reactive oxygen species. In addition, they increase the levels of superoxide dismutase (SOD) enhancing the antioxidant mechanism. Okra (Abelmoschus esculentus) mucilage has shown functional health properties, such as antitumor, antioxidant, antimicrobial, hypoglycemic, and antiulcerogenic activities, as well as the capacity to bind cholesterol and bile acids, removing toxins from the liver. It is a highly viscous polysaccharide that is mostly composed of monosaccharides D-galactose, L-rhamnose, and galacturonic acid, as well as proteins and minerals. Due to its rheological properties, okra mucilage may be used as an alternative in the pharmaceutical industry and has attracted a great attention of researchers as diluents, binders, disintegrants in tablets, thickeners in oral liquids, protective colloids, gelling agents and suppository bases. Generally, the plant mucilage could also be used as a film coating for microencapsulation, administration of osmotic and ophthalmological drugs, oral films, and drug delivery. This review paper aims to highlight the methods of extraction of okra mucilage, properties of this mucilage, and use of okra mucilage in the pharmaceutical field.

Keywords: Role, okra, Abelmoschus esculentus, mucilage, pharmaceutical, fields

1. INTRODUCTION

Okra (Abelmoschus esculentus L.) belonging to the family Malvaceae is believed to have its origin in Ethiopiα and Sudan, the north-eastern African countries. From these regions it spread to tropical and subtropical regions of the world. The plant is one of the oldest cultivated crops and presently grown in many countries and is widely distributed from Africa to Asia, Southern Europe, and America. (Fiqure 1) . It is sensetive to frost, low temperature, water logging and drought conditions, and the cultivation from different countries have certain adapted distinguishing characteristics specific to the country to which they belong. Okra plants are grown commercially in many countries such as India, Japan, Turkey, Iran, West Africa, Yugoslavia, Bangladesh, Afganistan, Pakistan, Maynmar, Malaysia, Thailand, Brazil, Ethiopia, Cyprus and in the Southern United States (Gemede et al., 2015). Word okra production increased from 1.91 million tons in 1973 to 11.2 million tons in 2022, growing at an average annual rate of 8.85 (Knoema Co., 2024). Based on a comparison of 46 countries in 2022, India ranked the highest in okra production with 6,85,000 tons (Helgi Library, 2024).

Okra is multipurpose crop due to the various uses of its fresh leaves, buds, flowers, pods, stems and seed (Gemede et al., 2015). All parts of the plant are edible and are used to have several food. Okra immature fruits (Figure 2), which are consumed as vegetables, can be used in salads, soups, fresh or dried, fried or boiled (Gemede et al., 2015). The mucilaginous extract obtained from the fruit is often added to different recipies like soups, stews and sauces to increase the consistency. The polysaccharides present in okra are used in sweetend frozen foods such as Icecreams, as well as bakery products due to their health benefits and longer shelf-lives (Yuennan et al; 2014). Okra immature pods are also used in making pickle. The seeds of okra are source of oil and protein and have been used on a small scale for oil production. Okra seeds may be roasted and ground to form a caffeine-free substitute to coffee (Calisir and Yildiz, 2005).

Research on the leaves, fruits (pods), seeds, roots and flowers of A.esculentus have a variety of bioactivities, including

antidiabetic, hypolipidemic, antioxidant, antimicrobial, and anticancer properties in addition to wound healing, hepatoprotective immunomodulative, neurological, gastroprotective, weight reduction potential and cardioprotective properties. Other pharmacological activitis were also reported such as nootropic, antistress, anti-inflammatory and antinociceptive. These biological activities were attributed to the secondary metabolites present in all parts of the plant, which include phenolic acids, terpenes, vitamins, flavonoids, sterols. fatty acids, acyclic derivatives, aldehydic derivatives, ketonic derivatives, alcoholic derivatives, and miscellaneous other compounds.

Figure 1. Okra (Abelmoschus esculentus) plant

Figure 2. Okra (Abelmoschus esculentus) pods

Plant mucilages are natural products of metabolism and. are found in the cell, and do not dissolve easily in water. They are present in various parts of the plant. Mucilages are plant hydrocolloids. They are a mixture of clear amorphous polymers and monosaccharide polymers, combined with uronic acid. Mucilages contain hydrophilic molecules that can combine with water to form viscous or gel-like solutions. Advantages of using mucilages in the pharmaceutical industry include the following: that they are biodegradable, biocompatible, non-toxic, provide better tolerance to the patient , have fewer side effects, do not cause allergies in humans, do not irritate the skin or eyes, and have low production costs (Deogade et al., 2012; Amiri et al., 2021). On the other hand, disadvantages of the use of these materials include microbial contamination because the moisture content of mucilages is 10% higher, and they are carbohydrate in structure. The amount of hydration in them is difficult to be controlled, and on storage a decrease in their viscosity occurs due to contact with water .

This paper aims to highlight the extraction methods of okra mucilage, characterization of okra mucilage, and applications of okra mucilage in the pharmaceutical fields.

2. METHODS OF EXTRACTION OF OKRA MUCILAGE

Several methods of extraction of okra mucilage have been described and the most common ones could be grouped into : (1) conventional method (Tavakoli et al., 2008; Farooq et al., 2013), (2) ultrasound -assisted extraction method (Wang et al., 2018, Rajalakshmi and Sangeetha, 2023; Glaue et al., 2023; Akcan and Glaue, 2024), and (3) microwave-assisted extraction method (Shah and Seth, 2011) . In all these three methods different processes are involved like soaking and boiling by using fresh or dried okra with or without seeds. Final extraction is done using different organic solvents such as acetone, ethanol, methanol, etc . The extraction procedure is shown in Figure 3 . The ultrasound-assisted extraction method (UEM) is reported to be environmentally friendly and economical extraction method. It is described to have promising potential as a technique fer extracting okra polysaccharides that are thermally stable , namely, they have the ability to maintain its properties and structure when exposed to high temperatures or varying level of heat, which makes them suitable for industrial applications that require heat resistance (Glaue et al., 2023). Zhai et al. (2015) investigated the extraction of polysaccharides from okra pods by ultrasound- assisted heating extraction using the response surface methodology (RSM). They found that the optomized conditions were ultrasonic temperature 63.19°C, ultrasonic time of 10. 40 min, liquid/solid ratio of 47-39:1 (ml:g). The experimental optomized yield was 6.375%, which was well matched with the predicted value (6.435%).Wang et al. (2019) used ultrasound assisted extraction to obtain water-soluble polysaccharides from okra fruits. The ideal conditions for a better performance of the extraction process were the temperature of 59 °C for a time of 30 min using 522 W of ultrasonic power. Olawyi et al. (2020)

investigated the effect of extraction conditions on ultrasonic-assisted extraction of polyphenolic compounds from okra leaves. They found that optimal conditions for okra leaves extraction were 60% ethanol solid- to-solvent ratio of 1:40 g/mL, temperature 70°C and extraction time of 30 min. High polyphenolic contents (total phenolic content and total flavinoid content) and antioxidant activities [2,2-diphenyl-
1-picrylhydrazyl and 2.2-azino-bis (3 ethylbenzothiazdine-6-sulfonic acid) radical scavenging activities].

The microwave-assisted extraction (MAE) method was developed to optimize the extraction of mucilage. When the mucilage was extracted by both the conventional and microwave- assisted methods, it was found that microwave extraction at 160w intensity and 40 min heating duration increased by 11.55% the yield of mucilage when compared to 1 h conventional heating method. Chemically, the product obtained by both the methods were of similar nature. It was advised that the microwave procedure can be used successfully in commercial and routine laboratory isolation of mucilage without deteriorative effects on the structural and functional properties of the extracted material (Shah and Seth, 2011). Advantages of this method are increasing greatly the speed of breaking up of plant cells and plant tissues. This reduces the processing time (economic advantage) and also decreases the risk of decomposition or disintegration and oxidation of the valuable plant constituents. The microwave assisted extraction method require shorter time, less solvents, higher extraction rate and better products with lower costs (Shah and Seth, 2011).

3. CHARACTERISTICS OF OKRA MUCILAGE

Okra macilage has a viscous appearance due to its acidic polysaccharides (Kontogiorgos et al., 2012). These polysaccharides are soluble in acidic or alkaline solutions as well as in hydro alcoholic solutions. Water extraction of the mucilage results in a highly viscous solution (Palanisamy et al., 2017). Gao et al. (2018) isolated two polysaccharide fractions prem okra (AEP-1 and AEP-2, identified as rhamnogalacturonan I and type II arabinogalactan, respectively). These polysaccharides are soluble in water but insoluble in organic solvents such as ethanol, -acetone, chloroform, and n-butanol. Main okra mucilage polysaccharides include mannose, rhamnose, glucuronic acid, glucose, arabinose, galacturonic acid RH (67±0.01), percentage loss on drying. (10.0±0.03), percentage of total ash (0.2 ± 0.04), percentage of acid insoluble ash (0.02.±0.01), tissue density (1.59±0.01 g/cm^3), bulk density (0.219±0.00 g/cc),tapped density (0.326 ± 0.01 g/cc), and compressibility index (32.82%).,

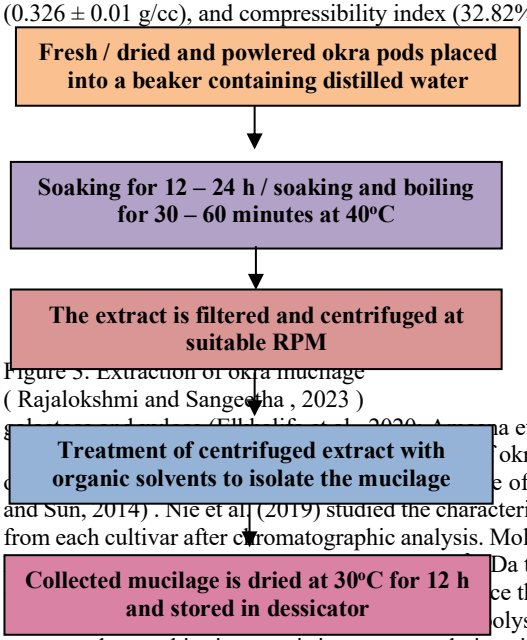

Figure 3. Extraction of okra mucilage
(Rajalokshmi and Sangeetha , 2023)

et al., 2010; Gao et al., 2018).

okra polysaccharides is directly related to their bioactive properties. Polysaccharides e of high molecular weight, as they have difficulty crossing cell membranes (Sheng and Sun, 2014) . Nie et al. (2019) studied the characteristics of polysaccharides of 5 different cultivars of okra and isolated two fractions from each cultivar after chromatographic analysis. Molecular weights of the different cultivars ranged from 2.76 x 10^3 kDa to 4.20x 10^3 Da to 0.9X10^3 kDa for another fraction. The different cultivars did not influence the ce the molecular weight.

olysaccharides and phenolic compounds. In the okra fruits and extract, the phenolic compounds catechin, isoquercitrin, protocatechuic acid, quercitin, quercetin - 3-0-gentiobioside, and rutin have been reported (Wu et al., 2020) . Mucilage extracted from okra cultivated in different parts of the globe may show differences in their biochemical composition , such as the total phenolic content (Adetuyi and Dada 2014, Chukwuma et al., 2018, Li et al 2017, Sheg and Sun, 2014). Pectin is the main pelysaccharide found in okra mucilage and has been considered responsible for the viscous aspect of okra extracts (Kpodo et al.,2017). It is classified as complex polysaccharide and is found in plants and consists mainly of α 1,4 chains linked to D-galacturonic acid (Chen et al 2015). In industry, pectinic polysaccharides are used to increase viscosity as well as to act as a stabilizer and a protective colloid in food and beaverges (Canteri et al., 2012).

Farooq et al. (2013) investigated the characteristics of okra mucilage extracted by the water based method. The results showed that the micllage exhibited good flow properties (Angle of responce 27.29°), the surface tension of 0.25% w/v solutions of mucilage was found to be 0.0405 joule/m^2 , total ash was 7.53 % w/w , loss on drying was 9.917% and PH was found to be 7.5. Extracted mucilage was soluble in warm water and insoluble in organic solvents. The authors concluded that the mucilage can be safely used in dosage form without causing any adverse effect.

Adekanmi et al.(2020) using standard methods conducted a study on the qualitative and quantitative phytochemicals constituents of okra fruits. Results showed solubility (sparingly soluble in water and insoluble in acetone and ethanol), pH 6.9 ± 0.22, viscosity (245.58 ± 0.03), swelling ratio. (3.4 ± 0.03). Phytochemical screening revealed the presence of tannins, steroids flavonoids, saponins, alkaloids, anthraquinones, phenol, terpenoids, cardiac glycosides, and cardenoids. Quantitatively, okra contained flavonoids

(12.54%), saponins (19.33%) and alkaloids (10.53%). The estimated quantity of aqueous and ethanolic extracts were 17.43 and 14.65%.

4. APPLICATION OF OKRA MUCILAGE

4.1 Binder

Okra gum is reported to be a binder that produces some tablet formulations with good hardness, friability, disintegration time and dissolution rate (Biswal et al., 2014). Furthermore, it prolongs the dissolution rate of some slightly soluble drugs and can be considered as a good candidate for sustained release formulations . In a study done by Ameena et al., (2010), mucilages extracted from leaves of Hibiscus rosasinensis and okra (Abelmoschus esculentus) were subjected to various physicochemical properties for its suitability as an excipient in the formulation of tablet dosage form. Formulated tablets were evaluted by studying the standard parameters, like diameter, thickness, weight variation, hardness, friability, disintegration and in vitro dissolution. Results indicated that the formulated tablets using the mucilages of both Hibiscus and okra had good appearance. The in vitro drug release profile of the tablets prepared from okra mucilage had an optimum of 90% at a mucilage concentration of 1% w/v concentration mucilage itself within 4h. The authors concluded that the lower concentration levels of okra can be used as an alternative to starch. The higher concentration levels of okra mucilage show a slow and sustained release, and can be considered as an alternative natural excipient in the modified drug delivery systems. At the same time, the above natural excipient of Hibiscus mucilage could be used as a platform for prolonged release if its binder concentrations are increased.

Zaharuddin et al. 2014 studied the effectiveness of okra gum in sustaining the release of propranolol hydrochloride in a tablet. The gum was extracted from the pods of Hibiscus esculentus using acetone as a drying agent. Dried okra gum was made into powder form and its physicochemical characterestics such as solubility, pH, moisture content, viscosity, SEM morphology, infrared study using ETIR , crystallinity study using XRD, and thermal study using DSC and TGA were done. The powder was used in the preparation of a tablet using granulation and compression methods. Propronolol hydrochloride was used as a model drug and the activity of okra gum as a binder was compared by preparing tablets using a synthetic and a semisynthetic blinder which are hydroxyl methylpropyl cellulose (HPMC) and sodium alginate, respectively. Dissolution studies that were carried out to evaluate drug release kinetics showed that okra gum retarded the release up to 24h and exhibited the longest release as compared to HPMC and sodium alginate. It was also found that okra gum produced tablets with the highest hardness value and lowest friability. The authors concluded that okra mucilage could be considered an effective adjunct to produce favourable sustained release tablets with strong tensile and crushing strength.

Okoye et al. (2011) compared the mechanical and release properties of paracetamol tablets formulated with okra gum, providone, gelatin, and hydroxypropylmethyl cellulose (HPMC) as wet binders. Each was separately employed at 1.0-5.0% w/w to granulate powder mix of paracetamol (82%), lactose (8%), and corn starch BP (10%). Results revealed that tablets tensile strengths to be in the order: HPMC > gelatin > okra mucilage > providone. All the tablets (except those formulated with 1.0% w/w HPMC) passed the friability test. Friedman's test showed okra mucilage as the most effective binder while regression analysis proved okra gum to be the most economical binder with respect to reduction of BF1 value ($P<0.05$) which is directly related to binder's abilities to ameliorate capping and lamination in tablets. The dissolution profiles of tablets formulated with okra gum were good at binder concentrations of 1-2% w/w and closely followed those of tablets formulated with providone. Beyond 2% w/w binder concentration, the profiles declined. in comparison to those of providone yet better than those of gel and HPMC.At 1.0% w/w concentration okra gum reduced the BF-1 of paracetamol tablets to an acceptable level (0.296), and with a dissolution profile similar to that of providone formulated tablets. It has proved to be more effective and economical than providone which imparted a similar BFI values to the tablets at concentration thrice that of okra gum. Okra gum is therefore recommended as an alternative to providone, an expensive binder.

Hussain et al. (2017) investigated the binding strength of different concentrations (1/%, 3%, and 5%) of okra gum. Results from universal testing machine indicated that the binding strengths of all dispersions of okra increased as the concentration was increased from 1% to 5% and ranged from 2.5 to 4.5 N, which are almost twice high as those of pregelatinized starch. Tablets that were prepared with okra mucilage showed good mechanical strength and hardness values of 7-8.5 kg/cm² and a friability of <1%, comparable to tablets prepared with starch . The disintegration time was longer (7.50 min with okra gum and 6.05 min with starch paste), and the drug release from the tablets was slower than the formulations with starch. The authors suggested that the higher binding ability of okra gum probably linked with its chemical composition as it mainly contains galactose, rhamnose and galacturonic acid. They arrived to a conclusion that okra gum is a better binder than pre-gelatinized starch.

Chatterjee and Mazumder (2019) extracted a natural polymer (okra gum) and evaluted its compression-coated tablet using okra as binder along with synthetic hydrophilic polymers like various grades of hydroxypropyl methylcellulose (HPMC). Results revealed that the polymers were subjected to the Fourier transform infrared and differential scanning calorimetry thermogram had no significant interactions between the drug and the polymers. Characterization of the polymer showed that it has swelling properties, and inspite of being a hydrophilic polymer, it can be successfully used in pharmaceutical formulation as a good binder. Owusu et al. (2021) utilized paracetamol tablet formulations in investigating the potential binding characteristics of pectin harnessed from various okra genotypes (PCI-PC5) in Ghana . Okra mucilage formulated tablets passed the weight uniformity, drug content, hardness, and friability tests. Based on their crushing strength, tablets prepared with pectin from the various genotypes were relatively harder ($P<0.05$) than tablets prepared with tragacanth BP.Tablets prepared with pectins as binders at 10% w/v and 15% w/v passed the disintegration and dissolution tests with the exception of PCR at 15% w/v, produced tablets which failed the disintegration test and showed poor dissolution profiles. it was concluded that pectin from these genotypes can be industrially commodified as binders in immediate release tablets using various concentrations. Shah et al.(2023) studied the extraction, isolation and characterization of okra mucilage, as potential source of binder in tablet. Results of the study indicated that okra mucilage can be used as a binder in paracetamol tablets formulation with good physical properties. In this study, tablets of long disintegration times were produced.

4.2. Mucoadhesive polymer

Okra mucilage is considered as important natural and safe gel former that can be developed to serve as an alternative to currently used synthette gel formers for nasal drug delivery (Sharma et al, 2013). Okra gel formulation has good properties in terms of pH ,viscosity, and mucoadhesion. Permeation of the okra gel formulation through the nasal mucosa occurrs within 255 min. In their study on the mucoadhesive character of okra mucilage, Meenakshi and Prerna (2016) found that the ratio (okra mucilage/lactose) has more pronounced effect on ex-vivo bioadhesion time than that of compression force. Optomized formulation using okra mucilage/lactose ratio (0.5) and compression pressure (7 ton) provided adequate ex-vivo bioadhesion time (22h) and percentage of 98.23% after 24h. Naveen et al. (2020) extracted natural okra gum and following thiolation (TOG) evaluated the mucoadhesion property and role of the gum in enhancing the efficacy of repaglinide as a model drug (short-acting Type 11 antidiabetic drug). Results of the study indicated that thiomers based formulations can be promising drug delivery systems, even in targeting onerouse mucosal surfaces like nasal, occular or vaginal.

4.3 Suspending agent

Among the various pharmaceutical properties, the suspension property finds application in the preparation of most pharmaceutical suspensions. It is well known that the suspending agent reduces the settling ratio and permits easy redispersion of any settled particulate matter such as the associated drug. Nair and Fahsa (2013) analyzed the physical, physicochemical and phytochemical properties of the mucilage of cultivated and wild species of Abelmoschus using standard procedures. The suspension properties of the mucilage of these two species was assessed using the suspending properties such as sedimentation volume, flow rate, particle size analysis, pH and viscosity. Results showed that the mucilages of both species were advantagious and that the suspending property of A. moschatus was par to that of A. esculentus. Okra mucilage powder has been found to be an effective as disintegrant in low concentration (4%) (Kumar et al., 2009). It was a superior disintegrating agent than Ac-Di-Sol® .Additionally, there was a poor relation between the swelling index and disintegrating efficiency. Results also showed that the extracted mucilage may be a good source of pharmaceutical adjuvant, specifically a disintegrating agent. In a study by Nyandoro et al. (2019) the authors investigated the effect of particle size of okra gum as a suspending agent on the physicochemical properties of oral drug paracetamol suspension. They found that the physicochemical properties differed among the batches of paracetamol dry suspension and were influenced by size of the particle of the suspending agent. Among the okra gum samples, particle size under 180 um yielded paracetamol suspension with best physico- chemical properties thus implying that there is an optimum particle size of suspending agents that should be used in a suspension

4.4 Floating Agent

Okra mucilage is natural, non-toxic, cheap and suitable for use in the development of floating drug delivery systems. A study carried out by Edukondalu et al. (2011) involved optomization and evaluation of the floating tablets of atenolol that prolongs the gastric residence time. In this study semi-synthetic polymer, HPMC k 100m and natural polymer (okra gum) were used as release retarding agents by its swelling nature. Atenolol tablets were prepared by direct compression, and sodium bicarbonate was used as a gas-generating agent- Physicochemical properties of the prepared tablets were found to be within range viz, hardness, swelling index, floating capacity, thickness, and weight variation . Further, in vitro release characteristics of the tablets for 8 h were evaluated. Optimization of the concentrage of okra gum with a gas-generating agent was performed to get the sustained release of atenolol for 8 h, drug release from all the formulations followed first order kinetics and higuchi's mechanism. The optomized formulation was of better release rate. Chodavarapu et al. (2011) investigated the effectiveness of edible okta gum as a polymer in the development of a gastric floating dosage form of metformin HCL. Results of this study, it was evident that the formulation which included okra gum have lesser floating capacity but showed a sustained release of drug whereas the formulation which contained only HPMC has higher floating capacity but poor sustained release of drug . Okra gum formulation showed a prolonged release of the active ingredients . Shirwaikar et al. (2008) mentioned that there will be an increase in the use of herbal excipients as they are biodegradable materials, these can be compatable with the excipient in drug delivery systems. Additionally, they are non-toxic, freely available, and less expensive compared to their counterparts. Herbal excipients will have a major role to play in pharmaceutical industry.

4.5. Film Coating Agent

At present, the use of aqueous solvent is prefered as compared to organic solvents, because aqueous solvent is non-flammable, environmental friendly, cheap, readily available, and safe. Film coating is much better than sugar coating because it involves low weight increase of 2 to 3% and less rigid coats which reduce the craking and other defects observed in sugar coating. Among other advantages is that the polymer constitute the main ingredient in a film coating operation and could be a natural or synthetic polymer. Ogaji and Hoag (2014) studied the effect of extraction method on the application of okra gum as an aqueous film coating agent The novel extraction process described by the authors enhanced the film coating potential of okra gum by delivering more solids on the substrate at a shorter time with improved operation frequency. Ogaji and Nonoli (2010) investigated the film coating potential of okra gum extracted from pods of Abelmoschus esculentus L. plant using paracetamol as a model drug. Results showed that the coated tablets had lower friabillty, increased disintegration time (24 min) compared to the core (3 min) and improved hardness, but there was no difference in the dissolution profile of the samples from the batches containing okra and HPMC as film formers. The authors concluded that okra gum is a promising natural, biodegradable, cheap and eco-friendly film former in aqueous tablet film coating operation, particularly when masking of taste ar objectional odor in a solid dosage formulation is needed.

4.6. Emulsifying Agent

Polysaccharides are soluble and dispersible in water due to their ability to interact with water and swell. The swelling properties involve enterapment of large amount of water between the polymer chains and branches . Plant mucilage can be used as food additives, to modify the food quality in terms of food stability, texture and appearance properties by acting as emulsifiers, thickeners , gelling agents or texture modifiers. Noorlaila et al. (2015) studied the emulsifying properties of extracted okra (Abelmoschus esculentus L.) mucilage at different maturity indices (1,2, and 3). Based on preliminary findings, okra mucilage index 2 was selected to be added into

oil-in-water (o/w) emulsion system of coconut milk at different percentage of 0.25%, 0.50% and 1.0%. Results showed that okra mucilage (maturity index 2) at 1.0% percentage in coconut milk obtained the highest value in emulsion capacity (EC) . It was concluded that okra plant has potential to be used as emulsifier in food emulsion system . In a study by Albo et al. (2013) extracts. rich in pectin were isolated from okra (Abelmoschus esculentus pods). These extracts were examined in terms of their composition and emulsion stabilizing capacity in model acidic emulsions (hexadecane-in-water at pH 3.0). Results revealed that the extracts had good emulsification capacity under acidic conditions . Emulsions with extract isolated at pH 6 were more stable than those at pH 4. Additionally, Ostwald ripening was found to be one of the major coarsening mechanisms for both emulsions. Viscosity of both emulsions increased by aging. It was concluded that okra extracts can be strong candidates for emulsification in acidic environments. Temenouga et al. (2016) found that heat-treated okra extracts can act as very efficient emulsifiers. These products can be better emulsifiers than conventional maillard conjugates. The authors reported that intrinsic components of natural extracts can lead to maillard products of commercial interest, and constitute a solid basis for the possible exploitation of okra as an emulsifier rather as thickening agent. In their study, John. et al (2020) found that aspirin and okra mucilage have good compatibillty with olive oil, which can serve as a means of formulating aspirin emulsion to enhance compliance in children. According to same authors, okra mucilage can be useful in formulating stable emulsions when combined with other natural emulsifiers in small quantities.

4.7 Stabilizer

Stabilizers are materials that stabilize drug particles by forming a stabilizer layer around them . Natural-origin polymers that have been used as stabilizers are cellulose, starch and pectin. Stabilizers are very important in maintaining the bioavailability of drugs (Choudhury et al., 2023). Okra mucilage is non-toxic, readily available, palatable, eco-friendly and could be used as stabilizer in cosmetic, pharmaceutical, and food industries (Nair and Fahsa, 2013). Chumsri et al.(2022) investigated the properties of mucilage extracted from green okra (Abelmoschus esculentus L.) and the suitable ratio of the okra mucilage powder that can be used in chocolate ice cream. Results indicated that the scores of aroma, taste, and texture of the 1.5% mucilage powder formula ice cream were significantly greater than standard formula ice cream. Okra mucilage was found to contain 18.72% fat, 0.03% fiber, 9.99% ash as well as high percentage of protein (18.72%) and carbohydrate (16.72%). The mucilage powder had 8.81% moisture content that was not greater than standard for dried food set by Thai Industrial standards Institute (15%). It was concluded that the mucilage powder from green okra had nutritional composition suitable for its use as a stabilizer in ice cream and various food products. Chompuja et al. (2023) reported the potential use of okra mucilage powder as a stabilizer in ice cream production. By substituting okra mucilage powder for guargum, the viscosity of overrun percentage of the ice cream mixture was reduced, resulting in proper mixture and slower melting. The chemical analysis revealed moisture, fat, protein, fiber, and carbohydrate percentages of 71.04, 1.67,4.83,0.45, 1.57, and 20.44, respectively , with a total energy of 116.11 kilocalories per l00 grams.

4.8. Antiadhesive

Okra polysaccharides reportedly possess antiadhesive properties that interrupt the adhesion of Helicobacter pylori to human stomach tissue (Lengsfeld et al., 2004) The antiadhesive effects were reported to be due to interaction with the bacteria, while pretreatment of human stomach tissue with okra polysaccharides prior to the addition of H. pylori does not lead to reduced bacterial adhesion . Polysaccharides have no cytotoxik effects against H. pylori (Lengsfeld et al., 2004) . Plant -derived compounds could provide a preventive, cytoprotective strategy to control H.pylori colonization, particularly to prevent its recurrence after antibiotic eradication therapy. From results of their study, Messing et al. (2014) concluded that non- specific interactions between high molecular compounds from okra fruits and the H. pylori surface lead to strong antiadhesive effects.Lengsfeld et al. (2004) investigated the effects of several crude and purified carbohydrate-containing fractions from immature okra fruits against H. pylori in an in situ adhesion model on sections of human gastric mucosa. Pretreatmen of the bacteria with a fresh juice preparation inhibited the bacterial adhesion almost completely. The authors assumed that the antiadhesive qualities of okra are due to a combination of glycoproteins and highly acidic sugar compounds making up a complex three-dimensional structure that is fully developed in the fresh juice of the fruit.

4.9. Thickener

Okra (Abelmoschus esculentus) mucilage is widely used as a thickener and viscosifier in medical and food industries due to its low cost, availability, longer shelf-life, and high thermal tolerance . In a study carried out by Murtaza et al. (2021), the performance of okra contained drilling fluids was compared with that of starch-based drilling fluid. Addition of okra reduced the thickness of the cake. The addition of okra powder also increased the viscosity and gel strength of the water based drilling fluid . Authors concluded that okra mixed drilling fluid can be used as an alternate solution to starch mixed drilling fluids. Okra mucilage can also be used as egg white and fat substitutes in baked and frozen desserts (El-Sayed et al., 2014).

4.10. Antioxidant

Khomsug et al. (2010) evaluated the antioxidant activities of seeds and pulped okra by DPPH radical scavenging and ABTS radical cation decdorization ssays. Extraction yields with methanol of seeds and pulps were 1.97 and 5.53%, respectively. Both methods (DPPH and ABTS) revealed that pulp and seeds of Abelomoschus esculentus L. had high relative antioxidant activity. Concentration that provided 50% radial scavenging (IC50) in DPPH method was 44.1 and 55.73 mg mL^{-1} for seeds and pulp, respectively. In comparison, the IC50 values measures by the ABTS assay were 74.33 and 24.9 mg mL^{-1} for seeds and pulp, respectively.

Doreddula et al.(2014) investigated the in vitro antioxidant capacity and in vivo protective effects of the aqueous and methanolic seed extracts of Abelmoscus esculentus against scopolamine-induced cognitive impairment using passive avoidance task and acute restraining stress-induced behavioural and biochemical changes using elevated plus maze (EPM) and forced swimming test (FST) in mice. The results revealed that the pretreatment of mice with aqueous and methanolic seed extracts of Abelmoscus esculentus (200 mg/kg, p.o.) for seven days significantly $p<0.01$) attenuated scopolamine-induced cognitive impairment in the passive avoidance test. Furthermore, the extracts reduced significantly the blood glucose, corticosterone, cholesterol, and tryglyceride levels elevated by

acute restraint stress and also significantly increased the time spent in open arm in EPM and decreased the immobility time in FST. Results also demonstrated that the extracts showed a significant antioxidant activity and no signs of toxicity or death up to a dose of 2000 mg/kg, P.0 . It was concluded that seed extracts of Abelmoschus esculentus L. possess antioxidant, antistress, and nootropic activities

Ahmed and Kumar (2016) studied the antioxidant potential and in vitro antidiabetic activities of Abelmoschus esculentus. The antioxidant activity of Abelmoschus esculentus was determined by total antioxidant activities like DPPH . ferrous ion chelating activity and inhibition of β-carotene bleaching . At 0.125 to 2.0 mg/mL , the scavenging activities of a queous ethanol and methanol extracts on DPPH radical ranged from 10.2 to 80.25% 11.5 to 90.6 %, 93.6% and 12.8 to 93.6% respectively. The perecentage chelation was obtained from methanol (68.5% mg/mL) whereas ethanol ferrous lon showed 65.6% at 1.0 mg/mL . The lowest ferrous ion chelating effect was exhibited by aqueous extract (62.4%) . Abelmoschus esculentus was found to inhibit efficiently both α-amylase and α-glucosidase enzymes in vitro in a dose dependent manner. The authors concluded that methanolic extracts of Abelmoschus esculentus have better antioxidant and antidiabetic activity than ethanol and aqueous extracts.

A study was carried out to determine the in vitro antidiabetics and and antioxidant ability of Abelmoschus esculentus methanolic extract using α-amylase and α-glucosidase inhibition model (Siddique et al., 2022). Results demonstrated that the methanolic extract at concentrations of 31-1000 µg/mL caused scavenging percentage of DPPH radicals ranging from 1.618 to 13.487% . Enzymatic antioxidant activities of the extract such as catalase (CAT), peroxidase (POD) and superoxide dismutase (SOD) revealed their significant potentials with values of 3.99± 1.05,1.27±2.6 and 23.80±0.03 U/mg protein respectively. At 50 - 200 µg/mL, the inhibition percentage of α-glucosidase and α-amylase were 14.36±0.099 to 19.23 ±0.172% and 15-89±1.877 to 37.19±7.430% respectively. It was concluded that Abelmoschus esculentus constitutes a potent source of natural antioxidants as well as having potential antidiabetic activity

Liao et al. (2012) studied the free radical scavenging activities of 80% methanol extracts of the flower, fruit, leaf, and seed of Abelmoschus esculentus. The DPPH radical scavenging and ferric reducing antioxidant power assays were used. Results showed that all the different parts have high phenolics and flavonoids content, and that the extracts have the effect of scavenging free radicals.

Wang et al. (2020) reported that the bioactive polysaccharides 50 (obtained by the precipitation method at saturation of 50%) separated from fresh okta pods exhibited stronger DPPH radical - scavenging ability, antioxidant capacity, and α-amylase and α-glucosidase inhibitory activities in vitro than polysaccharides 30 and 40.

The antioxidant properties of acid-soluble okra pectin components and their antiinflammatory activities were studied by Xiong et al., 2021. Two acid-soluble okra pectic fractions, namely crude acid-soluble okra pectin (CAOP) and acid- soluble okra pectin (AOP) were used. In comparison with CAOP, Aop expressed better antioxidant activity, and suppressed the NO production in LPS-induced RAW 264-7 macrophages. The authors concluded that AOP had the potential to act as a natural antioxidant or a functional anti-inflammatory food.

A common way to evaluate the antioxidant potential of hydroxylated fullerenols is the β-carotene bleaching assay. Okra was found to display outstanding antioxidant activities on DPPH (EC50= 1.03 mg/mL), FRAP (EC50=0.89 mg/mL), and β-carotene bleaching (EC50 = 0.47mg/mL) (Romdhan et al., 2020). The high antioxidant activities have been attributed to the high content of phenolic compounds holding hydroxyl groups, which denotes protons to free radicals to scavenge them

4.11. Antibacterial.

Using the agar diffusion method, Mollick et al. (2014). investigated the antibacterial activity of the gold nanoparticle (AuNPs) of Abelmoschus esculentus extract against Bacillus subtilis, Bacillus cereus, Micrococcus luteus, Pseudomonas aeruginosa and Escherichia coli . Results showed that the AuNPs solution (0.2mg/mL^{-1}) exhibited an excellent antibacterial activit against the five tested bacterial strains, with inhibition zones of 26, 24, 35, 21 and 15 mm, respectively.

Devanesan and AlSalhi (2021) tested the antibacterial effects of A. esculentus silver nanoparticles (AgNPs) on the Gram-positive pathogens: Bacillus subtilis, Staphylococcus epidermidis and Streptococcus pyogenes as well as the Gram- negative pathogens; Klebsiella pneumoniae, Escherichia coli, Pseudomonas aeruginosa, Proteus vulgaris, Salmonella typhimurium and Shigella sonnei. The agar well diffusion method was used for this purpose. An AgNPs solution of A. esculentus was prepared at a concentration of 100µg/mL^{-1} and the positive control antibiotic was ciprofloxacin (1mg/mL^{-1}). The AgNPs solution inhibited the growth of all tested Gram-positive and Gram-negative pathogenic bacteria. However, inhibition was greater for Gram-negative bacteria than for Gram-positive bacteria. At a dose of 100 µL, P.vulgaris constituted the most inhibited bacterium (16±1.0mm) followed by K.pneumoniae (14±0.5 mm) and S. sonnei (14±0.7 mm). Ahmed et al.(2021) studied the bactericidal potential of green synthesized CeO2 NPs to S. aureus (Gram-positive) and K.pneumoniae (Gram-negative) bacteria. Results indicated that the green synthesized cerium oxide nanoparticles showed high antioxidant activities and bactericidal effect against both Gram-positive and Gram-negative strains.

4-12-Anticancer

Mollick et al. (2014) evaluated the anticancer activity of golden nanoparticles of okra in vitro. Jurkat (human acute myeloid leukemia), k562 (human chronic myeloid leukemia) and DL (Dalton's lymphoma) cells were exposed to AuNPs at concentrations of 0,1,5,10, 25 and 50 µg/mL^{-1} for 24 h and cytotoxicity was measured using the MTT assay. Results showed that AuNPs up to the concentration of 50 µg/mL^{-1} produced a significant reduction in the viability of Jurkat cells and that this effect was dese-dependent. The AuNPs exposed Jurkat cell viability significantly decreased by 45.1%, 48.6%, 81.3% and 87.2% at 5, 10, 25 and 50 µg/L^{-1} doses. In the case of K562 cells and DL cells, viability was significantly reduced by 38 . 38% and 50-165% at 25 and 50 µg/L^{-1} doses, respectively.

The cytotoxic effects of silver nanoparticles (AgNPs) synthesized using extracts of the flowers of A.esculentus were studied by Devanesan and AlSalhi, 2021. Results demonstrated the tumor_inhibiting activity of the synthesized nanoparticles which reduced the cell viability of the tested cancer cell lines A-549 (lung cancer) and TERT-4 (mesenchymal cancer) in a concentration dependent

manner. Concentrations of 25 and 50 µg mL^{-1} of AgNPs significantly reduced the cell viability and cell death was very significant at a dose of 100 µg mL^{-1} of AgNPs compared with that of the control drug 5-fluorouracil. IC_{50} values of the synthesized AgNPs against A-549 and TERT-4 was 1.74 and 1.65 µg mL^{-1} respectively.

Solomon et al. (2016) examined in vitro the anti-cancer effect of flowers of Abelmoschus esculentus. The ethanolic extract of the flowers was investigated against the human liver cancer HepG2 cell line using the 3-(4,5-dimethylthiazol-2-y1)-2,5-diphenyltetrazolium bromide (MTT) assay. Concentrations of 1000, 500, 250, 125 and 62.5 µg mL^{-1} of the extract showed a significant anti- cancer activity with CTC_{50} values 68.37,57.28, 48.91,34.86, 29.49 µg / mL^{-1} against HepG2 cell line, respectively.

Okra raw polysaccharides extract (ORPE) was obtained by ethanol extraction from the raw fruit and its anticancer potential was tested against human liver cancer cells (Huh 7it) using 10-µg doxorubicin as a positive control (Hayaza et al., 2019). Huh 7it cell cin proliferation was measured by MTT assay, while measurement of cell apoptosis, necrosis, and cell cycle analysis were performed using Annexin VFITC-PI antibody test and flow cytometry. The 7 extract significantly inhibited Huh 7it cell proliferation and induced apoptosis.

Treatment with a dose of 600 µg/mL of the extract induced 5.82% late cell apoptosis and 5.62% early apoptosis. Cell arrest occurred during GO/G1 phase.

The antiproliferative effect of lectin isolated from Abelmoschus. esculentus on human u87 glioma cells was proved by Musthafa et al., 2021. Results of the MTT assay indicated significant concentration dependent cytotoxic activity and the IC_{50} value was found to be 21µg/mL^{-1} . Cytotoxicity of the lectin was comparable with temozolomide (1%) employed as positive control. In addition, lectin increased the expression of apoptotic caspases with downregulation of clock and Bmal1 circadian genes. The results also demonstrated that lectin induced Go/G_1 cell cycle arrest and increased the intracellular reactive oxygen species generation.

Ahmed et al. (2021) assessed the in vitro cytotoxicity of green synthesized CeO2 from A.esculentus extract against cervical cancerous cells (HeLa).CeO2 in a dose of 10-125 µg/ml caused a loss in cellular viability in a dose-dependent manner. A decrease in the cell viability of 93%, 75%, 66%, 55%, 43% and 33% was noted when HeLa cells were exposed to CeO2 at increasing concentrations (10, 25, 50, 75, 100, and 125 µg/mL). The IC_{50} value was found to be 85.74 µg/ml for the HeLa cells viability.

Pramudya et al. (2022) studied the anticancer activity of an ethanolic extract of red okra pods (Abelmoschus esculentus L. Moench) in rats induced by N-methyl-N-nitrosourea (MNU). Results showed that red okra pods at doses of 100 and 200 mg/kg BW significantly downregulated interleukin IL-6, IL-1β, tumor necrosis factor (TNF)-α, IL-17, IL-10, and tumor growth factor β($P<0.05$). Additionally, doses of 200 mg/kg BW significantly increased the activity of CD4+ and CD8+ T cells, prevented the proliferation of mammary gland epithelial cells, and yielded a significantly thinner epithelium of the mammary gland ($P<0.05$).

The cytotoxic actions of Tunisian okra pods against human. non-small cell lung cancer (NCL-H460), human breast adenocarcinoma cell line (MCF-7), human cervical cancer cells (HELA), and human. liver hepatocellular cells (HEPG-2) were investigated by Romdhane et. al., 2020. The authors found that okra pods induced cytotoxicity in a dose-dependent manner and inhibited the development of NCL-H460, MCF-7, HELA, and HEPG-2 cells to 50% at concentrations of 49.62, 56.40, 67.27, and 167.95 mg/mL, respectively .

4.13. Antidiabetic and antihyperlipidemic

The antidiabetic and antihyperlipidemic activities of Abelmoschus esculentus peel and seed powder (AEPP and AESP), were studied in streptozotocin (STZ)-induced diabetle rats (Sabitha et al., 2011). AEPP and AESP did not cause any toxicity or death up to a dose of 2000 mg/kg. Glibenclamide (5mg/kg) was orally given for up to 28 days as the standard drug. Administration of AEPP and AESP at 100 and 200mg/kg dose in diabetic rats caused significant ($P<0.001$) reduction in bloed glucose level and increase in body weight compared to diabetic control rats. Additionally, a significare ($P<0.001$) increased level of Hb, TP, and decreased level of HbAIC, SGPT were detected after the treatment. Also, the elevated lipid profile levels reverted to near normal in diabetic rats after the treatment with AEPP and AESP, 100 and 200 mg/kg dose, compared to diabetic control rats.

Saha et al. (2011) explored the biological use of Abelmoschus esculentus Linn. in the treatment of diabetes in mice. Ethanolic and aqeous extracts of okra fruits were evaluated for the hypoglycemic activity in alloxan induced diabetes mice model. Results showed that aqeous extract of powdered drug had maximum effect when compared to glibenclamide group..

Sabitha et al. (2012) provided in vitro evidence for antidiabetic activity through potential inhibition of α-glucosidase and α-amylase enzymes using the aqeous extracts of Abelmoschus esculentus (L.) Moench peel (AAPP) and seed (AASP). The AAPP and AASP showed a notable concentration_dependent inhibition of α-glucosidase (IC_{50}=142.69±0.32gm mL^{-1} and 150-47± 0.28 gm ml) and α-amylase (IC_{50} = 132.63±0.16 gm mL^{-1} land 147.23 10.21 gm mL^{-1}), supporting the hypoglycemic impact ofAbelmoschus esculentus aqueous extract.

Ahmed and Kumar (2016) investigated the in vitro anti-diabetic activity of Abelmoschus esculentus. Aqueous, ethanolic and methanolic extracts at concentrations of 50, 100, 150, 200 and 250 µg mL^{-1} were used. Results showed that the aqueous extract exhibited 88-6% and methanolic extract showed 92.3% at the highest concentration. Maximal α-amylase inhibition of methanolic extract was 91.6% at a concentration of 250 µg/mL. Ethanol and aqueous extracts showed 86.9% and 82% inhibition, respectively. Methanol extract showed a higher α-amylase inhibitory potential than ethanol and aqueous extracts.

Liu et al. (2018) purified the main polysaccharide fraction of the Abelmoschus esculentus pods aqueous exeract and investigated the hypoglycemic effect of the polysaccharide rhamnogalacturonan (50 mg kg^{-1}) by intragastric administration , 200 mg kg^{-1} by intragastric administration) in vivo. Induction of diabetes was performed by an intraperitoneal injection with 1% streptozotocin (45 mg kg^{-1} BW). Results demomprated that the high-dose rhamnogalacturonan group exhibited decreased blood glucose level and glucose tolerance in comparison with the model group. The authors concluded that the rhamnogalacturonan was responsible for the hypoglycemic effect of okra.

Liao et al. (2019) studied the possible impact of a novel polysaccharide isolated from okra pods (OP) on mice feded with a high-fat diet (HFD) combined with an intraperitoneal administration of 100 mg/kg streptozotocin (STZ) twice, to Induce type 2 diabetes mellitus (T2DM). Results showed that the injection of OP at 200 or 400 mg/kg BW for eight weeks significantly alleviated the symptoms related to elevations in blood glucose, triglycerides (TG), total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C), as well as reducing high-density lipoprotein cholesterol (HDL-C), body weight, food and water consumption. The OP treatment increased the hepatic glycogen and decreased the mussy hepatic cords and liver fibrosis in the T2DM mice. Results of this work suggested that a polysaccharide isolated from okra exerts anti-T2DM effects partly by modulating oxidative stress through the PI3K/AKT/GSK3/3,3 pathway-mediated Nrf2 transport activity of ABA . It was found that ABA at a concentration of 4.4 $\mu g/gm^{-1}$ present in 500 mg of sample was able to lower the blood glucose level.

The antidiabetic potential of a newly developed akra mucilage biopolymer was examined using the enzyme inhibitory assay of α-amylase and α-glucosidase (Elkhalifa et al., 2021). Results demonstrated that okra mucilage biopolymer at different concentration of 1,2,3,4,and 5 mg/mL showed 9.9, 16.5, 24.5,28.2, and 49.8 α-amylase inhibitory activity as well as 30,41.5,50.5,62.2, and 69-72 α-glucosidase inhibitory activity. respectively. Results also showed that the higher the concentration the higher the inhibition of α-amylase and α-glucosidase inhibition

Peter et al.(2021) investigated the optimal extraction conditions for extracting polyphenols from A. esculentus fruits and evaluated their antihyperglycemic activity in vivo. The anti-hyperglycemic activity was studied in a high-fat diet- streptozotocin rat model. Rats were divided into five groups : Group 1 and 2 were normal and diabetic control received distilled Water 1 mL/100gm; treatment group 3 and 4 received standardized A. esculentus fruit extract (AEFE) at a dose of l00 and 200 mg/kg respectively; group & received 5mg/kg glibenclamide. Treatments were orally for 14 days. Results indicated that at optimal extraction conditions, extract with a high content of total polyphenols and good antihyperglycemic activity could be obtained.

Haque et al. (2022) assessed the effect of A.esculentus pod extract (AEE) administered concomitantly with metformin. (Aiz Mandambove (Ack) in a glucose induced hyperglycemic mice model. The mice were divided into five groups: (1) negative control (2) positive control. (3) MET only. (4) MET and ACR, and (5)MET. ACR and AFE. Oral doses of the MET, ACR, and the extract were 150 mg/kg BW, and 0.2 mL/kg BW, respectively. Induction of hyperglycemia was done by giving each mice a gastric lavage dose of 2.5gm/kg BW glucose. Results demonstrated that MET only and a combination of MET and ACR reduced glucose levels significantly ($p<0.01$) compared to the positive control.

The in vitro antidiabetic potential of A.esculentus methanolic extract was studied by Siddique et al. (2022) employing an inhibitory model for the enzymes α-amylase and α-glucosidase. At a concentration of 50-200 µg/ml of the extract, inhibition percentage of α-glucosidase and α-amylase ranged from 14.36±0.099 to 19.23±0.172 % and 15.89 ± 1.877 to 37.19± 7.430%, respectively. Yeast glucose uptake assay showed a glucose absorption which was directly proportional with concentration of extract and inversely proportional with the molar concentration of glucose. The percentage of maximum. glucose uptake by the extract was 68.420 ± 1.752% at 3 mg/ mLextract and 5 mM glucose concentration .

4.14. Anti-inflammatory

Lee and Joo (2021) prepared ethanolic extracts of okra using four different cooking methods (raw, blanching, steaming and sous-vide), and analyzed anti-inflammatory and antioxidant effects on lipopolysaccharide (LPS) or hydrogen peroxide (H_2O2) treated RAW-264-7 macrophages. Results indicated that cell viability was similar between all four cooking methods confirming that okra extracts (≤200µg/mL) were not cytotoxic. All cooking methods inhibited nitric oxide production (Indicator of inflammatory responses). Sous-vide cooking showed low inhibitory effect at 100 -200 µg/mL of okra extract. In addition, examining the mRNA expression of inducible cycloxygenase-2 (cox-2), inducible nitric oxide synthase (iNOS) and inflammatory cytokines: TNF-α, IL-6 and IL-1β showed inhibitory effects by all cooking methods. There was a reduction in the reactive oxygen specles (ROS) levels for all cooking methods with sous-vide cooking showing the highest rate of reduction. The authors concluded that the anti- -inflammatory and antioxidant effects of raw and multimethod cooked okta were confirmed. Additionally, sous-vide cooking showed the greatest potential to improve okra's therapeutic effects.

An in vitro study investigated the inhibitory effects of okra (Abelmoschus esculentus Linn) extract on the production of reactive oxygen species (Ros) and pro-inflammatory cytokines in lipopolysaccharide (LPS)-stimulated BV2 microglia (Mairuae et al., 2017). Results demonstrated that treatment of BV2 cells with okra concentrations of 50, 100 and 200µg/mL significantly suppressed LPS-induced NO, as well as ROS compared to untreated cells. A significant decrease in the production of TNF - α and IL-1β in okra-treated BV2 microglia cells was found. The level of LPS-induced nfkb P65 phosphorylation was significantly decreased by okra treatment. In addition, okra inhibited LPS-induced Akt-mediated NFkB Pathway. The authors concluded that okra might be a valuable agent for the treatment of anti-neuroinflammatory diseases mediated by microglial cells.

Panighel et al. (2022) investigated the effects of fruit and leaf extracts of okra (Abelmoschus esculentus) on proinflammatory cytokines (IL-1β, IL-6 and TNF-α) expressed by THPI-derived macrophages. Evaluation of the potential anti-inflammatory effect showed a significant activity of leaf butanol extract with reduced mRNA levels of IL-1β (-28 ± 8% vs control), IL-6(-11±1% vs control) and TNF-α (-43±8% vs control), while fruit extract did not show any anti-inflammatory activity. The authors concluded that okra's extracts reduced the expression of pro-inflammatery cytokines from THPI-derived macrophages and that this may indicate a vascular protective action of okra.

The anti-inflammatory activity of two acid-soluble okra pectin components was studied using the inflammation model of RAW264.7 cells (Xiong et al., 2021). Compared to crude acid soluble okra pectin (CAOP) component, the acid-soluble okra pectin (AOP) component better antioxidant activity, and suppressed the NO production in LPS-induced RAW264.7 macrophages . Results demonstrated that AOP had the potential to act as a natural antioxidant or a functional anti-inflammatory food.

Luthfi et al.(2020) investigated the anti-inflammatory effect of okra (Abelmoschus esculentus) fruit extract during wound healing process after tooth extraction of diabetic wistar rat.Results revealed that the administration of okra extract to the tooth extraction wounds significantly reduced neutrophil expressions compared to that in the untreated group. The authors concluded that okra fruits extract exhibits anti-inflammatory activity and is therefore, an effective agent for healing process of tooth extraction wounds in diabetic mellitus rats.

4.15. Wound Healing promoter

The wound healing potential of okra fruit was investigated in vitro and in vivo (Sipahi et al., 2022). Both the aqueous and ethanolic extracts of okra fruits exhibited antioxidant activity with significant protective effect against H_2O_2 induced damage in HDF cells by diminishing the MDA level. In addition, the highest dose of ethanolic extracts showed a potent anti-inflammatory activities on LPS-induced RAW264.7 cells. The extracts showed antimicrobial activity and the the formations prepared from the extracts ware non-imitant on in vitto Epiderm^{TM} -skin irritation test (SIT). The in vívo excision assay indicated that tissue TGF-β and IL-1 levels were significantly decreased by the 5% ethanolic gel formulation . Histopathologically collagenization and granulation tissue maturation were found higher in 5% (w/v) okra ethanolic extract-treated group . The authors concluded that 5% of okra ethanolic extract might be a potent wound healing agent

Effects of green synthesized cerium oxide (C_2O_2) nano- particles from A.esculentus on wound healing were investigated (Ahmed et al., 2021). Male albino rats were divided into three groups of 4 rats each. Group one administered chitosan hydrogel (control group). The second group received chitosan hydrogel membrane loaded with 1% CeO2 nanoparticles, and group three received 5% CeO2 nanoparticles. Rats were anesthetized before having 2cm of their skin completely excised. The nanopartides were daily applied locally at the site of the wound and the wound diameters were measured daily. Healing of the wounds was. assessed by tracking the regular changes in wound color. Results showed that the groups treated with CeO_2 nanoparticles incorporated in chitosan hydrogel membrane exhibited better healing after 11 days

Xin et al.(2023) studied the use of okra extract as the main component of a wound dressing. The robust antioxidant activity of okra significantly reduced intracellular reactive oxygen species production, thereby accelerating the wound healing process. Results also showed that okra extracts and their hydrogel dressings increased cell migration, angiogenesis, and reepithelialization of the chronic wound area, considerably promoting wound remodeling in diabetic rats. It was concluded that okra-based hydrogels are promising candidates for skin regeneration and wider tissue engineering applications.

A novel peptic polysaccharide-based hydrogel derived from okra (Abelmoschus esculentus L. Moench) fer chronic diabetic wound healing was investigated (Hana et al., 2023). A pectic polysacharide (OPS) was extracted and purified from Tunisian okra pods, and Its antioxidant and in vivo and in vitro wound healing activities were studied. The OPS showed antioxidant potential, gelling ability.cytocompatability properties, non-cytotoxicity and cell migration and proliferation promoting activities, which met the requirements for wound dressings. The effect OPS-based hydrogel on in vivo cutaneous wound healing was studied using an alloxan-induced diabetic rat model, and results revealed that it significantly accelerated the wound healing process by acting in the acceleratton of the recovery of the dermis and inducing more blood vessels formation and tissue granulation. Results of this study provided new insights into the development of a promising and effective okra pectin-based hydrogel for the treatment of chronic diabetic wounds.

4.16. Hepatoprotective

Wahyuningsih et al. (2020) investigated the effect of okra (Abelmoschus esculentus L.) pod methanol extract (OPME) on mice with hepatotoxicity induced by sodium nitrite. Thirty BALB/c mice were divided into six groups: normal control, negative control (sodium nitrite 50mg/kg BW exposure), and treatment groups. (sodium nitrite exposure and OPME at doses of 50, 100, 200 and 400 mg/kg BW). mice were exposed to sodium nitrite and administered multiple doses of OPME for 19 days by gavage. Results showed that all doses of OPME reduced the levels of nitric oxide (NO), malondialdehyde (MDA), alanine aminotransferase (ALT), and aspartate aminotransferase (AST) . There was increased levels of superoxide dismutase (SOD) and catalase (CAT) in all OPME-administered mice. All doses also reduced necrotic cells, proportion of swollen cells, and inflammation in liver. It was concluded that OPME exerted hepatoprotective effects by lowering MDA,NO, ALT, and AST levels. OPME also improved SOD and CAT levels and reverted damaged liver tissue to its normal state . The optimal dose of OPME was 50-100 mg/kg BW.

The preventive action of ethanolic extracts of okra (EEO) against liver injury was examined in rodents using carbon tetrachloride -induced hepatotoxicity model (Algasoumi, 2012) . Results showed that EEO , at doses of 250 and 500 mg/kg BW , exerted significant dose-dependent hepatoprotection by decreasing the CCL_4-induced elevation of serum SGOT, SGPT. ALP.GGT, cholesterol, triglycerides and malondialdehyde (MDA) non-protein sulfhydryle (NP-SH) and total protein (TP) levels in the liver tissue.A significant decrease pentobarbital-induced sleeping time was also observed in mice. The hepatoprotective and antioxidant activities of the extract were comparable to standard silymarin.

In a study carried by Yan et al. (2023) a peptic polysaccharide (OPS-50) prepared from fresh okra pods by three-phase partitioning and gradient $(NH4)_2SO4$ precipitation at a saturation of 50% was employed in carbon tetrachloride (CCL_4)-caused acute liver damage in mice to evaluate the hepatoprotective potential.OPS-50 was mainly composed of a limited linear homogalacturonan backbone and abundant rhamnogalacturonan-1 domains as side chains. OPS-50 was found to possesses postively protective effects on acute liver damage induced by CCL_4 in mice through relieving weight reduction and organ damage. ameliorating liver function and dyslipidemia, alleviating oxidative stress, suppressing proinflammatory cytokines, modulating gut microbiota, and promoting short-chain fatty acid secretion. Histopathology of the liver revealed the protective benefit of OPS-50 on CCL_4-caused acute liver damage in mice.

4-17. Antistress

Doreddula et al. (2014) investigated the in vitro antioxidant sctivity and in vivo protective effect of aqueous and methanolic

seed extracts of Abelmoschus esculentus against scopolamine- induced cognitive impairment using passive avoidance task and acute restraining stress-induced behavioral and biochemical changes using elevated plus maze (EPM) and forced swimming test (FST) in mice. Results showed that pretreatment of mice with aqueous and methanolic seed extracts of A.esculentus (200mg/kg,p.o) for 7 days significantly (P<0.01) attenuated scopolamine-induced cognitive impairment in the passive avoidance test. The extracts also reduced the blood glucose, corticosterone, cholesterol, and triglyceride levels elevated by acute restraint stress and also significantly increased the time spent in open arm in EPM and decreased the immobility time in FST. These results suggested that the seed extracts of A.esculentus L. possess antistress and nootropic activities.

4-18-Cardioprotective

Al-Attar et al.(2022) evaluated the protective activity of moringa oil and okra oil against thioacetamide (TAA) induced cardiotoxicity in wistar rats . Experimental mice were divided into 6 groups: group one (control), group 2 was treated with TAA (300mg/kg BW), group 3 was exposed to moringa ail (800 mg/kg BW) Plus TAA, group 4 was treated with okra oil (800mg/kg BW) plus TAA, groups 5 and 6 were administered with moringa oil and okra oil respectively .TAA treatment induced significant increases of serum creatin kinase (ck) , lactare dehydrogenase (LDH) levels in group 2, while the levels of scrum reduced glutathione (GSH) and superoxide dismutase (SOD) were statistically decreased. Administration of moringa oil and okra oil reduced the severity of alterations of these parameters. The authors concluded that meringa oil and okra oil represent protective effect against cardiotoxicity induced by TAA due to their antioxidant roles.

4-19. Immunomodulator

Hayaza et al. (2021) studied the effect of okra raw polysaccharide extract (ORPE) to immune cells and cytokines of mice with hepato carcinogenic conditions induced by diethylnitrosamine (DEN) . Thirty-six male mice were divided into six groups : the normal control (CN) , negative control (C-) , positive control (C+) given doxorubicin (C+) , and three groups of ORPE treatment given the dose of 50 (P1) , 100 (P2) and 200 (P3) mg/kg BW. Treatmend with ORPE directly suppressed the regulatory T cells accumulations, suppressed macrophages activations , and balanced the number of effector T cells. However it promoted CD8+T cell activation and increased IL 2 levels at all doses. these results indicated that ORPE has unique dual-functions as immunosuppressive and Immunostimulant.

An investigation on the immune stimulatory effects of okra leaf ethanol extract (OLE) and okra leaf water extract (OLW) on nitric oxide (NO) production in macrophages was carried out by Ko et al. (2022). OLE significantly decreased nitrite accumulation in LPS-stimulated RAW264.7 cells indicating that it potentially inhibited NO production in a concentration-dependent manner. In contrast, OLW ignificantly enhanced the production of prostaglandin E2 (PGE2), tumor necrosis factor (TNF-α), IL-1βand NO in a dose-dependent manner. OLW also increased the expression levels of NO synthase (iNOS) and cyclooxygenase (cox)- 2, potentially explaining the OLW-induced increase in NO and PGE2 production.OLW also stimulated the phosphorylation of mitogen- activated protein kinases (MARKS, ERK, P38, and JNK) as well as the activation and subsequent nuclear translocation of nuclear factor KB (NF-kB). This indicated that OLW activates macrophages to secrete PGE2, TNF-α, IL-1β, and NO, inducing iNOS and cox-2 expression via activation of the NF-kB and MAPK signaling pathways. The authors concluded that OLW can effectively promote the activation of macrophages, suggesting that OLW may possess potent immunomodulatory effects.

4.20. Weight reduction potential

Okra complex (OKC) was found to significantly reduces the body and WAT mass of mice by inhibiting adipogenesis and lipogenesis. Also, OKC administration reduced fasting blood glucose and serum cholesterol and triglyceride (TG) concentrations and ameliorated liver steatosis in HFD-fed obese mice. In addition, OKC activated the protein kinase A (PKA) signaling pathway, which increased lipolysis; and induced the uncoupling protein I (LUCPI)- mediated browning of WAT. These results indicated that OKC has potentially beneficial effects on lipid metabolism and upregulates thermogenesis which implies that it may be useful for the therapy and lor prevention of obesity and related metabdic diseases (Jin et al., 2022).

Nikpayam et al.(2022) investigated the effect of dried okra extract (DOE) supplementation on anthropometric measures, body composition, appetite, and dietary intake in diabetic nephropathy (DN) patients. Results showed that energy (P=0.047.CI:-425.87, -3.25, ES:0.539) and carbohydrate (P=0.038, CI:-85-64,-2.53, ES: 0.555) intake as well as desire to eat salty food (P=0.023) were reduced in DOE group at the endpoint, compared to the baseline values No significant difference was found between anthropometric measures, body composition, and appetite score in the two study groups. Authors concluded that DOE could significantly decrease energy intake and carbohydrate consumption in the DN patients.

4.21. Neuroprotective

Chenoly et al. (2023) carried out a study to determine if there was any neuroprotective effect of Abelmoschus esculentus L. and its role in preventing memory loss during stressful condicions. A powder of A.esculentus was extracted with methanol and was used to determine antistress activity in experimental mice groups. Mice were divided into control, stress control, animals treated with extract followed by exposure to stress animals exposed to stress followed by extract treatment, and mice groups treated with diazepam. Biomarkers included were cortisol brain homogenous acetylcholine esterase (AchE), superoxide dismutase (SOD). and malondialdehyde (MDA). In conjugation, working memory and reference memory were also examined in all animal groups by radial arm maze test, and results were recorded. as the percentage of alteration score (PAS). Results demonstrated that concentration of stress indicaters such as cortisol, MDA, and AchE activity was significantly elevated in stress control animals and associated with deficit working and reference memory. However, SOD reduction was not in stressed mice and SOD elevation was found in treatment groups compared to the control mice. The anti-stress activity of A.esculentus L. pods was significantly correlated with higher working memory and reference memory with 1.33 ± 0.51 and 1.17±0.40 PAS in pre-stress and post- stress treated mice groups, respectively. It was concluded that methanolic extract of A. esculentus L.pods exhibited excellent anti-stress potential and also played a significant role in enhancing both working

memory and reference memory in mice.

5. CONCLUSIONS

Numerous in vitro and in vivo studies reported a variety of intringuing bioactivities of okra, including antidiabetic, hypolipidemic, antioxidant, anti-inflammatory, antibacterial. antistress and anticancer properties. In addition, okra possess hepatoprotective, neuroprotective, cardioprotective, immunomodulatory, and gastroprotective and wound healing promoting features. These activities have been attributed to the various bioactive compounds present in the plant such as phenolic acids, trepenes, vitamins, flavonoids, sterols. fatty acids and others. Further studies are needed on the uses of okra mucilage particularly in the pharmaceutical fields

6. REFERENCES

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