Original Article

Okra Mucilage - Method Of Extraction And A Novel Strategy For Pharmaceutical Drug Delivery System

Rajalakshmi M[1], Sangeetha S[2*]

[1] Department of Pharmaceutics, SRM College of Pharmacy, SRMIST, Kattankulathur, Chengalpattu – 603203, India. Mail Id: rm8574@srmist.edu.in
Corresponding Author: [2*] Department of Pharmaceutics, SRM College of Pharmacy, SRMIST, Kattankulathur, Chengalpattu – 603203, India. Mail Id: drsangeetha1978@gmail.com
Oricid Id: 0000-0001-5226-4268
DOI: 10.47750/pnr.2023.14.S02.291

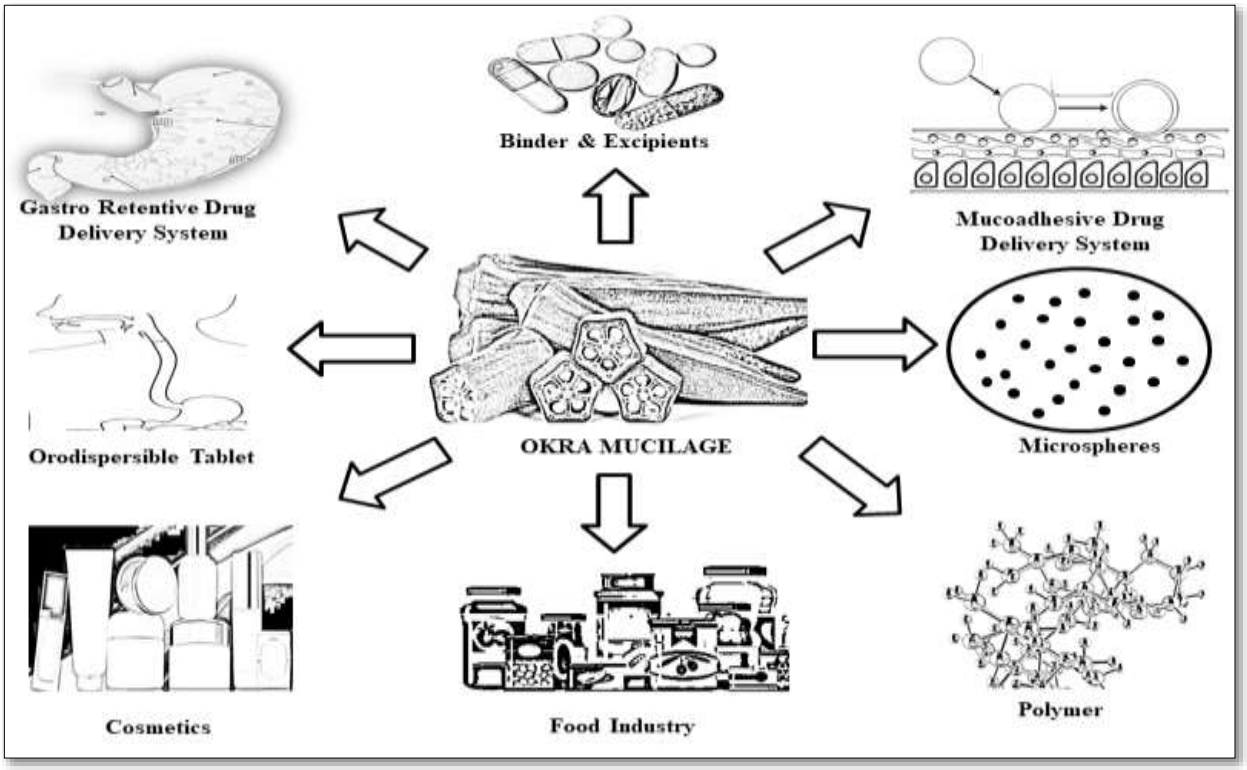
Abstract

This paper summarizes the current approaches in method of extraction of okra mucilage and application in pharmaceutical drug delivery system. Okra is a species of Abelmoschus esculentus L. belongs to the family of malvacae. In India, medicinal activity of okra is reported in traditional system like Unani, siddha and Ayurveda. Pharmacological uses of okra are anti-cancer, anti-diabetic, anti-oxidant, anti-microbial and anti-ulcer activity. Easily available in tropical and sub-tropical countries, non-toxic, biodegradable and cost effective used as excipient. Okra mucilage's were extracted in different method using acetone, ethanol etc. It is a property of highly viscous the may retard the drug in sustained release. This article mainly scrutinized that okra mucilage approaches in pharmaceutical drug delivery system.

Key Words: Okra, Mucilage, Natural gum, drug delivery.

GRAPHICAL ABSTRACT:

APPLICATION OF OKRA MUCILAGE IN PHARMACEUTICAL FIELD



1. INTRODUCTION

In recent days, allopathic system focuses on plants, vegetables and natural sources to develop a medicine than synthetic one. Abelmoschus esculentus L. (Okra) is dicotyledonous self-pollinated crop belongs to the kingdom of plantae and the family of malvacae. Okra origin is unknown, but in Africa, it has grown as a crop for centuries. In all kind of soil, okra can be grown very fast and among the most heat and drought tolerant vegetable in world, so it can be cultivated in all kind of regions like tropical, sub-tropical and shores of the Mediterranean Sea. [1, 2] Okra contains good source of vitamin, minerals, fiber and antioxidant; it plays a vital role in human health. In India okra is an important medicinal plant and it has been included in traditional medicine system like siddha, ayurvedha and unani. Okra gives a viscous gum or mucilage that has a many applications in pharmaceutical, nutraceutical, cosmetology and food science. [3-5]

1.1 Properties

Mucilage means a hydrocolloids from natural sources contains a polymer of monosaccharide or polysaccharide. [6] In fact, polysaccharide mucilage's are having high molecular weight and highly hydrophilic in nature; so that it can be easily interact with water and dispersed uniformly [7]. Okra mucilage (OM) develops gelation in acidic pH and highly soluble in alkaline pH [8]. Natural acidic polysaccharides of okra mucilage extracted by type I partially methylated or acetylated rhamno-galacturonans attains maximum viscosity at neutral pH [9 - 11]. The rheological behaviour of okra mucilage is pseudo plastic enhances the stability and viscosity of products [12].

The polymer properties are improved by "graft copolymerization technique", In this, "natural polysaccharides are chemically modified by inclusion of synthetic, non-biodegradable monomers onto their backbone"; so the novel properties of polymer improved by gains some of the desired properties of the guest monomers used for grafting ending up with novel polymer and properties. [13, 14] It has many advantages like safer, non-irritant, biodegradable, chemically inert, biocompatible, eco-friendly and economical. So it does not require toxicological studies. [15, 16]

Okra turns browning due to loss of water, thereby reducing the economic value. [17, 18] These rejected okra pods are utilized due to mucilaginous content high in matured fruit.[19] This seed is a rich in source of protein and oil has been known to have superior nutritional quality.[20]

1.2 Chemical constituents

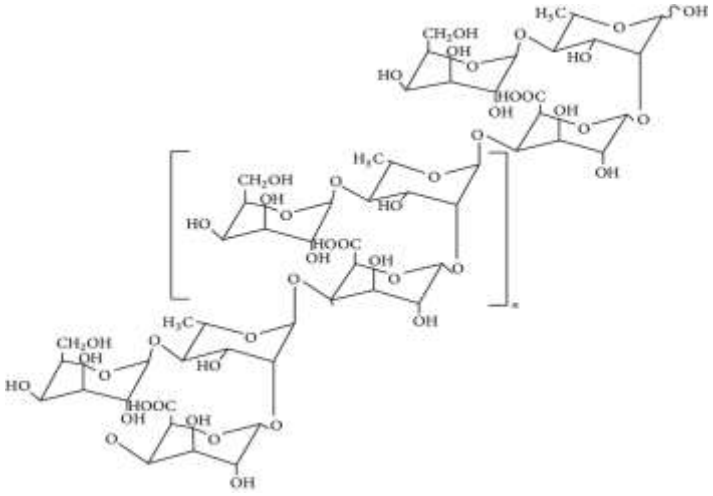
The thick and slimy okra mucilage containing of sugars glycosides and acid like glucose, galactose, rhamnose, amino acid and galacturonic acid respectively, Okra mucilage contain significant level of protein, carbohydrate, vitamin, minerals like zinc etc. [21 - 23]

Figure.1: showing chemical structure of polysaccharides of okra mucilage.

1.3 Phytochemical constituents of Okra mucilage

Tests for tannins, favonoids, saponins, alkaloids and anthraquinones were conducted to confirm the suitability of Okra mucilage as an excipient devoid of pharmacological activity.[24]

Figure.1: Chemical structure of polysaccharides of okra mucilage



2. METHOD OF EXTRACTION OF OKRA MUCILAGE:

Most commonly extraction of okra mucilage from the plant of Abelmoschus esculentus L by

- Conventional method, [25]

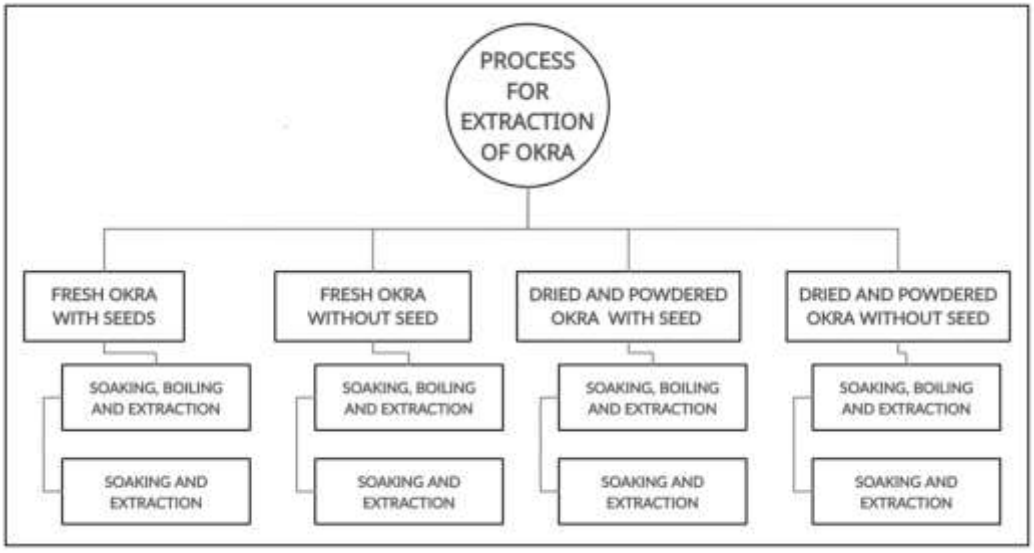
- Ultrasound-assisted extraction method and
- Microwave assisted extraction method (MAE)

These three methods may undergo extraction process shown in Figure.2. The okra mucilage extracted through different process like soaking, boiling by using fresh or dried okra with or without seeds. Final extraction can be done by using different organic solvents such as acetone, ethanol, methanol etc.[26, 27, 28] common extraction procedure mentioned in Figure.3.

In MAE, okra mucilage is extracted by adding 5gm of okra powder with 80 ml of ethanol; then refluxed for 1hr at 80^0 C. In Microwave at 480 W, refluxed mixture added with 150 ml of 50mM phosphate buffer solution kept in oven for 10 minute. Then the extract is centrifuged with α-amylase and concentrated by using rotary evaporator. Ethanol was added to precipitate the mixture. Finally the crude extract of okra mucilage if collected. [29, 30, 31]

In ultrasound assisted method, extraction was carried out at 59 °C, 30 min, and 522 W of an extraction temperature, time, and ultrasonic power respectively. The fresh okra was freeze dried for 36 h and minced in mechanical disintegrator; then sieved through 40-mess size. Impurities were removed with refluxing solvent and centrifuged to collect the residue. [79]

Figure.2: Different Methods for Extraction of Okra Mucilage



2.1 TYPE I: By Soaking and Extraction:

2.1.1, STEP 1: Extraction of okra mucilage

Method I: Conventional method of extraction of okra mucilage is done by unripe pods of fresh okra collected from the local market; then the okra pods cut into small pieces with or without seeds. Minced okra transferred into 1000ml beaker and filled with water, then soak for 12 – 24 h; afterwards, using muslin cloth the swollen pods were squeezed and get extracted. [32]

Method II: Nicely cleaned and sliced okra were dried under shade for 12 – 24h, further dried in hot air oven at 40^o C for 5 – 6 h to obtain constant weight. Dried okra were blended into powder, and then passed through sieve. The okra powder transferred to a beaker containing water; then soak for 12 – 24 h and then filter through muslin cloth and collect the extract. [33]

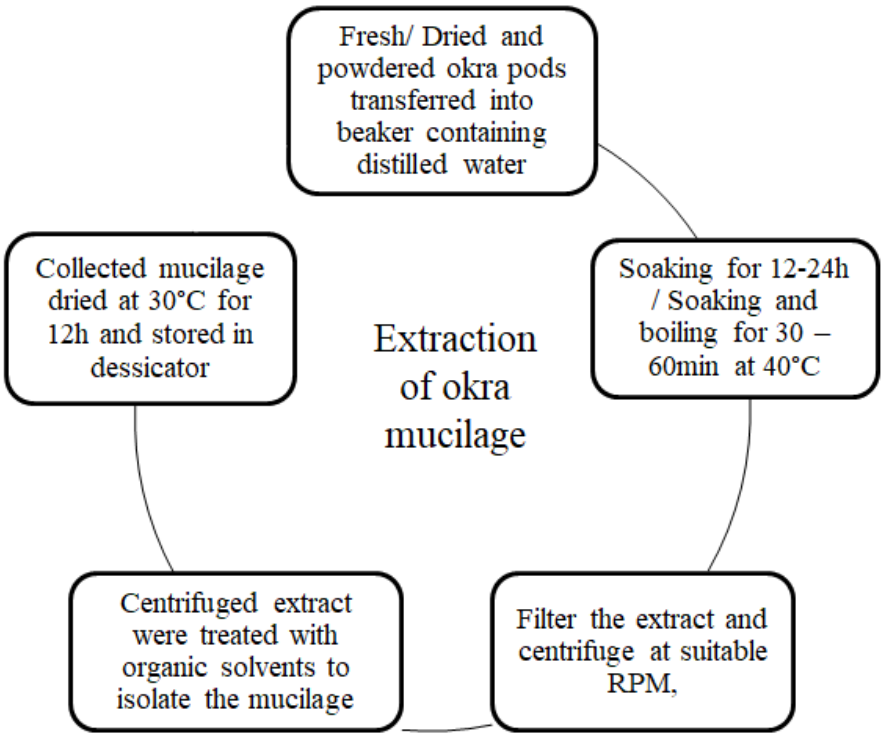
2.1.2, STEP 2: Isolation of okra mucilage

Above extraction undergoes centrifugation and treated with ethanol or acetone to under continuous stirring isolate mucilage; okra mucilage get separating from extraction; then collect the mucilage by filtering through muslin cloth. Dry the collected mucilage under shadow for 24h; further dried at 35–45°C in hot air oven to get constant weight. Dessicator or amber color bottle used to preserve the mucilage for prevent from moisture. [34, 35, 36]

2.2 TYPE II: By Soaking, boiling and extraction:

Fresh minced okra pods were soaked in 300ml of distilled water for 5-6 h, and it was heated in a water bath for 30 - 60 minutes. Then collect the extraction through muslin cloth. Further procedure similar as followed in type I. [37, 38]

Figure.3: Extraction of okra mucilage



2.3 Advantages okra extraction methods

The conventional approach has the benefit of producing a significant yield of okra mucilage. Furthermore, impurities are sometimes present in the product, for that required to add high-quantity of organic solvents in the extraction process. [39,40]. In ultrasound-assisted extraction method is environmental friendly and it requires low quantity of solvent; but it provides higher yield, So this is the best extraction method than conventional method. Moreover, due to the higher costs, the ultrasound-assisted extraction method is not suitable for large scale. [41]. In the MAE method also requires low quantity of solvent, economically and environmental friendly; produce higher yield of extraction with less time. So MAE is better than conventional and ultrasound-assisted extraction methods of okra mucilage.[42]

2.4 Identification of Okra Mucilage

Okra mucilage as excipients is identified through ash value test, solubility, pH, swelling index, surface tension, moisture content, viscosity swelling index, surface tension, bulk density, tapped density, carr's index, hausner's ratio, angle of repose, IR and DSC.[43, 44]

The functional properties of okra mucilage and their values were mentioned in table.1.

Table.1: Functional Properties of Okra Mucilage [45, 46]

S.No	Functional properties of okra mucilage	
1	Bulk density	0.58-0.63g/ml
2	Water absorption capacity	2.5-4.60ml/g
3	Oil absorption capacity	0.02-3.64ml/g
4	Emulsifying capacity	42.22 - 74.45%
5	Foaming capacity	50.51 - 62.50%
6	Total phenolic content	4.66-49.93 mgGAE/g
7	Total flavonoid content	8.18-18.72mg CE/g

8	Chelating agent	1.10 - 1.85

3. Application of Okra mucilage:

Okra mucilage has potential effect on pharmaceutical field mentioned in Table 2. which play a vital role in development of formulation as excipients, emulsifier, binder and anti-oxidant because of the intrinsic properties and developing as a gel when in contact with acidic pH. [47] In current era okra mucilage applied in drug delivery system, that improves the bioavailability, release the drug at targeted site, act as mucoadhesive polymer by enhancing tissue penetration, for sustaining the drug release.[48] Okra polysaccharides also used in development of Okra gum matrix tablet, okra beads, okra based polymeric microspheres, okra nano-composite fibre, okra buccal patches, okra as a coating agent, in veterinary vaccine delivery and okra mucoadhesive gel.[49] The pharmacological effect of okra mucilage as a excipient and also application in pharmaceutical field showed in Table.2.

Most of the polysaccharides derived from microorganisms, plants, and animals have anticoagulant [40], anticancer [41], antioxidant [50], antiviral [51], and anti-diabetic properties [52]. Attempts are being undertaken to improve the biological activity of these polysaccharides by chain elongation [53]. Polysaccharides, the major species in okra, have powerful antioxidant [54], anti-hyperglycaemic [55], immunomodulatory [42], and anti-fatigue properties [56]

Table.2: Application of Okra Mucilage in Pharmaceutical Field

S.No	Okra mucilage in Pharmaceutical field	Application of okra mucilage
1	Diabetes	It reduces the glucose level by increasing the sensitivity to beta cells in the pancreas that enhances the insulin secretion.[57]
2	Gastric ulcer, Peptic ulcer	Okra mucilage helps in neutralize acid secretion in stomach, because OM is alkaline in nature [58]
3	In GIT	OM has probiotics, so it is gut bacteria friendly. It prevents and relieves from constipation and also lowers the risk of colon cancer. [59]
4	In pharmaceutical field	OM used as a emulsifier, binder, anti-oxidant, excipient, polymer in drug delivery system [60]
5	In Food industry	Used as emulsifying agent, stabilizer, confectionery and thickening agent in sauce [61]
6	In cosmetics	Skin cleanser, moisturizer, prevent skin pigmentation, reduce acne, hair conditioner, etc…[62]
7	Binder	Extracted okra mucilage as a binder in tablet formulation shows significant effect on physicochemical property like hardness, friability disintegration time, etc..[63]
8	Excipient	In atenolol floating tablet, the okra mucilage with gas forming agent like sodium bi carbonate gives effective floating tablet with extended the drug release and also followed the first order kinetics and higuchi's mechanism. [64]
9	Polymer	The okra mucilage as a polymer in Lamivudine tablets shows better drug release because that retarded the drug due to increased gel strength.[65]
10	Microspheres	Ambroxol hydrochloride microspheres developed by OM shows better impact on sustaining the drug release and improved bioavailability.[66]
11	Oral dispersible tablet	Taste masking of bitter drug (Promethazine HCl oral dispersible tablet) was successfully prepared by okra mucilage.[66]
12	Gastro retentive drug delivery system	Ziprasidone HCl gastro retentive formulation enhanced gelation property and shows excellent buoyancy rate in oral gastro retentive drug delivery sytem.[68]

31	Mucoadhesive polymer	Okra mucilage gel is potentially mucoadhesive polymer in nasal drug delivery system. [69]

Okra mucilage for drug delivery Okra

Inherent features in okra mucilage as their ability to produce a gel forming, coating agent, and controlled-release matrix, okra mucilage frequently employed as drug-delivery carrier in various ways. Furthermore, they promote tissue permeability to improve medicine oral bioavailability and can substitute synthetic polymers for improved mucoadhesive nature. [70]

Okra mucilage matrix tablets

In blood pressure for treat early-morning variations, okra mucilage assisted as a controlled release matrix for propranolol HCl for colon-targeted medication administration. They investigated the propranolol's bioavailability in different natural polymers and compressed as a tablets using direct compression. The findings of this investigation supported the stated theory of sustained release for longer periods of time. [71{}]

Okra mucilage-based microspheres

Drug rapid absorption and metabolization can be inhibited in the body by developing as polymeric microspheres of oxcarbazepine using okra mucilage, because that may cause adverse effects such as insomnia, headache, dizziness, vomiting, weakness, and skin inflammation. The drug has short half-life, necessitating regular dosing to maintain bioavailability in the body. This investigation proves that, drug-dosing frequency and adverse effects were reduced by developing as okra and alginate microspheres to manage its release. [72]

Okra mucoadhesive gels

Mucoadhesive gels containing Rizatriptan benzoate were developed utilizing okra mucilage. A comprehensive examination of all variables revealed that okra gel has formulation qualities and allows the medication to enter the goat nasal mucosa. As a result, okra mucilage can be utilized instead of synthetic polymers and also act as cholesterol-reducing agent. [73]

Okra Mucilage as a binder

Okra mucilage was used as a binder and its binding efficiency in tablet form was investigated in this study. The in-vitro drug-release investigation demonstrated that okra mucilage performed similarly to starch as a binder. The integrated medication displayed a delayed and prolonged release profile at increased concentration of mucilage; hence, this system might be employed as a natural pharmaceutical excipient in dosage forms. [74]

Okra beads

Glibenclamide has short plasma half-life, so repeated drug administration necessary to maintain the therapeutic dose in the systemic circulation. Drug was incorporated in okra mucilage-alginate beads (made with CaCl2 as crosslinking agent) developed through ionic gelation to minimise dosing frequency while preserving drug for longer time period. [75]

Okra buccal patches

Verapamil HCl has a low plasma half-life, narrow absorption window in GIT and less bioavailability. So, buccal patches were created via solvent casting and tested in vitro and ex vivo. The formulations showed significant swelling and ex vivo muco-adhesion strength, with overall findings indicating that okra mucilage and chitosan acetate had superior physical qualities to the buccal patch and significant control release from the matrix film. [76]

Okra nano-composite film

The nanoparticle were prepared by inclusion of CMC and okra mucilages at the proper level in the films to improve their tensile strength and decrease elongation at break. So, CMC inclusion boosted the film's water vapour permeability and solubility. In vitro tests revealed that the produced nanocomposite films significantly inhibited the development of Gram-positive Staphylococcus aureus rather than Gram-negative Escherichia coli. The antibacterial activity of films contains okra mucilage has greater effect than that of pure CMC films. [77]

4. CONCLUSION:

Studies described okra mucilage used as pharmaceutical excipient and which has excellent buoyancy time in gastro retentive formulations. Consequently the okra mucilage may utilize as an in-situ gel forming agent in antacids. Because okra mucilage has an anti-ulcer activity, so which can prevent the gastric acidity in stomach. In current era, natural polymers play a vital role almost in all kind of industries especially in pharmaceutical field. The formulation scientists have achieved a great success in developing the most adorable drug delivery systems with suitable natural polymers to overcome the patient compliance. This can be useful in several unsolved problem, minimize side effects; because, being nontoxic in nature, this okra fruit can be easily tried used as polymer in formulations and also pharmacological activities directly can be tested on human rather than animal models. Okra based anti-diabetic food, antioxidant rich food formulation; pharmaceutical products can be thus easily be tried avoiding complicated medical trials.

However further research on okra mucilage should be addresses application of OM in pharmaceutical field and mechanism of action of the pharmacological activities.

DECLARATION

Acknowledgement:
The authors would like to thank Department of Pharmaceutics, SRM College of Pharmacy, SRMIST, Kattankulathur for providing facilities and guidance to carry out the research.

Funding:
None.

Data Availability:
All datasets analyzed in the study are included in the manuscript and presented as tables.

References

1. L. G. Bakre, K. T. Jaiyeoba: Evaluation of a new tablet disintegrant from dried pods of Abelmuscus esculentus L (Okra): Asian J Pharm Clin Res 2009; 3(2):83–91.
2. Alba, K., Laws, A. P., Kontogiorgos: Isolation and characterisation of acetylated LM371 pectins extracted from okra pods: foodhydrocoll 2015; (43): 726-735
3. Bottenberg P, Cleymaet R, De Muynck C, Remon JP, Coomans D, Michotte Y, et al. Development and testing of bioadhesive, fluoride containing slowrelease tablets for oral use. J Pharm Pharmacol. 1991;43(7):457-64.
4. Lehr CM, Bouwstra JA, Schacht EH, Junginger HE. In vitro evaluation of mucoadhesive properties of chitosan and some other natural polymers. Int J Pharm. 1992;78(1-3):43-8.
5. Parodi B, Russo E, Cavgilioli G, Cafaggi S, Bignardi G. Development and characterisation of a buccoadhesive dosage form of oxycodone hydrochloride. Drug.Dev Ind Pharm. 1996;22(5):445–50
6. Deogade, U.M, Deshmukh, V.N, Sakarkar, D.M: Natural gums and gum's in NDDS Applications and recent approaches: Int. J. Pharmtech Res 2012;2(4): 799-814.
7. Noorlaila A, Siti Aziah A, Asmeda R, Norizzah A R: Emulsifying properties of extracted Okra (Abelmoschus esculentus L.) mucilage of different maturity index and its application in coconut milk emulsion: IFRJ 2015;2(22): 782-787
8. Jaleh V, Naser T, Fatemeh K: Use of Hydrophilic Natural Gums in Formulation of Sustained-release Matrix Tablets of Tramadol Hydrochloride: AAPS Pharm Sci Tech 2006; 7(1):1–7
9. Sengkhamparn N, Verhoef R, Schols H A, Sajjaanantakul T, Voragen A G J: Characterisation of cell wall polysaccharides from okra (Abelmoschus esculentus (L): Moench. Carbohydr. Res. 2009; 14(344):1824–1832
10. Nipaporn Sengkhamparn, Edwin J.Bakx, René Verhoef, Henk .A.Schols, Tanaboon Sajjaanantakul, Alphons G.J.Voragen: Okra pectin contains an unusual substitution of its rhamnosyl residues with acetyl and alpha-linked galactosyl groups: Carbohydr. Res. 2009 (344): 1842–1851
11. Haydar A, Bari A, Kamarulizam SN, Che Man R: Investigating drag reduction characteristics using okra mucilage as new drag reduction agent: Appl. Sci 2011; 11(14): 2554-2561
12. Gurbuz I, Ustun O, Yesilada E, Sezik E, Akyurek N: In vivo gastro protective effects of five Turkish folk remedies against ethanol induced lesions: J. Ethnopharmacol 2004(83): 241-244
13. P. Adhikary, K.N. Tiwari, R.P. Singh: Synthesis, characterization, and flocculation characteristics of polyacrylamide-grafted glycogen: J. Appl. Polym. Sci 2007 (103): 773–778
14. Brown AHD, Marshall R, Frankel OH. The use ofplant genetic resources. London: Cambridge University Press; 1990.
15. Malviya R. Extraction characterization and evaluation of selected mucilage as pharmaceutical excipient: Polim.Med 2011;1(3): 39–44
16. Oppong-Sekyere D, Akromah R, Nyama EY, Brenya E. Characterization of okra (Abelmoschus spp. L.) germplasm based on morphological characters in Ghana. J of Pl Breed and Crop Sci. 2011;3:367–78.
17. Freitas T K S M, et.al. Ind. Crops Prod: 2015;76: 538.
18. Whistler R, Conrad H E. 2-O-(D-Galactopyranosyluronic Acid)-L-rhamnose from Okra Mucilage: J. Am. Chem. Soc 1954;76: 3544.
19. Shayeri chatterjee, Rana mazumder: Novel approach of extraction and characterizatio of okra gum as a binder for tablet formulation: Asian J Pharm Clin Res 2019;12(1):189-192
20. Priyanka Sinhaa, U. Ubaidullaa, M. Saquib Hasnainb, Amit Kumar Nayakc, Bobba Rama: Alginate-okra gum blend beads of diclofenac sodium from aqueous template using ZnSO4 as a cross-linker: Int J Biol 2015;79: 555–563
21. Capitani M I, Tomás M C, Nolasco S M. Effect of mucilage extraction on the functional properties of Chia meals. In: Food Industry. InTech; 2013.
22. Hong N T, Ibrahim N H. Extraction and characterization of mucilage from leaves of Pereskia Bleo (rose cactus). Jurnal Teknologi dan Industri Pangan, 23(2), 210.
23. Okunlola A, Odeniyi MA, Arhewoh MI. Microsphere formulations of ambroxol hydrochloride: influence of Okra (Abelmoschus esculentus) mucilage as a sustained release polymer. Prog Biomater. 2020;9(1–2):65–80.
24. Tian, Z.-H., Miao, F.-T., Zhang, X., Wang, Q.-H., Lei, N., & Guo, L.-C. (2015). Therapeutic effect of okra extract on gestational diabetes mellitus rats induced by streptozotocin. Asian Pacific Journal of Tropical Medicine, 8, 1038–1042
25. Ideani V A, Bello B M. Functional properties of okra protein products containing different levels of mucilage. J Food Agric Environ, 2009; 7(2), 252–255.
26. Thanatcha R, Pranee A. Extraction and characterization of mucilage in Ziziphus mauritiana Lam. Int. Food Res. J 2011; 18(1):201–212.

27. Nafee NA, Boraie MA, Ismail FA, Mortada LM. Design and characterization of mucoadhesive buccal patches containing cetylpyridinium chloride. Acta Pharm. 2003;53(3):199-212.
28. Tomoda M, Shimizu N,Gonda R. Isolation and characterisation of mucilage 'Okra Mucilage R' from the roots of Abelmoschus esculentus. Chem. Pharm. Bull 1985; 33(8): 3330-3335.
29. Ngoc TH, Ngo QN, Van AT, Phung N V. Hypolipidemic effect of extracts from Abelmoschus esculentus L. (Malvaceae) on Tyloxapol-induced hyperlipidemia in mice. Warasan Phesatchasat 2008; 35: 42-46.
30. Kahlon TS, Chapman MH and Smith GE: In vitro binding of bile acids by okra, beets, asparagus, eggplant, turnips, green beans, carrot and cauliflower. Food Chem. 2007; 103: 676-80.
31. Nurul Dhania Zaharuddin, Mohamed Ibrahim Noordin, Ali Kadivar: The Use of Hibiscus esculentus (Okra) Gum in Sustaining the Release of Propranolol Hydrochloride in a Solid Oral Dosage Form: BioMed.Res. Int 2014: 1-8
32. Konstantinos Anastasakis, Dimitrios Kalderis, Evan Diamadopoulos: Flocculation behavior of mallow and okra mucilage in treating wastewater: Desalination 2009 (249):786–791
33. Mirhosseini.H, Amid.B.T: A review study on chemical composition and molecular structure of newly plant gum exudates and seed gums: Food Res Int 2012;46 (1): 387-398.
34. Kunal Pal. Synthesis, characterization of Okra mucilage as a potential new age therapeutic intervention. Int. Conf. Biomed. Eng: Empower. Biomed. Technol. 2020; 6: 1-13.
35. Amin IM. Nutritional Properties of Abelmoschus Esculentus as Remedy to Manage Diabetes Mellitus: A Literature Review. Int. Conf. Biomed. Eng: Empower. Biomed. Technol. 2011; 11: 1-5
36. Jaleh V, Naser T, Fatemeh K: Use of Hydrophilic Natural Gums in Formulation of Sustained-release Matrix Tablets of Tramadol Hydrochloride. AAPS Pharm Sci Tech 2006, 7(1):1–7.
37. Momoh M A, Akikwu M U, Ogbona J I, Nwachi U E. In Vitro Study of Release of Metronidazole Tablets Prepared from Okra Gum, Gelatin Gum and their Admixture. BioResearch 2008; 6: 339-342.
38. Mohammadi H, Kamkar A, Misaghi A. Nanocomposite films based on CMC, okra mucilage and ZnO nanoparticles: Physico mechanical and antibacterial prop- erties. Carbohydr. Polym 2018(181): 351–357.
39. Araujo A, Galvao A, Silva Filho C, Mendes F, Oliveira et.al. Okra mucilage and corn starch bio-based film to be applied in food. Polymer Testing 2018(71): 352–361
40. Wang M, Gu Q, Luo Y, Bukhvalov D, Ma X, Zhu L, Luo Z. Understanding mechanism of adsorption in the decolorization of aqueous methyl violet (6B) solution by okra polysaccharides: Experiment and theory. ACS Omega 2019;4: 17880–17889
41. Yuan Q, Lin S, Fu Y, Nie X. Effects of ex- traction methods on the physicochemical characteristics and biological activities of polysaccharides from okra (Abelmoschus esculentus). Int. J. Biol. Macromol 2020;147: 1053–1063.
42. Pollard M, Kelly R, Fischer P, Windhab E, Eder B, Amadò R: Investigation of molecular weight distribution of LBG galactomannan for flours prepared from individual seeds, mixtures, and commercial samples. Food Hyd 2008;22:1596–1606
43. Alalor C A, Uhumwangho M U, Iwuagwu M A: Evaluation of ciprofloxacin floating-bioadhesive tablet formulated with okra gum as multifunctional polymer: UK. J. Pharm. Biosci 2018; 6(2):1-11
44. Gemede HF, Haki GD, Beyene F, Rakshit SK, Woldegiorgis AZ. Indigenous Ethiopian okra (Abelmoschus esculentus) mucilage: A novel ingredient with functional and antioxidant properties. Food Sci Nutr. 2018;6(3):563–71.
45. Rishabha Malviya UF. Design and development of multi particulate system for targeted drug delivery using natural polymer. Pharm Anal Acta. 2015;06(05).
46. Pintu Dhar, Himangshu Sarmaa, Hemanta Kumar Sharma: Fixed Dose Oral Dispersible Tablet of Bitter Drug Using Okra Mucilage: Formulation and Evaluation J.Drug Deliv.ther 2020; 10(5):149-158
47. Sharma N, Kulkarni GT, Sharma A. Development of Abelmoschus esculentus (Okra)-Based Mucoadhesive Gel for Nasal Delivery of Rizatriptan Benzoate. Trop J Pharm Res 2013;12(2).
48. Koland M, Sandeep V, Charyulu N. Fast dissolving sublingual films of ondansetron hydrochloride: Effect of additives on in vitro drug release and mucosal permeation. J Young Pharm [Internet]. 2010;2(3):216–22.
49. Yuan Q, et.al,.. Effects of ex- traction methods on the physicochemical characteristics and biological activities of polysaccharides from okra (Abelmoschus esculentus). Int. J. Biol. Macromol 2019;127: 178–186
50. Mohammadi, H., Kamkar, A., Misaghi, A., Zunabovic-Pichler, M., & Fatehi, S. (2019). Nanocomposite films with CMC, okra mucilage, and ZnO nanoparticles: Extending the shelf-life of chicken breast meat. Food Packaging and Shelf Life, 21, 100330.
51. Lengsfeld, C., Titgemeyer, F., Faller, G., & Hensel, A. (2004). Glycosylated compounds from okra inhibit adhesion of Helicobacter pylori to human gastric mucosa. Journal of Agricultural and Food Chemistry, 52, 1495–1503
52. Wang, K., Li, M., Wen, X., Chen, X., He, Z., & Ni, Y. (2018). Optimization of ultrasound- assisted extraction of okra (Abelmoschus esculentus (L.) Moench) polysaccharides based on response surface methodology and antioxidant activity. International Journal of Biological Macromolecules, 114, 1056–1063
53. Nagpal, M., Kaur, M., Sharma, D., Baldi, A., Chandra, R., & Madan, J. (2019). Optimization of sulfation of okra fruit gum for improved rheological and pharma- cological properties. International Journal of Biological Macromolecules, 122,1–9.
54. F.O. Adetuyi, A.U. Osagie and A.T. Adekunle. Nutrient, antinutrient, mineral and zinc bioavailability of okra Abelmoschus esculentus (L) Moench Variety. Am. J. Food. Nutr, 2011, 1(2): 49-54.
55. Karakottsides P A, S M. Okra seeds, a new protein source. J.Agric. Food Chem.1975, 23: 1024.
56. Ashwini Rajendra, Bushetti S.S: Formulation and evaluation of matrix tablets based on polyelectrolyte complex between okra mucilage and chitosan: IRJP 2012;3(2):279-286
57. Samim S, Sood S, Singh A, Verma A, Kaur A. Morphological Characterization of Okra [Abelmoschus esculentus (L.) Moench]. Int J Curr Microbiol Appl Sci. 2018;7(10):2011–9
58. Edukondalu V, Ashok Kumar, Jagadeesh.K, Pushpalatha.V, Satyanadam.Sade, Lakshmi Narasaiah: Formulation and evaluation of oral floating tablets of Atenolol using Okra gum: Der Pharmacia Lettre 2011;3(3):342-349
59. Narahari N. Palei, Santhosh K. Mamidi, Jayaraman Rajangam: Formulation and evaluation of lamivudine sustained release tablet using okra mucilage: J. Appl. Pharm.Sci: 2016;6 (09):069-075
60. Pratibha Kale: Extraction and Characterization of Okra Mucilage as a Pharmaceutical Aid: IJSTR 2020;5(4): 189-193
61. Nandi G. Poly (Methacrylic acid)-Grafted-Okra gum: Synthesis, characterization and evaluation as mucoadhesive. Int. j. pharm 2019(11): 250–254

62. Hayaza S, Wahyuningsih S P A, Susilo K, Joko R, Permanasari A A, et.al. Anticancer activity of okra raw polysaccharides extracts against human liver cancer cells. Trop. J. Pharm. Res 2018: 18.
63. Ndjouenkeu R, Goycoolea FM, Morris ER, Akingbala J.O: Rheology of okra-Hibiscus esculentus L and dika nut-Irvingia gabonensis polysaccharides: Carbohydr. Polym 1996;29: 263–269.
64. Pieroni A, Ansari NM: Antioxidant activity of five vegetables traditionally consumed by South Asian migrants in Bradford, Yorkshire, UK Phytotherapy Research 2005(19): 907-11.
65. Shui G, Lai Peng L. 2004. An improved method for the analysis of major antioxidants of Hibiscus esculentus Li: J. Chromatogr.A 2004;1048: 17-24.
66. Kochhar, S.L: Okra (Lady's finger) In Tropical crops, a textbook of economic Botany 1986: 263 – 264.
67. Joshi, A.B., Gadwal, V.R. & M.W. Hardas: Evolutionary studies in world crops, In Diversity and Change in the Indian Sub-Continent. Hutchinson, J.B., London: Cambridge University Press 1974: 99-105
68. Nayak AK, Das B, Maji R. Calcium alginate/gum Arabic beads containing glibenclamide: development and in vitro characterization. Int J Biol Macromol. 2012;51(5):1070–8.
69. 50. Archana, G, Sabina K, Babuskin S, Radhakrishnan K, et.al. Preparation and characterization of mucilage polysaccharide for biomedical applications. Carbohydrate Polymers 2013 (98): 89–94.
70. Newton A, Indana V, Kumar J. Chronotherapeutic drug delivery of Tamarind gum, Chitosan and Okra gum controlled release colon targeted directly compressed Propranolol HCl matrix tablets and in-vitro evaluation. Int. J. Biol. Macromo 2015(79): 290–299.
71. Ghumman, S. A., Bashir, S., Noreen, S., Khan, A. M., Riffat, S., & Abbas, M. Polymeric microspheres of okra mucilage and alginate for the controlled release of oxcarbazepine: In vitro & in vivo evaluation. Int. J. Biol. Macromo 2018(111):1156-1165
72. Sharma N, Kulkarni G T, Sharma A. Development of Abelmoschus escu- lentus (okra)-based mucoadhesive gel for nasal delivery of rizatriptan benzoate. Trop. J. Pharm. Res 2013(12): 149–153
73. Ameena K, Dilip C, Saraswathi R, Krishnan P, Sankar C, Simi S. Isolation of the mucilages from Hibiscus rosasinensis linn. and Okra (Abelmoschus esculentus linn.) and studies of the binding effects of the mucilages. Asian Pac. j. trop. Med 2010(3): 539–543
74. Navamanisubramanian R, Nerella R, Chamundeeswari D, Seetharaman S. Use of okra mucilage and Chitosan Acetate in verapamil hydrochloride buccal pat- ches development; in vitro and ex vivo characterization. J Young Pharm 2017: 93(1): 33-38.
75. Khanna R, Agarwal SP, Ahuja A. Preparation and evaluation of mucoadhesive buccal films of clotrimazole for oral Candida infections. Indian J Pharm Sci. 1997;59(6):299-305.
76. Ravi Kumar, M. B. Patil, Sachin R. Patil, Mahesh S. Paschapur, Evaluation of Abelmoschus Esculentus Mucilage as Suspending Agent in Paracetamol Suspension. Int. J. Pharmtech Res 2009; 1(3):658-665.
77. Tavakoli N, Ghassemi Dehkordi N, Teimouri R, Hamishehkar H. Characterization and Evaluation of Okra Gum as a Tablet Binder. Jundishapur J. Nat. Pharm. Prod 2008; 3(1): 33-38.