Chapter

Phytochemical and Nutritional Studies in the Genus *Abelmoschus* Medik

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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

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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.
A. esculentus Cv. Benin, Auchi, Ikaro, Akure, Okeneand Lokoja	Fruit	Spectroscopy	Acetone, Methanol, Water	Vitamin C, total phenolic content, iron chelating activity and reducing power	[13]
A. esculentus	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]
A. esculentus	Fruit	—	Ethanol, Water	Carbohydrate, mucilage, protein, amino acids, fat and oil, flavonoids, phenolic compounds, tannins, saponins, phytosterols, alkaloid, glycoside, hypoglycemic activity	[11]
A. esculentus (25 accessions)	Fruit	Spectroscopy	Distilled water	Total phenolics, flavonoids and antioxidant contents	[15]
A. esculentus (7 accessions)	Fruit	Spectroscopy	Methanol	Total phenolics, flavonoids	[16]
A. manihot	Flower	HPLC	Ethanol, Methanol	Hyperin, isoquercetin, hibifolin, myricetin, quercetin-3'-O-glucoside, and quercetin	[17]
A. manihot	Leaf	Spectroscopy and FTIR	Ethanol	Flavonoid and DPPH	[18]
A. moschatus	Fruit	—	70% Ethanol	Total phenolic, total flavonoids	[19]
A. esculentus, A. esculentus cv. Phule Utkarsha *A. ficulneus, A. manihot*	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.
A. esculentus, A. esculentus cv. Phule Utkarsha *A. ficulneus, A. manihot*	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	
A. esculentus (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	
A. esculentus (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	
A. esculentus (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	
A. esculentus (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	
A. manihot (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 agronomical and yield characters in okra [72–76]. Ethyl methane sulphonate was greatly affected most of the agronomic and yield characters in M_2 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.

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