We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,300

Open access books available

172,000

International authors and editors

190M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Phytochemical and Nutritional Studies in the Genus *Abelmoschus* Medik

Ashwini Venkatrao Mohite and Rajaram Vithoba Gurav

Abstract

Genus *Abelmoschus* Medik (family - Malvaceae Juss.) comprising about 11 species in India. Among which some are cultivated on an economic scale as important vegetables and the rest are wild. Apart from cultivated species, wild species of *Abelmoschus* also showed a wide range of phytochemicals and nutritional components. *Abelmoschus esculentus* (L.) Moench an economically important vegetable crop popularly known as okra which cultivated throughout the world. Nutritionally, okra plays an important role in the human diet because it has enormous value of nutritional factors like carbohydrates, protein, fibers, minerals and vitamins, including vitamin C. Mucilage obtained from *Abelmoschus* is natural and digestive in nature and used as a tablet binder. The plant shows various pharmacological activities like, antioxidants, antidiabetic, antiulcer and antimicrobial. Apart from cultivated species, the studies on wild species were carried out and concluded some important findings viz. *Abelmoschus manihot* (L.) Medik. is rich source of various secondary metabolites like; hyperin, isoquercetin, myricetin, hibifolin, adenosine and stigmasterol. *Abelmoschus ficulneus* (L.) Wight & Arn. and *A. manihot* are consumed by the local people worldwide. The present chapter is focused on the previous work done in genus *Abelmoschus* in the area of nutrition, phytochemical, genetic diversity and breeding.

Keywords: *Abelmoschus*, okra, phytochemical, nutritional, mucilage

1. Introduction

The word *Abelmoschus* has meaningful etymology Arabic language “Abu-al-misk”, means “Father of Musk and Kaab-el-misk means source of musk in reference with its musky odor of seeds [1, 2]. Genus is native to Africa, South and South East Asia and distributed throughout tropical and subtropical regions of the world with center of diversity at South Asia and South-West Pacific region [3–5]. Indian subcontinent has been considered as the center of diversity of the genus *Abelmoschus* due to the presence of wide morphological diversity. In India *Abelmoschus* species are found in the dense evergreen forests to open wastelands as well as cultivated in gardens and commercial farm. In addition, *Abelmoschus* species are also distributed in various regions from a range of Himalayan Mountain [6] to the Southern Peninsular India [7, 8]. About 11 species, 3 sub-species and

4 varieties of *Abelmoschus* are known in India [8]. Due to potential nutritional importance okra gain attention to improve nutrition and health status of mankind. Sabitha et al. demonstrated anti-diabetic activity through *in vitro* α -glucosidase and α -amylase enzyme inhibitory effect of aqueous extract of the okra peel and seeds and concluded that the consumption of okra may help to maintain blood sugar [9]. Due to widely use in the arena of food and medicine, the area under cultivation of *Abelmoschus* has progressively increased during last few years [10]. Besides that, *Abelmoschus* species are used for various other purposes like fiber yielding, paper making, waste water treatment, substitute for jute and used in the textile industries [11]. It is the rich reservoir of essential micronutrients for food fortification process e.g.; bread fortification. In this chapter, we have interpreted phyto-constituents from *Abelmoschus* species and their potential roles in human diet and pharmaceutical applications. Along with that we are also focused on qualitative and quantitative assessment of mucilage and its application in various fields. Further chapter revealed genetic diversity, plant breeding and mutation studies of various species of *Abelmoschus*.

2. Phytochemical analysis of genus *Abelmoschus*

During regular metabolic activities of plant some chemical compounds are formed known as phytochemicals. These chemicals are produced by plants for their defense mechanism, but many research studies reveals the numerous phytochemicals can be used against many diseases of humans. Phytochemicals are often referred as “secondary metabolites” which includes alkaloids, flavonoids, phenols, tannins, terpenoids, gums and polysaccharides [12]. Adetuyi et al. analyzed Vitamin C, total phenolic content, iron chelating activity and reducing power of six varieties of okra cultivated in Nigeria and proved that during storage period from 0 to 10 days, the loss of antioxidants percentage were lowest in “Benin” okra variety [13]. A variety of phytochemicals and antioxidants have been isolated from different *Abelmoschus* species. The list of phytochemicals isolated from *Abelmoschus* species are depicted in **Table 1**. *A. moschatus* solvent extract contains higher level of polyphenols and flavonoids which are responsible for antioxidant and other cumulative activities, so it can be used as food and medicine mainly to improve insulin sensitivity [19]. The four quercetin derivatives and epigallocatechin were first time reported in okra [14]. *A. esculentus* fruit is rich in phenolics and flavonoids may be serve as good source of natural antioxidants [15, 16]. Along with cultivated some wild species also rich in antioxidants [20].

2.1 Phytochemical analysis of *Abelmoschus* seeds

Abelmoschus seeds are the potential source of various nutrients as well as having immense biological properties; therefore some researchers focused their attention towards the examination of chemical composition and their use in the area of nutrition and medicines. Rao reported amino acids, fats, heat labile proteins, dietary fibers from seeds and kernels of okra variety “Pusa Swani” [21]. Sami et al. carried-out studies on analysis of fatty acids and amino acid from the fruit of *A. esculentus* collected from four localities by GC-MS and amino acid analyzer [22]. Camiciuc et al. carried out the GC-MS and NMR spectroscopic analysis of essential oil obtained from okra and ambrette seeds and subsequently reported the 40 and 35 bio-active compounds respectively [23, 24]. *A. moschatus* species is known for its aromatic compound and it has been used in Chinese traditional medicine to cure depression and anxiety. The effect of decoction has

Name of species	Plant part	Analytical techniques used	Solvent	Phytochemicals	Ref.
<i>A. esculentus</i> Cv. Benin, Auchi, Ikaro, Akure, Okeneand Lokoja	Fruit	Spectroscopy	Acetone, Methanol, Water	Vitamin C, total phenolic content, iron chelating activity and reducing power	[13]
<i>A. esculentus</i>	Fruit	HPLC and NMR	70% ethanol, hexane, methanol	ABTS, Quercetin 3-O-xylosyl (1 → 2) glucoside, quercetin 3-Oglucosyl (1 → 6) glucoside, quercetin 3-O-glucoside, quercetin3-O-(6-O-malonyl)-glucosideand epigallocatechin	[14]
<i>A. esculentus</i>	Fruit	—	Ethanol, Water	Carbohydrate, mucilage, protein, amino acids, fat and oil, flavonoids, phenolic compounds, tannins, saponins, phytosterols, alkaloid, glycoside, hypoglycemic activity	[11]
<i>A. esculentus</i> (25 accessions)	Fruit	Spectroscopy	Distilled water	Total phenolics, flavonoids and antioxidant contents	[15]
<i>A. esculentus</i> (7 accessions)	Fruit	Spectroscopy	Methanol	Total phenolics, flavonoids	[16]
<i>A. manihot</i>	Flower	HPLC	Ethanol, Methanol	Hyperin, isoquercetin, hibifolin, myricetin, quercetin-3'-O-glucoside, and quercetin	[17]
<i>A. manihot</i>	Leaf	Spectroscopy and FTIR	Ethanol	Flavonoid and DPPH	[18]
<i>A. moschatus</i>	Fruit	—	70% Ethanol	Total phenolic, total flavonoids	[19]
<i>A. esculentus</i> , <i>A. esculentus</i> cv. Phule Utkarsha <i>A. ficulneus</i> , <i>A. manihot</i>	Fruit	Spectroscopy	Ethanol, Methanol, Distilled water	Total phenolic, total flavonoids, DPPH and FRAP	[20]

Table 1.
Phytoconstituents from Abelmoschus taxa.

been reported to exhibit hypotensive properties [25]. The volatile compounds identified from *A. moschatus* seeds having an odor similar to the musk therefore used in perfume and cosmetics formulations [26]. In addition, the cultivated as well as wild species of *Abelmoschus* were also used to study seed oil and fatty acid content using GC-MS and structural analysis using TD-NMR [27]. Thirty five compounds were identified using GC-MS along with their antibacterial properties were reported from ambrette seed oil [28].

2.2 Importance of mucilage in *Abelmoschus*

Mucilage is the water soluble polysaccharides found in various plant systems and in some microorganisms [29]. In present days, there is an immense interest have been seen in studying the mucilaginous compounds due to their viscosity and pharmaceutical applications like, excipient, tablet binder, thickeners in oral liquids, gelling agents, purifiers, protective colloids in suspension gum substitute and effluents in rheological engineering [30]. Most of the species from family Malvaceae are well-known for their mucilage content and it was studied by Ahmad et al. for their properties [31]. The whole plant of *Abelmoschus* species harbor considerable quantity of mucilage, associate mucilage is an acidic polysaccharide composed of galacturonic acid, rhamnose, and glucose with the ratio of 1.3:1.0:0.1, respectively [32]. Okra mucilage contains a significant amount of carbohydrate, neutral sugars, minerals and other complex polysaccharides [33] which medically confirmed that mucilage is associated with antimicrobial, antiulcer, hypoglycemic and anticancer activities [26].

Mucilage isolated from immature fruits and roots of okra showed significant anti-complementary activity and extensive hypoglycemic activities because root mucilage possesses side chains composed of D-galactopyranose residues and L-rhamnopyranosyl residues in the part of the backbone [34]. Okra mucilage was described as water soluble polysaccharide based material which can be further modified by grafting acrylamide for the synthesis of green polymeric material and it was issued as the biomaterial for waste water treatment as an environment cleaning approach [35]. Nair and Fasha analyzed mucilage of *A. esculentus* and *A. moschatus* and recommended for their used in preparation of pharmaceutical suspensions [36]. Apart from the environment cleaning and medicinal values, there are various applications discussed, okra mucilage can be utilized for pharmaceutical adjuvant, emulsifying agent [37] excipients and binding agent for the formulation of pharmaceutical dosage using Ibuprofen and Paracetamol tablet [38]. It is also used to prepare polyelectrolyte complex with the help of chitosan and used as coating material [39]. Okra mucilage is also used as the suspending agent and pharmaceutical excipients [40, 41]. Mucoadhesive gel was prepared from okra fruit mucilage and used for nasal drug delivery [42].

Abelmoschus stem and *Hibiscus* leaves mucilage was used to analyze the nutritive values such as moisture, fat, fiber, protein, carbohydrate, and energy value and further same mucilage powder was used to prepare idli, upma and roti and evaluate for consumer acceptability and nutritive values. These products have great acceptableness in terms of texture, color, taste and flavor [43]. Okra mucilage can be potentially utilized as the blending mediator in a food emulsion system [44] and having biodegradable and non-toxic coagulant property [45]. Apart from these it is natural source for edible film production [46] and has excellent potential in food packaging [47].

3. Nutritional potential of genus *Abelmoschus*

Production of nutritionally rich food is the major challenge in the fulfillment of healthy diet against tremendous explosion of population. Throughout the year, numerous vegetables have been basically examined for their nutritional parameters. Nutritionally, okra plays an important role in the human diet because it contains carbohydrates, protein, fibers, minerals and vitamins, including vitamin C which will fulfill dietary requirements of the body [27]. Some nutritional parameters with their quantity were depicted in **Table 2**.

Species name	Plant part used	Nutritional parameter	Quantity	Ref.
<i>A. esculentus</i> , <i>A. esculentus</i> cv. Phule Utkarsha <i>A. ficulneus</i> , <i>A. manihot</i>	Fruit	Proximate (Moisture, fat, ash, fiber, protein, carbohydrate)	2.52–48.47 g/100 g	[20]
		Mineral Composition (B, Ca, Cu, Fe, Mg, Mn, Mo, N, P, K, Na, S, Zn)	0.0005–3.51 g/100 g	
<i>A. esculentus</i> (6 varieties)	Fruit	Moisture	88.02–90.13%	[48]
		Protein	13.61–16.27%	
		Fiber	10.15–11.63%	
		Fat	9.03–10.57%	
		Ash	7.19–9.63%	
		Mineral (Zn, Fe, Mg, Cl and K)	0.87–62.17 mg/100 g	
<i>A. esculentus</i> (22 accessions)	Fruits	Macro elements (Ca, Cl, K, Mg and Na)	32.06–319 mg/kg	[49]
		Micro elements (Al, Cu and Mn)	17.8–42.45 mg/kg	
		Trace elements (As and Br)	2.84–34.41 mg/kg	
<i>A. esculentus</i> (4 accessions)	Fruits	Water soluble vitamins (B3, B6, B12, C)	1.42–91.20 µg/100 g	[50]
		Fat soluble vitamins (E, K3)	0.05–1.47 µg/100 g	
<i>A. esculentus</i> (8 accessions)	Fruit	Moisture	9.69–13.33 g/100 g	[51]
		Crud protein	10.25–26.16 g/100 g	
		Ash	5.62–11.30 g/100 g	
		Crude fiber	11.97–29.93 g/100 g	
		Crude fat	0.56–1.69 g/100 g	
		Carbohydrate	36.66–50.97 g/100 g	
		Mineral (Ca, Fe, K, Zn, P, Na)	3.33–318.20 mg/100 g	
<i>A. manihot</i> (23 accessions)	Leaves	Mineral composition (Cl, Fe, Mg, Mn, K, Na, Zn and Cu)	0.8–635 mg/100 g	[52]

Table 2.
Nutritional potential of Abelmoschus taxa.

Sun dried okra fruits were examined for the nutritional parameters like moisture, ash, crude fat, fiber, carbohydrate, protein and microbial composition. Dried okra with light deep green and light purple colored had highest carbohydrate (76.8%) and crude protein (23.2%) [53]. Effect of different processes like cooking, sun drying of okra fruit caused effects on proximate composition and some other parameters like loss of vitamin C and nutritional factor [54]. Fruits of cultivated as well as wild taxa are the rich in, proximate and mineral composition. The highest fiber content i.e. 23.49 and 22.90% were isolated from the wild species *A. ficulneus* and *A. manihot* respectively [20].

4. Genetic diversity study in *Abelmoschus*

The accessibility of the genetic diversity and its collection, maintenance and conservation is essential for the crop improvement program [55]. *Abelmoschus* is an important genus in terms of nutrition, pharmaceuticals point of view, due to it has high industrial and economic importance. Despite that very slight attention has been paid to assess genetic diversity of *Abelmoschus* species at molecular level. The conservation and distribution of the germplasm genetic diversity of *Abelmoschus* species has been studied with the various DNA markers. Techniques based on the genetic material such as Random Amplified Polymorphic DNA (RAPD) have been employed to assess the genetic diversity in the five species of *Abelmoschus* [56]. Similarly Martinello et al. also successfully employed RAPD marker to study of genetic diversity within 42 accessions of *Abelmoschus* species. The study revealed existence of the most important genetic heterogeneity in the tested germplasm [57]. RAPD makers were applied over the okra accessions which lead to 96% polymorphism [58] along with the phenotypic markers [59, 60]. Sequence related amplified polymorphism (SRAP) and phenotypic markers determined the genetic diversity of Turkish okra. These markers showed 50% polymorphism among the studied germplasm and useful for studying diversity and relationships among them and have potential marker aided selection, linkage mapping and evolutionary studies [61]. Cross species Simple sequence repeats (SSR) primers were used to study genetic diversity of 20 [62], 65 [63] and 24 [64] different accessions of okra by different scientists. SSR markers help to discrimination among okra accessions and provide vital information for use in the improvement of genomic resource in vegetable crop [64]. AFLP markers were separated the Greek landraces from other significant pool of variation [65]. Inter simple sequence repeat (ISSR) markers and morphological markers were effectively used to study 28 genotypes of West African okra [66].

5. Breeding studies

5.1 Mutation breeding in *Abelmoschus*

Induction of the mutation in plant breeding has become a well-known and important tool to supplement current germplasm and improvement of cultivars for the expression of specific traits. Several improved crop varieties have been released to farmers shows great economic value of the technology of mutation breeding [67]. From the past 70 years, near about 2252 mutant varieties from 175 crop plants including cereals, pulses, oilseeds, fibers, fruits, vegetables and ornamentals have been released in different countries throughout the world [68]. Induced mutations using different chemical and physical mutagens were studied by many breeders in *Abelmoschus*. Induction of mutation with the help of gamma radiations, ethyl methane sulphonate and diethyl sulphate in *Abelmoschus esculentus* cv. PusaSawani was reported [69] and 35 true breeding mutants were isolated [70]. The physical mutagen, Gamma radiations with different doses were useful to induced mutations for the screening of yellow vein mosaic disease resistant [71] and to develop agro-nomical and yield characters in okra [72–76]. Ethyl methane sulphonate was greatly affected most of the agronomic and yield characters in M₂ generation [77].

5.2 Crossability study among different species of *Abelmoschus*

Interspecific hybridization plays a vital role in the increasing genetic variation by interchanging genetic information in between different species, which is helpful

to solve taxonomic relationship and also useful in preparation of genetic linkage map [78]. However artificial crossing methods are easy and simple in *Abelmoschus* but the rate of success is still an important constraint in the interspecific hybridization. Earlier reports revealed that crossing between cultivated species and wild species of *Abelmoschus* is more difficult. The breeding possibilities among the four species and one variety of *Abelmoschus* were studied [79] by Pal et al. The sterile hybrid obtained from the cross between *Abelmoschus esculentus* ($2n = 130$) and *A. tetraphyllus* ($2n = 138$) [80], partially fertile and resistant to yellow vein mosaic (YVM) virus was obtained from crossed between *A. manihot* and *A. manihot* ssp., *manihot* with the cultivated okra, *A. esculentus* cv. “PusaSawani” [81]. The interspecific crosses seems to be a major cause of variation perceived in cultivated species that are, *A. esculentus*, *A. manihot* and *A. moschatus* [82]. During reciprocal crosses between *A. caillei* and *A. tetraphyllus* 69–76 meiotic bivalents were obtained in F_1 hybrids [83]. The pollen germination and pollen tube growth behaviour with respect to seed set between four species of *Abelmoschus* revealed that, *A. caillei* may be served as potential connection parent for the transfer of alien gene for the okra breeding programmes [84].

6. Conclusion

Abelmoschus is an economically important genus which is distributed worldwide. Along with the cultivated species, some of wild species are traditionally used to cure many disorders. *A. manihot* is rich source of phytochemicals and antioxidant activities. *A. moschatus* has great number of phytoconstituents and contains aromatic compounds in its seeds which are utilized in perfume industries. *Abelmoschus* species contains mucilage which has several food and medicinal applications. It is useful in cleaning the sugar cane juice in jaggery preparation. Isolation and identification of many compounds from wild species proved to have diverse medicinal properties along with extraordinary nutritional potential. A large number of intervarietal combinations have been studied, but not much progress has been made in the improvement of this genus. As a rich source of phytochemicals and nutrition, wild species of *Abelmoschus* offers opportunities for the development as a substitute for cultivated species as a vegetable.

Author details

Ashwini Venkatrao Mohite and Rajaram Vithoba Gurav*
Department of Botany, Shivaji University, Kolhapur, Maharashtra, India

*Address all correspondence to: botanyraj@rediffmail.com

IntechOpen

© 2020 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

- [1] Don G. General History of the Dichlamydeous Plants. Vol. 1. London: Malvaceae; 1831. pp. 430-505
- [2] Quattrocchi U. CRC World Dictionary of Plant Names: Common Names, Scientific Names, Eponyms, Synonyms, and Etymology. Boca Raton: CRC Press; 2000
- [3] Borssum Waalkes JV. Malesian Malvaceae revised. Blumea. 1966;14:89-105
- [4] Vredereg JH. Taxonomic and ecological observations on species of *Abelmoschus* Medik. In: Report of an International Workshop on Okra Genetic Resources Held at NBPGR. New Delhi, India; 1991, 8-12 October 1990. pp. 60-76
- [5] Bisht IS, Bhat KV. Okra (*Abelmoschus* ssp.). In: Singh RJ, editor. Genetic Resources, Chromosome Engineering, and Crop Improvement: Vegetable Crops. Vol. 3. New York: CRC Press; 2006. pp. 147-184
- [6] Negi KS, Pant KC. Wild species of *Abelmoschus* Medik. (Malvaceae) from central Himalayan regions of India. Journal of the Bombay Natural History Society. 1998;95:148-150
- [7] Sivarajan VV, Pradeep AK. Malvaceae of Southern Peninsular India. Delhi, India: Daya Pub. House; 1996. pp. 1-73
- [8] Sutar S, Patil P, Aitawade M, John J, Malik S, Rao S, et al. A new species of *Abelmoschus* Medik. (Malvaceae) from Chhattisgarh, India. Genetic Resources and Crop Evolution. 2013;60:1953-1958
- [9] Sabitha V, Panneerselvam K, Ramachandran S. In vitro α -glucosidase and α -amylase enzyme inhibitory effects in aqueous extracts of *Abelmoschus esculentus* (L.) Moench. Asian Pacific Journal of Tropical Biomedicine. 2012;2(1):S162-S164
- [10] Anonymous. Fruits, Vegetable and Condiments Statistics 2006-07. Islamabad, Pakistan: MINFAL; 2008
- [11] Saha D, Jain B, Jain VK. Phytochemical evaluation and characterization of hypoglycemic activity of various extracts of *Abelmoschus esculentus* Linn. Fruit. International Journal of Pharmacy and Pharmaceutical Sciences. 2011;3(2):183-185
- [12] Harborne JB. Phytochemical Methods. London: Chapman and all, Ltd; 1973. pp. 49-188
- [13] Adetuyi FO, Osagie AU, Adekunle AT. Antioxidant degradation in six indigenous okra *Abelmoschus esculentus* (L) Moench varieties during storage in Nigeria. Journal of Food Technology. 2008;6(5):227-230
- [14] Shui G, Peng LL. An improved method for the analysis of major antioxidants of *Hibiscus esculentus* Linn. Journal of Chromatography A. 2004;1048:17-24
- [15] Ahiakpa JK, Quartey EK, Amoatey HM, Klu GYP, Achel DG, Achoribo E, et al. Total flavonoid, phenolic contents and antioxidant scavenging activity in 25 accessions of okra (*Abelmoschus* spp L.). African Journal of Food Science and Technology. 2013;4(5):129-135
- [16] Mohammed MI, Bayero AS, Shettima UI. Levels of total phenolic and flavonoids in *Abelmoschus esculentus* L. from some irrigation areas of Kano state- Nigeria. Bayero Journal of Pure and Applied Sciences. 2016;9(2):121-124
- [17] Lai X, Liang H, Zhao Y, Wang B. Simultaneous determination of seven active flavonols in the flower of *Abelmoschus manihot* HPLC. Journal

of Chromatographic Science.
 2009;**47**:206-210

[18] Sudewi S, Lolo WA, Warongan M, Refai Y, Rante H. The ability of *A. manihot* L. leaf extract in scavenging of free radical DPPH and total flavonoid determination. IOP conf. Series. Materials Science and Engineering. 2017;**259**:12-20

[19] Liu IM, Tzeng TF, Liou SS. *Abelmoschus moschatus* (Malvaceae), an aromatic plant, suitable for medical or food uses to improve insulin sensitivity. Phytotherapy Research. 2010;**24**:233-239

[20] Mohite AV, Gurav RV. Nutraceutical and antioxidant evaluation of *Abelmoschus* taxa. International Journal of Vegetable Science. 2019;**25**(6):610-618

[21] Rao PU. Chemical composition and biological evaluation of okra (*Hibiscus esculentus*) seeds and their kernels. Plant Foods for Human Nutrition. 1985;**35**:389-396

[22] Sami R, Lianzhou J, Yang L, Ma Y, Jing J. Evaluation of fatty acid and amino acid compositions in okra (*Abelmoschus esculentus*) grown in different geographical locations. BioMed Research International. 2013;**2013**:1-6

[23] Camciuc M, Vilarem G, Gaset A. Volatile constituents of the seed teguments of *Abelmoschus esculentus* (L.) Moench. Journal of Essential Oil Research. 1999;**11**:545-552

[24] Dung NX, Khien PV, Nhuan DD, Hoi TM, Ban NK, Leclercq PA, et al. Composition of the seed oil of *Hibiscus abelmoschus* L. (Malvaceae) growing in Vietnam. Journal of Essential Oil Research. 1999;**11**(4):447-452

[25] Bown D. Encyclopaedia of Herbs and Their Uses. London: Dorling Kindersley; 1995

[26] Pieroni A, Ansari NM. Antioxidant activity of five vegetables traditionally consumed by South Asian migrants in Bradford, Yorkshire, UK. Phytotherapy Research. 2005;**19**:907-911

[27] Jarret RL, Wang ML, Levy IJ. Seed oil and fatty acid content in okra (*Abelmoschus esculentus*) and related species. Journal of Agricultural and Food Chemistry. 2011;**59**:4019-4024

[28] Arokiyaraj A, Choi SH, Lee Y, Bharanidharan R, Islam V, Vijaykumar B, et al. Characterization of ambrette seed oil and its mode of action in bacteria. Molecules. 2015;**20**:384-395

[29] Woolfe ML, Chaplin MF, Otchere G. Studies on mucilages extracted from okra fruits (*Hibiscus esculentus* L.) and baobab leaves (*Adansonia digitata* L.). Journal of the Science of Food and Agriculture. 1977;**28**:519-529

[30] Tomoda M, Shimizu N, Oshima Y, Takahashi M, Murakami M, Hikino H. Hypoglycemic activity of twenty plant mucilages and three modified products. Planta Medica. 1987;**53**:8-12

[31] Ahmad MA, Bari HAA, Yunus RM. Studying the effect addition of okra-natural mucilage as drag reducing agent in different size of pipes in turbulent water flowing system. In: National Conference on Postgraduate Research (NCON-PGR), 1st October 2009. Malaysia: UMP Conference Hall, Centre for Graduate Studies, Universiti Malaysia Pahang; 2009. pp. 128-133

[32] Sengkhampan N, Verhoef R, Schols HA, Sajjaanantakul T, Voragen AGJ. Characterisation of cell wall polysaccharides from okra (*Abelmoschus esculentus* (L.) Moench). Carbohydrate Research. 2009;**344**(14):1824-1832

[33] Ndjouenkeu R, Goycoolea FM, Morris ER, Akingbala JO. Rheology of okra (*Hibiscus esculentus* L.)

- and dika nut (*Irvingia gabonensis*) polysaccharides. Carbohydrate Polymers. 1996;**29**:263-269
- [34] Tomoda M, Shimizu N, Gonda R, Kanari M. Anticompementary and hypoglycemic activity of okra and hibiscus mucilages. Carbohydrate Research. 1989;**190**:323-328
- [35] Mishra A, Clark JH, Pal S. Modification of okra mucilage with acrylamide: Synthesis, characterization and swelling behaviour. Carbohydrate Polymers. 2008;**72**:608-615
- [36] Nair BR, Fasha KS. Isolation and characterization of mucilage from some selected species of *Abelmoschus* Medik. (Malvaceae) and their application in pharmaceutical suspension preparation. International Journal of Pharmacy and Pharmaceutical Sciences. 2013;**5**(1):398-402
- [37] Gangurde AB. Preliminary characterization of *Abelmoschus esculentus* (L.) pod mucilage as o/w type emulsifier. International Journal of advances in Pharmacy, Biology and Chemistry. 2012;**1**(1):30-41
- [38] Patel VI, Patel HA, Jani M, Shah A, Kumar S, Patel JA. Formulation and evaluation of okra fruit mucilage as a binder in Paracetamol and ibuprofen tablet. International Journal for Pharmaceutical Research Scholars. 2012;**1**(4):156-161
- [39] Rajendra A, Bushetti SS, Giri A. Design and evaluation of compression coated formulations for an anti-inflammatory drug based on modified okra mucilage. Journal of Applied Pharmaceutical Science. 2012;**2**(7):238-245
- [40] Jayan SC, Manoj NK. Isolation and evaluation of mucilage of *Abelmoschus esculentus* as a suspending agent. International Journal of Pharmaceutical Sciences and Chemistry. 2013;**2**(3):1311-1315
- [41] Farooq U, Malviya R, Sharma PK. Extraction and characterization of okra mucilage as pharmaceutical excipient. Academic Journal of Plant Sciences. 2013;**6**(4):168-172
- [42] Sharma N, Kulkarni GT, Sharma A. Development of *Abelmoschus esculentus* (okra) based mucoadhesive gel for nasal delivery of Rizatriptan benzoate. Tropical Journal of Pharmaceutical Research. 2013;**12**(2):149-153
- [43] Nazni P, Vigneshwar P. Study on extraction and organoleptic evaluation of okra and hibiscus mucilage incorporated products. International Journal of Food and Nutritional Sciences. 2014;**3**(1):99-103
- [44] Noorlaila A, Siti AA, Asmeda R, Norizzah AR. Emulsifying properties of extracted okra (*Abelmoschus esculentus* L.) mucilage of different maturity index and its application in coconut milk emulsion. International Food Research Journal. 2015;**22**(2):782-787
- [45] Freitas TKFS, Oliveira VM, de Souza MTF, Geraldino HCL, Almeida VC, Favaro SL, et al. Optimization of coagulation-flocculation process for treatment of industrial textile waste water using okra (*A. esculentus*) mucilage as natural coagulant. Industrial Crops and Products. 2015;**76**:538-544
- [46] de Cotrim MAP, Mottin AC, Ayres E. Preparation and characterization of okra mucilage (*Abelmoschus esculentus*) edible films. Macromolecular Symposia. 2016;**367**:90-100
- [47] Araujo A, Galvão A, Filho CS, Mendes F, Oliveira M, Barbosa F, et al. Okra mucilage and corn starch bio-based film to be applied in food. Polymer Testing. 2018;**71**:352-361

- [48] Adetuyi F. O., Osagie A.U. and Adekunle (2011) Nutrient, antinutrient, mineral and zinc bioavailability of okra *Abelmoschus esculentus* (L) Moench variety. American Journal of Food and Nutrition, 1(2): 49-54.
- [49] Ahiakpa JK, Amoatey HM, Amenorpe G, Apatey J, Ayeh EA, Quartey EK, et al. Mucilage content of 21 accessions of okra (*Abelmoschus* spp L.). Scientia. 2014;2(2):96-101
- [50] Sami R, Li Y, Qi B, Wang S, Zhang Q, Han F, et al. HPLC analysis of water-soluble vitamins (B2, B3, B6, B12 and C) and fat-soluble vitamins (E, K, D, A, and β -carotene) of okra (*Abelmoschus esculentus*). Journal of Chemistry. 2014;2014:1-6
- [51] Gemedede HF, Haki GD, Beyene F, Woldegiorgis AZ, Rakshit SK. Proximate, mineral, and antinutrient compositions of indigenous okra (*Abelmoschus esculentus*) pod accessions: Implications for mineral bioavailability. Food Science & Nutrition. 2015;4(2):223-233
- [52] Yalambing L, Arcot J, Greenfield H, Holford P. Aibika (*Abelmoschus manihot* L.): Genetic variation, morphology and relationships to micronutrient composition. Food Chemistry. 2014;193:62-68
- [53] Kolawole OM, Ajiboye AE, Aturu EE, Anibijuwon II. Effect of solar drying on the proximate and microbial composition of *Abelmoschus esculentus*. Journal of Microbiology and Biotechnology Research. 2011;1(1):71-81
- [54] Tsado EK. Effect of method of drying okra fruits (*Abelmoschus esculentus*) on proximate composition of the dried product. Donnish Journal of Agricultural Research. 2015;2(8):66-70
- [55] Poehlman JM, Sleper DA. Breeding Field Crops. 4th ed. Ames, Iowa, United States: Iowa State Press; 1995. pp. 75-76
- [56] Bhat KV, Bisht IS, Mahajan RK, Rana RS. Analysis of the genetic relationship among *Abelmoschus* species using isozyme and RAPD markers. In: Abstract of Paper Presented in 2nd International Crop Science Congress. New Delhi, India; 1996. pp. 17-24
- [57] Martinello GE, Leal NR, Amaral AT, Pereira MG, Daher RF. Genetic diversity in okra using RAPD markers. Horticultura Brasileira. 2003;21(1):20-25
- [58] Haq I, Khan AA, Azmat MA. Assessment of genetic diversity in okra (*Abelmoschus esculentus* L.) using RAPD markers. Pakistan Journal of Agricultural Sciences. 2013;50(4):655-662
- [59] Singh D, Dudi BS, Dhankhar SK, Rajkumar. Genetic diversity analysis of okra genotypes using morphological markers. International Journal of Current Microbiology and Applied Sciences. 2018;7(1):1667-1675
- [60] Patel JS, Japda AR, Dhruve JJ. Assessment of genetic diversity of okra (*Abelmoschus esculentus* L.) for YVMV using RAPD and SSR markers. International Journal of Advanced Biological and Biomedical Research. 2018;8(2):2250-3579
- [61] Gulsen O, Karagul S, Abak K. Diversity and relationships among Turkish okra germplasm by SRAP and phenotypic markers polymorphism. Biologia. 2007;62(1):41-45
- [62] Sawadogo M, Ouedraogo JT, Balma D, Ouedraogo M, Gowda BS, Botanga C, et al. The use of cross species SSR primers to study genetic diversity of okra from Burkina Faso. African Journal of Biotechnology. 2009;8(11):2476-2482

- [63] Schafleitner R, Kumar S, Lin C, Hegde SG, Ebert A. The okra (*Abelmoschus esculentus*) transcriptome as a source for gene sequence information and molecular markers for diversity analysis. *Gene*. 2013;**517**:27-36
- [64] Fougat RS, Purohit AR, Kumar S, Parekh MJ, Kumar M. SSR based genetic diversity in *Abelmoschus* species. *Indian Journal of Agricultural Sciences*. 2015;**85**(9):99-104
- [65] Kyriakopoulou OG, Arens P, Pelgrom KTB, Karapanos I, Bebeli P, Passam HC. Genetic and morphological diversity of okra [*Abelmoschus esculentus* (L.) Moench] genotypes and their possible relationships, with particular reference to Greek landraces. *Scientia Horticulturae*. 2014;**171**:58-70
- [66] Ahiakpa JK, Magdy M, Werner O, Amoatey HM, Yeboah MA, Appiah AS, et al. Intra- specific variation in West African and Asian germplasm of okra (*Abelmoschus* spp. L.). *Annals of Agricultural Science*. 2017;**62**(2):131-138
- [67] Micke A, Donini B, Maluszynski M. Induced mutations for crop improvement. *Mutation Breeding Review*. 1990;**7**:1-44
- [68] Maluszynski M, Nichterlein K, Zanten LV, Ahloowalia BS. Officially released mutant varieties- the FAO/ IAEA database. *Mutation Breeding Review*. 2000;**12**:1-84
- [69] Yashvir. Induced quantitative mutations in okra (*Abelmoschus esculentus* Moench). *Proceedings of the Indiana Academy of Sciences*. 1975;**81**(4):181-185
- [70] Abraham V. Inheritance of ten induced mutants in okra (*Abelmoschus esculentus* (Linn) Moench). *Current Science*. 1982;**54**(18):931-935
- [71] Phadvibulya V, Boonsirichai K, Adthalungrong A, Srithongchai W. Selection for resistance to yellow vein mosaic virus disease of okra by induced mutation. In: Shu QY, editor. *Induced Plant Mutations in the Genomics Era*. Plant Breeding Section, Joint FAO/ IAEA Division of Nuclear Techniques in Food and, International Atomic Energy Agency. Vienna, Austria, Rome: Food and Agriculture Organization of the United Nation; 2009. pp. 349-351
- [72] Hegazi AZ, Hamideldin N. The effect of gamma irradiation on enhancement of growth and seed yield of okra [*Abelmoschus esculentus* (L.) Moench] and associated molecular changes. *Journal of Horticulture Science and Forestry*. 2010;**2**(3):38-51
- [73] Warghat AR, Rampure NH, Wagh P. Effect of sodium azide and gamma rays treatment on percent germination, survival, morphological variation and chlorophyll mutation in musk okra (*Abelmoschus moschatus* L.). *International Journal of Pharmacy and Pharmaceutical Sciences*. 2011;**3**(5):483-486
- [74] Ullah H, Khan RU, Khan SU, Mehmood S, Sherwani SK, Muhammad A, et al. Estimation of induced variability of yield contributing traits in M1 gamma irradiation germplasm of okra (*Abelmoschus esculentus* L.). *South Asian Journal of Life Sciences*. 2013;**2**(1):4-7
- [75] Amir K, Hussain S, Shuaib M, Hussain F, Urooj Z, Khan WM, et al. Effect of gamma irradiation on okra (*Abelmoschus esculentus* L.). *Acta Ecologica Sinica*. 2018;**38**(5):368-373
- [76] Mohite AV, Gurav RV. Induced mutation using gamma rays in okra (*Abelmoschus esculentus* (L.) Moench). *Journal of Applied Horticulture*. 2019;**21**(3):205-208

[77] Baghery MA, Kazemitabar SK.
Effect of EMS induction on
some morphological traits of
okra (*Abelmoschus esculentus* L).
International Journal of Biosciences.
2015;**6**(2):216-221

[78] Kaga A, Ishii T, Tsukimoto K,
Tokoro E, Kamijima O. Comparative
molecular mapping in *Ceratotropis*
species using an interspecific cross
between *Vignaumbellate* and *V.*
angularis. Theoretical and Applied
Genetics. 2000;**100**:207-213

[79] Pal BP, Singh HB, Swarup V.
Taxonomic relationships and breeding
possibilities of species of *Abelmoschus*
related to okra (*A. esculentus*). Botanical
Gazette. 1952;**113**:455-464

[80] Mamidwar RB, Nerkar YS,
Jambhale ND. Cytogenetics of
interspecific hybrids in the genus
Abelmoschus. Indian Journal of Heredity.
1979;**11**:35-39

[81] Jambhale ND, Nerkar YS.
Inheritance of resistance to okra yellow
vein mosaic disease in interspecific
crosses of *Abelmoschus*. Theoretical and
Applied Genetics. 1981;**60**:313-316

[82] Siemonsma JS. West African
okra- morphology and cytogenetical
indications for the existence of a natural
amphidiploid of *Abelmoschus esculentus*
(L.) Moench and *A. manihot* (L.)
Medikus. Euphytica. 1982;**31**:241-252

[83] Kondaiah GM, Kulkarni UG,
Nerkar YS. The evolution of West Africa
cultivated "Guinean" okra: Further
evidence. Journal Of Maharashtra
Agricultural Universities. 1990;**15**:65-68

[84] Patil P, Malik SK, Negi KS,
John J, Yadav S, Chaudhari G, et al.
Pollen germination characteristics,
pollen-pistil interaction and
reproductive behaviour in interspecific
crosses among *Abelmoschus esculentus*
Moench and its wild relatives. Grana.
2013;**52**(1):1-14