

Abundantly available cultigen Okra, a clandestine natural therapeutic treasure trove: A brief overview

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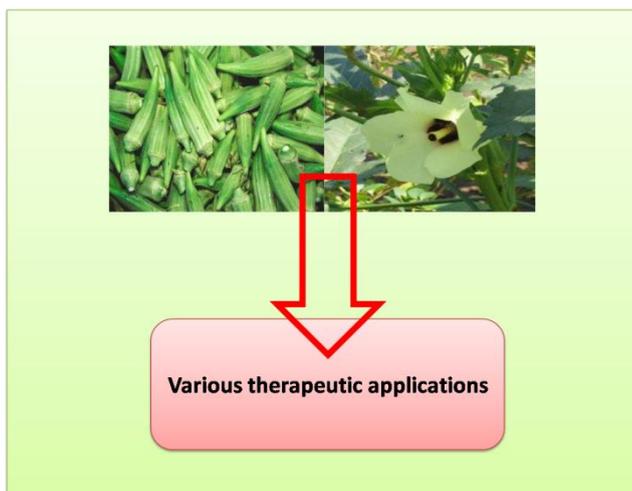
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Graphical Abstract



Abstract.

Okra is a cultigen (a plant that has been altered by humans through a process of selective breeding). The exact origin of okra is unknown, but it is thought to have come from Africa, where it has been grown as a crop for centuries. Evidence suggests it was grown in Egypt as long ago as 2,000 BC. Today it is widely cultivated for its edible green fruits, which are harvested when immature (after 3 - 5 days of development), and are infamous for their slimy mucilage. It plays a vital role to preserve our health. In recent times, the use of herbal products has increased tremendously in the western world as well as developed countries. India is one of the most medico-culturally diverse countries in the world where the

medicinal plant sector is part of a time-honoured tradition that is respected even today. Medicinal plants are believed to be safer and proved elixir in the treatment of various ailments. *Abelmoschus esculentus* (Okra) is an important medicinal plant of tropical and subtropical India. Its medicinal usage has been reported in the traditional systems of medicine such as Ayurveda, Siddha and Unani.

Keywords: Okra; high nutritional value; ethnomedicinal use; drug delivery system.

Introduction

Okra (*Abelmoschus esculentus*) is the only vegetable crop of significance in the Malvaceae family and is very popular in the Indo-Pak subcontinent. In India, it ranks number one in its consumption but its original home is Ethiopia and Sudan, the north-eastern African countries. It 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. It is a tropical to subtropical crop and is sensitive 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 [1].

It is an oligo purpose crop, but it is usually consumed for its green tender fruits as a vegetable in a variety of ways. These fruits are rich in Vitamins, calcium, potassium and other mineral matters. The mature okra seed is a good source of oil and protein has been known to have superior nutritional quality. Okra seed oil is rich unsaturated fatty acid, which is essential for human use.

Chemical Composition

Okra bast, a multicellular fibre was analysed and the estimated average chemical compositions of OBF (*Abelmoschus esculentus* variety) are 67.5% α -cellulose, 15.4% hemicelluloses, 7.1% lignin, 3.4% pectic matter, 3.9% fatty and waxy matter and 2.7% aqueous extract. It is clear that the main constituents of OBF are α -cellulose, hemicelluloses and lignin and the rest are very minor in proportion, so render a little influence to the structure of OBF. Therefore, the structure of α -cellulose, hemicelluloses and lignin and the mode of combinations that exist in between themselves are dominating the structure of OBF.

Percentages are related to US recommendations to for adults. (Source: USFDA database) Okra is a popular health food due to its high fibre, Vitamin C, and folate content. Okra is also known for being high in antioxidants. Okra is also a good source of calcium and potassium.

Utilisation

- **Parts Used:** Fruit, leave seed and roots.
- **Ethnomedicinal Uses:** Plants for a future cannot take any responsibility for any adverse effects from the use of plants. Always seek advice from a professional before using a plant medicinally. Antispasmodic; Demulcent; Diaphoretic; Diuretic; Emollient; Stimulant; Vulnerary Table 2. The roots are very rich in mucilage, having a strongly demulcent action. They are said by some to be better than marshmallow (*Althaea officinalis*). This mucilage can be used as a plasma replacement. An infusion of the roots is used in the treatment of syphilis. The juice of the roots is used externally in Nepal to treat cuts, wounds and boils. The leaves furnish an emollient poultice. A decoction of the immature capsules is demulcent, diuretic and emollient. It is used in the treatment of catarrhal infections, dysuria and gonorrhoea. The seeds are antispasmodic, cordial and stimulant. An infusion of the roasted seeds has sudorific properties [17, 189].
- **Other Uses:** Fibre; Paper; A fibre obtained from the stems is used as a substitute for jute. It is also used in making paper and textiles. The fibres are about 2.4 mm long. When used for paper the stems are harvested in late summer or autumn after the edible seedpods have been harvested, the leaves are removed and the stems are steamed until the fibres can be stripped off. The fibres are cooked for 2 hours with lye then put in a ball mill for 3 hours.

Distribution

- **Found In:** India, Myanmar, Bangladesh.
- **Introduced Into:** Alabama, Albania, Andaman Is., Angola, Bahamas, Benin, Borneo, Bulgaria, Burkina, Cambodia, Cape Verde, Cayman Is., Central African Repu, Chad, China South-Central, China Southeast, Congo, Cuba, Dominican Republic, Eritrea, Fiji, Gabon, Gambia, Greece, Guinea-Bissau, Gulf of Guinea Is., Hainan, Haiti, Illinois, Ivory Coast, Jamaica, Jawa, Krym, KwaZulu-Natal, Leeward Is., Malaya, Mali, Marianas, Mauritania, Mexico Southwest, Mozambique, Nicobar Is., Niger, Nigeria, Northern Provinces, Oman, Philippines, Puerto Rico, Romania, Senegal, Sierra Leone, South European Russia, Southwest Caribbean, Sudan, Tanzania, Togo, Uganda, Ukraine, Venezuela, Venezuelan Antilles, Windward Is., Zambia, Zaïre, Zimbabwe.

Other Botanical Information

Abelmoschus esculentus (usually $2n = 130$) is probably an amphidiploid (allotetraploid), derived from *Abelmoschus tuberculatus* Pal and H. B. Singh ($2n = 58$), a wild species from India, and a species with $2n = 72$ chromosomes (possibly *Abelmoschus ficulneus* (L.) Wight and Arn. ex Wight). Another edible okra species, *Abelmoschus caillei* (A. Chev.) Stevels occurs in the humid parts of West and Central Africa. There are strong indications that also *Abelmoschus caillei* is amphidiploid with *Abelmoschus esculentus* being one of the parental species. There are no apparent differences in use between the common and West African okra, which is why they are often lumped together. Morphologically *Abelmoschus caillei* differs in several respects from *Abelmoschus esculentus*, but the epicalyx offers the best discriminating characteristic: the width of the epicalyx segments are 0.5 - 3 mm in *Abelmoschus esculentus* and 4 - 13 mm in *Abelmoschus caillei*. The two okra species can be quite reliably (but not with absolute certainty) recognized on the basis of fruit form. Fruits of *Abelmoschus esculentus* are cylindrical to pyramidal, whereas fruits of *Abelmoschus caillei* are ovoid. Literature references on common okra have to be interpreted with care because they may include information related to *Abelmoschus caillei*. There are many cultivars of common okra. Some of the better known are 'Clemson Spineless', 'Indiana', 'Emerald' (United States) and 'Pusa Sawani' (India), which have been in use for about 30 years [3].

Diseases and Pests

The most serious fungal diseases of okra in Africa are damping-off (*Macrophomina phaseolina*, *Pythium aphanidermatum*, and *Rhizoctonia solani*), vascular wilt (*Fusarium oxysporum*), Cercospora blight (*Cercospora abelmoschus*, *Cercospora malayensis*) and powdery mildew (*Erysiphe cichoracearum*, *Oidium abelmoschi*). Okra mosaic virus (OkMV), transmitted by flea beetles (*Podagrica*), is widespread in Africa but damage is much less important than that caused by okra leaf curl disease (OLCV), transmitted by whitefly (*Bemisia tabaci*). Whitefly is also the vector of yellow vein mosaic virus (BYVMV), a major cause of crop failure in Asia. These viruses can only be controlled through control of the vectors. Nematodes of the genus *Meloidogyne* constitute a major problem. Damage by nematodes is avoided by crop rotation (e.g. with cereals) and by large applications of organic manure. Important pests are fruit and stem borers (*Earias* spp. and *Heliothis* spp., *Pectinophora gossypiella*), flea beetles (*Podagrica* spp.) and jassids (*Empoasca* spp.). Chemical control is hazardous because crop harvesting is frequent. Common okra is in general more seriously affected by diseases and pests than West African okra.

Yield A vegetable yield of 10 t/ha can be considered a good harvest, but yields of over 40 t/ha can be realized under optimal conditions. Yields are usually low (2 - 4 t/ha) as a result of non-intensive growing methods. Seed yields are in the range of 500- 1000 kg/ha.

Validated Pharmacological Properties of the Okra

Antioxidant Activity and Prevention of Cellular Damage Related Diseases: Reactive oxygen species (ROS) i.e. superoxide anion (O_2^-), hydrogenperoxide (H_2O_2), and the hydroxyl radical (OH^-) and reactive nitrogen species (RNS) i.e. nitric oxide (NO), peroxyntirite ($ONOO^-$) when produced in excess, cause cell dysfunction and ultimately death. This happens due to alteration of metabolic pathway [36] and/or the structure of cellular membranes, DNA, or proteins. Many medicinal plants, fruits and their products, fermented food, etc. are proved to have sufficient antioxidant to scavenge these free radicals and to prevent the ensuing damage. With regard to Okra, several studies have been conducted on the antioxidant activity with different parts of the plant. Atawodiet al., (2009) 46 has reported in vitro antioxidant assay of methanol extract of okra fruits. They have done antioxidant / radical scavenging activities by xanthine oxidase and 2-deoxyguanosine methods and reported 50% inhibitory concentration values of 25 and 43 ml.

According to Khomsug, Thongjaroenbuangam, Pakdeenarong, Suttajit, and Chantiratikul (2010) [48], total phenolic content of pulped and seeds of okra extracts as 10.75 ± 0.02 mg GAE/100g extract and 142.48 ± 0.02 mg GAE/100g extract which corresponds with scavenging activities. Besides they have also found procyanidin B2 as predominant phenolic compound followed by procyanidin B1 and rutin in seeds. In pulped seed catechin, procyanidin B2, epicatechin and rutin are reported to be present.

It is quite important to see that roasting ($1600^\circ C$ for 10 - 60 minutes) increased the nutrient composition and antioxidant activity of the seeds [48] whereas pre-treatment (soaking and blanching) increased the nutrient composition, but decreases antioxidant activity [49]. Ansari, Houlihan, Hussain, and Pieroni (2005) [50] reported Okra extract as in vitro non-enzymatic inhibitor of lipid peroxidation in liposomes. *A. esculentus* peel and seed powder contains significant in vivo antioxidant property in streptozotocin-induced diabetic rats.

Administration of different doses of peel and seed powder significantly increased liver, kidney and pancreas superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), reduced glutathione (GSH) levels and decreased thiobarbituric acid reactive substances (TBARS) ($P < 0.001$) levels in diabetic rats compared to diabetic control rats. [51].

- **Okra as Antidiabetic and Antihyperlipidemic and Related Disease Prevention:**In traditional medicine Okra seeds are reported to have ability in managing increased blood glucose concentration. Modern research has correlated this traditional claim with Tomoda et al., (1989) [52] reported that okra polysaccharide possesses anticomplementary and hypoglycaemic activity in normal mice. *A. esculentus* was found to have hypolipidemic activity in invivo tested rat model (Trinh, Nguyen, Tran, and Nguyen 2008) [53] and in mice 54. Okra polysaccharide lowers the cholesterol level in blood and may prevent cancer by its ability to bind bile acids [55]. Cholesterol levels decreased 56.45%, 55.65%, 41.13%, 40.50% and 53.63% respectively in mice groups orally administered with dichloromethane okra plant extract, methanol okra plant extract, dichloromethane okra fruit extract, methanol okra fruit extract and simvastatin as compared to the tyloxapol injected group [54]. The effects of crude extracts of *A. esculentus* on albumin and total bilirubin levels of diabetic albino rats were reported to have a significant ($P < 0.05$) increase (82%) in total bilirubin levels in diabetic control group over the normal control [56]. Ramachandran, Sandeep, Srinivas, and Dhanaraju, 2010 [57] reported anti-diabetic activity of okra on alloxan-induced diabetic rats. Sabitha, Ramachandran, Naveen, and Panneerselvam Sabita et al., (2012, 2013) [58, 59] has reported antidiabetic and antihyperlipidemic potential of okra peel and seed powder in streptozotocin (STZ)-induced diabetic rats.

Administration of peel and seed powder at 100 and 200 mg/kg dose in diabetic rats showed significant ($P < 0.001$) reduction in blood glucose level and increase in body weight than diabetic control rats. Water-soluble fraction of the fruits of Okra was studied to check the absorption of oral glucose as well as metformin from the gastrointestinal tract in the Long Evans rats. It showed significant reduction in absorption of glucose as studied in the 24hrs fasting rats [60]. Thanakosai and Phuwapraisirisan, (2013) [61] has reported, the presence of two major flavonol glucosides named isoquercetin (2) and quercetin-3-O-beta-glucopyranosyl- (1"→6")-glucoside (3) in okra seeds which are α -glucosidase inhibitors. These two compounds selectively inhibited rat intestinal maltase and sucrase, in which isoquercetin (2) were 6 - 10 times more potent than its related diglucoside (3) Subrahmanyamet al., (2011) [62] has reported antidiabetic activity of okra fruit extract.

The effects of *A. esculentus* fruits on alkaline phosphatase (ALP), aspartate aminotransferase (AST) and alanine aminotransferase (ALT) activities on diabetic albino rats were also investigated. Serum glucose levels and activities of enzymes viz. ALP, AST and ALT decreased significantly after administration of the extracts [56]. Hypoglycemic effect of ethanolic and aqueous extract of *A. esculentus* fruit was studied. Results revealed that aqueous extract of powdered drug had maximum effect (Saha, Jain, and Jain, 2011). Recent study reported that the extract of okra lowers

blood glucose and serum lipids in high-fat diet-induced obese C57BL/6 mice. Ethanol extraction of okra (EO) and its major flavonoids isoquercitrin and quercetin 3-O-gentiobioside reduced blood glucose and serum insulin levels and improved glucose tolerance in obese mice [63].

- **For Treating Dysentery and Diarrhoea in Acute Inflammation and Irritation of the Stomach, Bowels:**In Asia and African traditional medicine, okra fruits are served as mucilaginous food as a dietary meal in the treatment of gastric irritations and inflammatory diseases. Scientific explanation of such use came in recent years. Lengsfeld, Titgemeyer, Faller, and Hensel (2004) [64] pre-treated *Helicobacter pylori* with a fresh juice of okra that completely inhibited adhesion in an in situ adhesion model on sections of human gastric mucosa. The anti-adhesive qualities of okra were assumed to be due to a combination of glycoproteins and highly acidic sugar compounds making up a complex three-dimensional structure that is fully developed only in the fresh juice of the fruit. That is due to the blocking capacity of specific *Helicobacter* surface receptors that coordinate the interaction between host and bacterium. According to Messing et al., 2014 [65], it supported the previous claims and showed that the effectiveness in treating gastric irritations and inflammatory diseases is due to polysaccharides that inhibit the adhesion of *H. pylori* to stomach tissue.

Recent trends and future prospect Okra extract is used as a key ingredient in several commercially important products of food and medicine. The rheological behaviour [66], properties of forming oil water emulsion and ability to stabilize acidic emulsion [67] of okra can potentially be used as future value addition applications like composite materials [68] and food foam productions [69].

In last decade, extensive efforts have been given in developing of several nanoscale-carriers in to improve the drug delivery systems [42, 43, 70]. Okra may play a leading role in improved drug delivery system. Several reports came using okra polysaccharide as drug release agent. Okra gum as a mini-matrix for furosemide and diclofenac sodium tablets showed prolonged release of furosemide and diclofenac sodium from the compressed tablets [71]. Besides it is now used as a medium for several other drug deliveries. Bakre and Jaiyeoba (2009) [72] used it as metronidazole tablet formulation. Sharma, Kulkarni, and Sharma, (2013a) [73] used it in the development mucoadhesive gel for nasal delivery of rizatriptan benzoate. Recently mentioned research group (Sharma, Kulkarni, Sharma, Bhatnagar, and Kumar, 2013b) [74] have prepared and evaluated of mucoadhesive microspheres, using okra polysaccharide as a novel carrier for safe and effective delivery of rizatriptan benzoate into nasal cavity. It is also used to study the sustaining release of drug [75]. Besides colon specific drug delivery studies also been carried out [76]. If drug release is the present hunk of okra research, the future might come as a medium of probiotic, nutraceutical

delivery. Several new formulation might come like edible coating, preservative carrier etc. So more application oriented research might be carried out to get the full utilization of this novel natural gift

Conclusions

The okra fibre possess an excellent quantity of cellulose. Hence it can be used as cellulosic raw materials in cellulose based industries. It also contains low percentage of lignin, which is responsible for yellowing and photochemical degradation. It is a high molecular weight compounds. So it has some developed properties like color fastness, tensile strength etc. in Philippines OBF is used as textile fibre. It is also having excellent anti-oxidant activity and memory enhancement activity. If we collect and properly use the okra bast by isolating fibre from it then a good prospect must be await for our country. And also we can use this extract as a good medicine for Alzheimer's disease.

The strong scientific evidence of in vitro and in vivo biological activity confirms the doubt of its traditional use. Detailed investigations for its myriad beneficial effects may enlighten the future of medicinal exploitation. However further research should be focused to find out the mechanism of action of the pharmacological activities at the molecular level. This can solve several unanswered questions of origin, development and cure of diseases. Besides, being nontoxic in nature, this fruit can be easily tried for human trials rather than animal models. Okra based anti-diabetic food, antioxidant rich food formulation can be thus easily being tried avoiding complicated medical trials. It would get go for better value addition and commercialization in near future not being confined only in kitchen.

References

1. Kochlar SI. Okra (lady finger) in tropical crops. A text book of economic botany, **1986**, **1** 263-264.
2. Jain N. A review on *Abelmoschus esculentus*. *Pharmacacia*, **2012**, **1** 1-8.
3. Islam MT. Phytochemical information and pharmacological activities of Okra (*Abelmoschus esculentus*): A literature-based review. *Wiley*, **2019**, **33** 72-80.
4. Kumar S, Tony E, Kumar P, Kumar A, Srinivasa Rao BS, Nadendla R. A Review on: *Abelmoschus Esculentus* (Okra). *Int. Res J Pharm. App Sci*, **2013**, **3(4)** 129-132.
5. Chopra RN, Nayar SL and Chopra IC: *Glossary of Indian Medicinal Plants (Including the Supplement)*. Council of Scientific and Industrial Research. New Delhi, **1986**.
6. Facciola S. *Cornucopia- A Source Book of Edible Plants*. Kampong Publications, **1990**.

7. Huxley AJ, Griffiths M, Levy Margot. The New RHS Dictionary of Gardening. MacMillan Press **1992**.
8. Phillips R, Rix M. Vegetables. Macmillan Reference Books, London, **1995**.
9. Rice G. Growing from Seed. **1987**, **1** 40-47.
10. Murashige T, Skoog F. A revised medium for rapid growth and Bioassays with tobacco tissue culture. Physiology of Plant, **1962**, **15** 473-497.
11. Esau K. Plant Anatomy. John Wiley & Sons, New York, **1965**.
12. Abdul Baki AA, Anderson JP. Vigour determination in Soybean seed by multiple criteria. Crop Sci. **1976**, **13** 630-3.
13. Dubois M, Giltes KA, Hamilton JK, Rebers PA, Smith F. Carbohydrate estimation by phenol sulphuric acid method. Annual Chemistry, **1956**, **26** 350-51.
14. Lowry OH, Rosen Brough NJ, Farr A, Randall RJ. Protein measurement with the folin phenol reagent. J. Biol.Chemistry, **1951**, **193** 265-75.
15. Miller GL. Use of Dinitrosolicylic acid reagent from determination of reducing sugar. Annual Chemistry, **1959**, **31** 426-8.
16. Torkpo SK, Danquah EY, Offei SK, Blay ET. Esterase, total protein and seed storage protein diversity in okra. West Africa journal of applied ecology, **2008**, **9** 8-18.
17. Hedrick UP. Sturtevant's Edible Plants of the World. Dover Publications, **1972**.
18. Martin FW. "Okra, Potential Multiple- Purpose Crop for the Temperate Zones and Tropics". Economic Botany. **1982**, **36(3)** 340-345.
19. Smithsonian. Contributions to Botany. **2012**, **98** 1-1192.
20. Webbia. Raccolta de ScrittiBotanici. **2012**, **67**, 65-91.
21. Odedra, Nathabhai K. Ethnobotany of Maher Tribe in Porbandar District, Gujarat, India. Thesis PhD, Saurashtra University **2009**.
22. Lim TK. Edible Medicinal and Non-Medicinal Plants Springer Science + Business Media B.V. **2012**, **3** 160.

23. Maramag RP. Diuretic potential of *Capsicum frutescens*, *Corchorusoliturius* L., and *Abelmoschusesculentus* L. Asian journal of natural and applied science, **2013**, **2(1)** 60-69.
24. Smit R, Neeraj K, Preeti K. Traditional Medicinal Plants Used for the Treatment of Diabetes. International Journal of Pharmaceutical and Phytopharmacological Research, **2013**, **3(3)** 171-175.
25. Sayana SB, Khanwelkar CK, Nimmagadda VR, Dasi JMB, Chavan VR, Kutani A and Kotagiri K. Evaluation of Diuretic Activity of Alcoholic Extract of Roots of *CissampelosPareira* in Albino Rats. Journal of Clinical and Diagnostic Research, **2014**, **8(5)** HC01-HC04.
26. Babu PS, Srinivasan K. Influence of dietary curcumin and cholesterol on the progression of experimentally induced diabetes in albino rat. Molecular and Cellular Biochemistry, **1995**, **152** 13-21.
27. Barrett B. Medicinal plants of Nicaragua's Atlantic Coast. Economic Botany, **1994**, **481** 8-20.
28. Yesilada E, Honda G, Sezik E, Tabata M, Fusita T, Takenda Y. Traditional Medicine in Turkey, Folk medicine in the inner Taurus mountain. Journal of Ethnopharmacology, **1995**, **463** 133-52.
29. Crossley A and Hilditch TP. The fatty acids and glycerides of okra seed oil. Journal of the Science of Food and Agriculture **1951**, **2** 251-255.
30. Martin F. Okra, Potential Multiple-Purpose Crop for the Temperate Zonesand Tropics. Economic Botany, **1982**, **36(3)** 340-345.
31. Vaidya MV, Nanoti MV. Bhindi seed powder as coagulant in removal of turbidity from water. Indian Journal of Environmental Health, **1989**, **31(1)** 43-48.
32. Calisir S, Ozcan M, Haciseferogullari H, Yildiz MU. A study on some physico-chemical properties of Turkey okra (*Hibiscus esculenta*) seeds. Journal of Food Engineering, **2005**, **68** 73-78.
33. Jarret RL, Wang ML and Levy IJ. Seed oil and fatty acid content in okra (*Abelmoschusesculentus*) and related species. Journal of Agricultural Food Chemistry, **2011**, **59(8)** 4019-24.
34. Marwat SK, Rehman FR, Khan MA, Ahmed A, Zafar M, Gulam S. Medicinal folk recipes used as traditional used as traditional phytotherapies in district Dera, Ismail Khan, KPK, Pakistan. Journal of Botany, **2011**, **43(3)** 1453-1462.
35. Newsholme P, Keane D, Welters HJ, Morgan NG. Life and death decisions of the pancreatic beta-cell: the role of fatty acids. Clinical Science, **2007**, **112** 27-42.

36. Chandra J, Samali A, Orrenius S. Triggering and modulation of apoptosis by oxidative stress. *Free Radical Biology and Medicine*, **2000**, **29** 323-33.
37. Sánchez-Moreno C, Larrauri JA, Saura-Calixto F. Free radical scavenging capacity and inhibition of lipid oxidation of wines, grape juices and related polyphenolic constituents. *Food Research International*, **1999**, **32** 407-412.
38. Alia SS, Kasojua N, Luthraa A, Singha A, Sharanabasavaa H, Saha A, Bora U. Indian medicinal herbs as sources of antioxidants. *Food Research International*, **2008**, **41** 1-15.
39. Krishnaiah D, Sarbatly R, Nithyanandam R. A review of the antioxidant potential of medicinal plant species. *Food and Bioproducts Processing* **2011**, **89(3)** 217-233.
40. Roy A, Khanra N, Saha S, Bhattacharya C, Mishra A, Bhattacharyya N. An antioxidant-rich fermented substrate produced by a newly isolated bacterium showing antimicrobial property against human pathogen, may be a potent nutraceutical in the near future. *Advances in Life Science and its Applications*, **2012**, **1** 36-44.
41. Roy A, Khanra N, Mishra A, Bhattacharyya N. General analysis and Antioxidant study of Traditional fermented drink Handia, its concentrate and volatiles. *Advances in Life Science and its Applications* **2012**, **1** 54-57.
42. Roy A, Khanra N, Mishra A, Bhattacharya C, Bhattacharyya N. Bakhar-Handia Fermentation: General Analysis and a Correlation between Traditional Claims and Scientific Evidences *Advances in Bioresearch*, **2012**, **3(3)** 28.
43. Zhou Y, Zhang A, Sun H, Yan G, Wang X. Plant-derived natural products as leads to antitumor drugs. *Plant Science Today*, **2014**, **1(2)** 46-61.
44. Adelakun OE, Oyelade OJ, Ade-Omowaye BI, Adeyemi IA, Van de Venter M and Koekemoer TC. Influence of pre-treatment on yield chemical and antioxidant properties of a Nigerian okra seed (*Abelmoschus esculentus* Moench) flour. *Food and Chemical Toxicology*, **2009**, **47(3)** 657-661.
45. Ansari NM, Houlihan L, Hussain B, Pieroni A. Antioxidant activity of five vegetables traditionally consumed by south-Asian migrants in Bradford, Yorkshire, UK. *Phytotherapy Research*, **2005**, **19(10)** 907-911.
46. Liao H, Liu H, Yuan K. A new flavonol glycoside from the *Abelmoschus esculentus* *Pharmagnosy Magazine* **2005**, **8** 12-5.

47. Tomoda M, Shimizu N, Gonda R. Isolation and characterisation of mucilage 'Okra Mucilage R' from the roots of *Abelmoschus esculentus*. *Chemical and Pharmaceutical Bulletin*, **1985**, **33(8)** 3330-3335.
48. Trinh HN, Nguyen NQ, Tran TVA, Nguyen VP. Hypolipidemic effect of extracts from *Abelmoschus esculentus* – Malvaceae on tyloxapol- induced hyperlipidemia in mice. *Mahidol University Journal of Pharmaceutical Science*, **2008**, **35(1-4)** 42-46.
49. Ngoc TH, Ngo QN, Van AT, Phung NV. Hypolipidemic effect of extracts from *Abelmoschus esculentus* (Malvaceae) on Tyloxapol-induced hyperlipidemia in mice. *WarasanPheatchasat*, **2008**, **35** 42-46.
50. Kahlon TS, Chapman MH, Smith GE. In vitro binding of bile acids by okra, beets, asparagus, eggplant, turnips, green beans, carrot and cauliflower. *Food Chemistry*, **2007**, **103** 676-80.
51. Uraku AJ, Ajah PM, Okak AN, Ibiam UA, Onu PN. Effects of crude extracts of *Abelmoschus esculentus* on albumin and total bilirubin of diabetic albino rats. *International Journal of Science and Nature*, **2010**, **1** 38-41.
52. Ramachandran S, Sandeep VS, Srinivas NK, Dhanaraju MD. Anti-diabetic activity of *Abelmoschus esculentus* on alloxan-induced diabetic rats. *Research & Reviews in BioSciences*, **2010**, **4**.
53. Sabitha V, Ramachandran S, Naveen KR, Panneerselvam K. Investigation of in vivo antioxidant property of *Abelmoschus esculentus* (L) moench. fruit seed and peel powders in streptozotocin-induced diabetic rats. *Journal of Ayurveda and Integrative Medicine*, **2012**, **3(4)** 188-93.
54. Sabitha V, Ramachandran S, Naveen KR, Panneerselvam K. Antidiabetic and antihyperlipidemic potential of *Abelmoschus esculentus* (L.) Moench. in streptozotocin-induced diabetic rats. *Journal of Pharmacy and Bioallied Sciences*, **2013**, **3(3)** 397-402.
55. Khatun H, Rahman A, Biswas M, Islam AU. Water-soluble Fraction of *Abelmoschus esculentus* Interacts with Glucose and Metformin Hydrochloride and Alters Their Absorption Kinetics after Coadministration in Rats. *ISRN Pharmaceutical* **2011**, 260537.
56. Thanakosai W, Phuwapraisirisan P. First identification of α -glucosidase inhibitors from okra (*Abelmoschus esculentus*) seeds. *Natural Product Communications*, **2013**, **8(8)** 1085-8.

57. Subrahmanyam GV, Sushma M, Alekya A, Neeraja CH, Harsha HS, Ravindra J. Antidiabetic activity of *Abelmoschus esculentus* fruit extract. *International Journal of Research in Pharmacy and Chemistry*, **2011**, **1** 17-20.
58. Fan S, Zhang Y, Sun Q, Yu L, Li M, Huang C. Extract of Okra lowers blood glucose and serum lipids in high-fat diet-induced obese C57BL/6 mice. *The Journal of Nutritional Biochemistry*, **2014**.
59. Lengsfeld C, Titgemeyer F, Faller G, Hensel A. Glycosylated compounds from okra inhibit adhesion of *Helicobacter pylori* to human gastric mucosa. *Journal of Agricultural Food Chemistry* **2004**, **52(6)** 1495-503.
60. Messing J, Thöle C, Niehues M, Shevtsova A, Glocker E, Hensel A. Antiadhesive properties of *Abelmoschus esculentus* (Okra) immature fruit extract against *Helicobacter pylori* adhesion. *PLoS One*, **2014**, **9(1)** e84836.
61. Kontogiorgosa V, Margeloua I, Georgiadis N, Ritzoulis C. Rheological characterization of Okra pectins. *Food Hydrocolloids*, **2012**, **29(2)** 356-362.
62. Alba K, Ritzoulis C, Georgiadis N, Kontogiorgos V. Okra extracts as emulsifiers for acidic emulsions. *Food Research International*, **2013**, **54(2)** 1730-1737.
63. Dimopoulou M, Ritzoulis M. Composite materials based on okra hydrocolloids and hydroxyapatite. *Food Hydrocolloids*, **2014**.
64. Laporte M, Valle D, Loisel C, Marze S, Riaublanc A, Montillet A. Rheological Properties of Food Foams Produced by SMX Static Mixers. *Food Hydrocolloids*. Article, **2014**.