

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

6,900

Open access books available

186,000

International authors and editors

200M

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 Composition: Antioxidant Potential and Biological Activities of Corn

Haq Nawaz, Saima Muzaffar, Momna Aslam and Shakeel Ahmad

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/intechopen.79648>

Abstract

Corn seeds are used as a nutritional source for humans, and the stem and leaves are utilized as fodder for cattle throughout the world. Corn silk and corn cob are usually discarded as waste. This chapter highlights the nutritional as well as medicinal importance of various parts of corn plant. All parts of corn plant are good source of a variety of bioactive phytochemical compounds which possess antioxidant potential. The principal phytochemicals present in corn seed and corn silk include polyphenols, phenolic acids, flavonoids, anthocyanins, glycosides, carotenoids, and polysaccharides of biological importance, reducing compounds and some water-soluble vitamins. The presence of these phytochemicals makes corn a medicinal plant which shows various biological activities particularly the antioxidant, antimicrobial, antidiabetic, anti-obesity, antiproliferative, hepatoprotective, cardioprotective, and renal-protective activities. On the account of its high antioxidant potential, all parts of corn plant can be used for the management of oxidative stress and the treatment of various diseases.

Keywords: corn, *Zea mays*, maize, phytochemical composition, antioxidant potential, biological activities

1. Introduction

Corn (*Zea mays* L.), which belongs to the family Poaceae (Gramineae), is the principle cereal crop around the world following wheat and rice. Its annual production reaches almost 780 million metric tons, of which the larger producers are the USA, China, Brazil, and India. It is an annual herbaceous plant having 2–20 feet high stalk. The genus *Zea* comprises five species

Z. diploperennis, *Z. luxurians*, *Z. nicaraguensis*, *Z. perennis*, and *Z. mays*. *Zea mays* is the only cultivated species, while others are wild grasses [1–4].

The corn plant is classified as:

Kingdom	Plantae
Family	Poaceae
Subfamily	Panicoideae
Genus	<i>Zea</i>
Species	<i>mays</i>
Synonyms	Maize, corn, mealie

Various parts of corn such as grains, leaves, corn silk, stalk, and inflorescence are commonly used as food for humans, feedstuff for animals, fuel for small industries, and potential ingredient of homemade remedies [3, 5]. Corn seeds are served as food in Asian countries including China, Korea, Taiwan, Vietnam, Laos, Myanmar, Thailand, India, and Pakistan [6]. The unripe seeds of sweet corn are eaten raw or cooked, while the mature seeds are dried and ground to make flour that is used in various food preparations. The major products of wet and dry milling of corn seeds are used to make breakfast cereals, snacks, and tortillas, while the coproducts are used as animal feed. The maize flour has been found to enhance the nutritional and functional quality of food materials when used in the form of blend with other cereal flours [7, 8]. Corn kernel is also used to obtain ethanol as a fuel [9]. Oil obtained from seeds is edible and is used in the preparation of various food products. A semidrying oil obtained from seeds has many industrial uses like manufacturing of linoleum, paints, varnishes, and soaps.

The edible part of corn is covered by long, silky, and colored (yellowish to reddish) hairlike structures known as corn silk. Corn silk, due to its high medicinal value, has been traditionally used as herbal remedies for the treatment of various diseases [6]. It has been reported to be used in the treatment of hypercholesterolemia, urinary infections, and associated diseases [10]. Corn silk is also used as an important ingredient in development of various drugs [11]. It has been found to be nontoxic and is safe for human consumption [12, 13]. In Asia, it is used in tea as a healthy and medical drink [14]. Corn silk powder can also be used as food additive and flavoring agent as it does not change the taste; rather, it enhances the content and physical characteristics of meals like beef patties [15, 16]. Pith of the stem of corn plant is used to make corn syrup [17], the spathes are used in making papers, straw hats, and baskets, and dried cobs are used as fuel [3].

2. Nutritional composition

Corn, due to its high nutritional quality, is a permanent global crop used to fulfill the nutritional requirements of humans and cattle [3]. Corn is rich in nutritional compounds

such as carbohydrates, proteins, vitamins, and minerals including calcium, magnesium, potassium, and sodium salts [3]. Corn seeds contain sugars (16.39–21.20 g/100 g dw), protein (11.46–12.70 g/100 g dw), and crude oil (5.73–6.21 g/100 g dw) [18]. Corn silk contains moisture (9.65–10.4%), protein (9.42–17.6%), fat (0.29–4.74%), ash (1.2–3.91%), dietary fiber (7.34%), and carbohydrates (65.5–74.3%), and good composition of vitamins and minerals as sodium, potassium (28, 1360 mg/100 g dw, respectively), calcium, magnesium, iron, zinc, manganese, and copper (0.1869, 0.1939, 0.005, 0.0165, 0.0109, and 0.0073 mg/g fw, respectively) [3, 19, 20]. The processed corn silk contains significant amounts of crude fiber (13%), crude protein (13%), and carbohydrates (69%). Being low in crude fat content, corn silk can be preferably used in the preparation of fat-free food formulations [21].

3. Phytochemical composition

Phytochemicals are the non-nutritional bioactive compounds found in various parts of plants. In plants these compounds perform vital functions particularly protection from predators and harsh environmental conditions. These compounds are also important in pharmaceutical and medicinal field due to their antioxidant, antimicrobial, and other biological properties. Flavonoids are the bioactive phytochemical compounds which make the plant resistant to the attack of microbes and insects and also protect the animals against various diseases [22–24]. Flavonoids possess strong antioxidant activity and free radical-scavenging capacity and inhibit protein glycation [23, 25, 26]. The anthocyanins have been found to protect against ischemic reperfusion injury in rats [27]. These have been also found to show antioxidant and antiradical activities which are further associated with certain health-promoting activities such as anticancer, anti-inflammatory, anti-obesity, antidiabetic, cardioprotective, and hepatoprotective activities [28–30]. Tannins are polyphenolic compounds which show several biological activities such as anti-inflammatory, antioxidant, free radical-scavenging, and anti-mutagenic activities [31, 32].

Various parts of corn plant such as silk, seed, stem, leaves, and roots are good sources of bioactive phytochemical compounds such as phenolic acids, flavonoids, steroids, alkaloids, carotenoids, tannins, saponins, anthocyanins, and other phenolic compounds [6, 28, 33, 34]. Corn seeds contain polyphenols, phenolic acids, flavonoids, anthocyanins, carotenoids, vitamins, sugars, polysaccharides, and other phytochemicals of medicinal importance [35, 36]. Corn silk contains a number of bioactive phytochemical compounds including phenols, polyphenols, phenolic acids, flavonoids, flavone glycosides, anthocyanins, carotenoids, terpenoids, alkaloids, steroids, luteins, tannins, saponins, volatile oils, vitamins, some sugars, and polysaccharides (**Table 1**) [6, 11, 22]. The corn silk flavonoids have been also reported to reduce the oxidative stress and show anti-fatigue activity in mice [37, 38]. The content of the major phytochemical compounds found in various parts of corn are summarized in **Table 2**.

Corn part	Class of phytochemicals	Phytochemical components	Reference
Corn silks	Polyphenols	Tannins, saponins, flavonoids, alkaloids, steroids, cardiac glycosides, allantoin, anthocyanins, hesperidin, and resins	[19]
	Phenolic acids	Para-aminobenzoic acid (PABA), vanillic acid, p-coumaric acid, chlorogenic acid, protocatechuic acid, caffeic acid, ferulic acid, maizenic acid, hydroxycinnamic acid ester, and 3-O-caffeoylquinic acid	[20]
	Flavonoids	Catechin, protocatechin, quercetin, rutin, flavone, 3-hydroxyl, 4-hydroxy, 5-hydroxy, and 7-hydroxy flavones and isoflavones. 2-O- α -L-rhamnosyl-6-C-3-deoxyglucosyl-3-methoxy luteolin and 6,4-dihydroxy-3-methoxyflavone-7-O-glucoside. Isoorientin-2-2-O- α -L-rhamnoside, cardiac glycosides	[11, 36, 73–76] [20, 34, 77]
		Luteolins: 2''-O- α -L-rhamnosyl-6-C-quinovosylluteolin, 2''-O- α -L-rhamnosyl-6-C-fucosylluteolin, and 2''-O- α -L-rhamnosyl-6-C-fucosyl-3'-methoxyluteolin, 2''-O- α -L-rhamnosyl-6-C-3''-deoxyglucosyl-3' methoxyluteolin, 2''-O- α -L-rhamnosyl-6-C-(6-deoxyxylo-hexos-4-ulosyl)-luteolin, 2''-O- α -L-rhamnosyl-6-C-(6-deoxy-xylo-hexos-4-ulosyl)-luteolin-3'-methylether, kaempferol	
		Maysins: Rhamnosyl-6-C-(4-ketofucosyl)-5, 7, 3'4'-tetrahydroxyflavone, ax-5'-methane-3'-methoxymaysin, ax-4''-OH-3'-methoxymaysin, 6,4'-dihydroxy-3'-methoxyflavone-7-O-glucosides, 7,4'-dihydroxy-3'-methoxyflavone-2''-O- α -L-rhamnosyl-6-C-fucoside	
	Carotenoids	β -Carotene, zeaxanthin	
	Sterols	Phytosterols like stigmasterol, beta-sitosterol	
	Tannins	Gallotannins, phlobatannins	
	Volatile compounds	Menthol, carvacrol, thymol, eugenol, neo-iso-3-thujanol, <i>cis</i> -sabinene hydrate, 6,11-oxidoacor-4-ene, citronellol, <i>trans</i> -pinocamphone, <i>cis</i> -sabinene hydrate, <i>cis</i> -R-terpineol, and neo-iso-3-thujanol	[78]
	Vitamins	Vitamin C, vitamin K, vitamin E	[79]
	Sugars	Dextrose, xylose	
	Miscellaneous compounds	Polysaccharides (galactan), geraniol, limonene, terpenoids, α -terpineol, citronellol, <i>trans</i> -pinocamphone, formononetin, apigenin, pelargonidin, anthraquinones, hordenine, xanthoproteins,	[6, 23, 25, 34–36, 49, 55, 70, 74, 75, 78, 80]
Corn seeds	Polyphenols	Tannins, saponins, rutin, allantoin, quercetin, isoquercetin, morin, naringenin, kaempferol	
	Phenolic acids	Gallic acid, chlorogenic acid, syringic acid, hydroxycinnamic acid derivatives, ferulic acid, 7-hydroxy-2-indolinone-3-acetic acid, caffeic acid	[35]
	Flavonoids	Anthocyanins, quercetin, and catechin	[81]
	Carotenoids	Carotenes including lutein, cyclosadol, β -cryptoxanthin, zeaxanthin, α - and β -carotene, α and β -cryptoxanthin	[82]
	Anthocyanins	Cyanogenic glycosides including pelargonidin-3-glucoside, cyanidin-3-glucoside, and peonidin-3-glucoside	[36]
	Vitamins	Vitamin E (tocopherols), vitamin B (biotin, riboflavin, pantothenic acid, folic acid, niacin, pyridoxine, thiamine), vitamin C	[83]
	Miscellaneous compounds	Polysaccharide, sugars, proteins, inositols, resins, hexaphosphoric and maizenic acid, esters of indole-3-acetic acid, d-glucose hydroxyl-2-indolinone-3-acetic acid, N-coumaryltryptamine, N-feruloyltryptamine, 6-methoxybenzoazoline, oxalic acids, essential fatty acids, and choline	[28, 30, 35, 78, 82]

Corn part	Class of phytochemicals	Phytochemical components	Reference
Corn stem	Phenolic compounds	Methyl (E)-p-cumarate, methyl (Z)-p-cumarate, methyl ferulate, and 1,3-O-diferuloyl glycerol	[84]
	Lignan	Tetrahydro-4,6-bis(4-hydroxy-3-methoxyphenyl)-1H,3H-furo[3,4-c]furan-1-one	[81]
	Flavonoids	Tricin, salcolin A, and salcolin B	[81]
	Anthocyanins	Cyanidin-3-glucoside, pelargonidin-3-glucoside, and peonidin-3-glucoside	[27, 29, 67]
	Polyphenols, flavonoids, and others	Flavonoids, terpenoids, alkaloids, tannins, phlobatannins, saponins	[85]
Corn root and shoot			

Table 1. Bioactive phytochemical components in various parts of corn.

Corn part	Extracting solvent	TPC	TFC	TAC	TCC	References
Corn silk	Water	1.5 mg GAE/g extract	2–7 µg/ml extract			[86]
		35.34–64.22 mg GAE/g extract	2.31–7.55 mg CE/g extract			[79, 87]
		42.71 µg TAE/g extract				[88]
		256.36–272 mg GAE/100 g dw	4.1–38.01 mg CE/g dw			[87, 89],
	Hot water	68.61 mg GAE/g	72.74 mg QE/g	0.02 mg CGE/g		[21]
	Methanol	101.99–175.8 mg GAE/g dw	0.66–9.26 mg CE/g dw			[87, 90]
		40.38 µg TAE/g extract		0.017–0.023 g CGE/100 g dw.		[18, 88]
		272.81 mg GAE/100 g dw				[89]
	Methanol acidified with 1% citric acid	69.01–85.49 mg GAE/100 g of fw		78.90–408.54 mg CGE/100 g fw		[91]
	Ethanol	164.1 µg GAE/g dw	69.4 µg RE/g dw			[34]
		1756 mg chlorogenic acid/100 g dw		1779 mg CGE/100 g dw.		[92]
		86.26–143.58 mg GAE/g extract	14.66–26.63 mg CAE/g extract			[79, 93]
		80.8–117.1 µg GAE/g dw	30.1–88.8 µg RE/g dw	0.4–72.9 µg CGE/g dw		[57, 41]
	Aqueous acetone	93.43 mg GAE/g dw	65.58 mg RE/g dw			[87, 90],
		34029.37 ± 1926.61 mg /kg dw	211.05 ± 3.73 mg/kg dw		11.3 mg/kg dw	[94]
		2093–4447 81 mg GAE/100 g dw	1840–3644 mg CE/100 g dw	1.49 mg CGE/100 g dw		[20],
	Ethyl acetate	6.70 mg GAE/g extract	8.40 mg CE/g extract			[90]

Corn part	Extracting solvent	TPC	TFC	TAC	TCC	References
Corn kernel	Methanol	115.4–175.5 mg GAE/100 g dw			6.7 µg/g fw, 9.7 µg/g dw	[95]
	Methanol acidified with citric acid	17.67–23.97 and 2.1 mg GAE/g fw, 2.8 mg GAE/g dw		16.53–45.84 mg CGE/100 g fw, 0.3 mg CGE/g fw, 0.4 mg CGE/g dw		[61, 91]
	Methanol acidified with HCl		178–515 mg NE /100 g dw	0–90 mg CGE /100 g dw		[95]
	Ethanol	223–467 mg GAE /100 g dw			16–564 µg/100 g dw	[82]
	Ethanol acidified with citric acid	287.3 ± 0.03 mg GAE/100 g fw		70.50 mg CGE /100 g		[41]
		20.06–24.97 mg GAE/100 g fw		25.8–133.26 mg CGE/100 g fw		[61, 91]
		353 ± 53 mg GAE/100 g dw	270 ± 62 mg NE /100 g of dw	30 ± 26 mg CGE /100 g dw	135 ± 119 µg/100 g dw	[95]
Corn cob	Aqueous alcohol	215.8–3400 53 mg GAE/100 g dw		1.54–850.9 mg CGE/100 g dw		[96]
	Methanol			129–1166 mg/100 g dw		[67]
	Methanol acidified with citric acid	15.43–64.02 mg GAE/100 g fw		17.87–115.97 mg CGE/100 g fw		[91]
Corn leaves	Various polarity solvents	79.61–92.64 mg GAE/g extract, 0.86 g GAE/100 g	14.41 mg CAE/g extract, 1.56 g QE/100 g, 0.46 g QE/100 g		0.85–1.18 g BCE/100 g	[93, 97]
	Various polarity solvents	4.94–1.75 g GAE/100 g	17.68 g QE/100 g		3.73–44.91 g BCE/100 g	[97]
Corn shoot	Water	69 µg GAE/g extract				[85]
	Ethanol	31.32 µg GAE/g extract				[85]
Corn root	Water	9.98 µg GAE/g extract				[85]
Corn husk	Various polarity solvents	1.62–14.77 g GAE/100 g	1.48–2.05 g QE/100 g		0.45–3.63 g BCE/100 g	[97]

GAE, gallic acid equivalent; RE, rutin equivalent; TFC, total flavonoid content; TPC, total phenolic content; TAC, total anthocyanin content; CGE, cyanidin-3-glucoside equivalents; fw, fresh weight; CE, catechin equivalent; TCC, total carotenoid contents; QE, quercetin equivalent; BCE, β-carotene equivalent; dw, dry weight; NE, naringin equivalent; TAE, tannic acid equivalent.

Table 2. Phytochemical composition of extracts from various parts of corn.

4. Antioxidant potential

The pharmaceutical and medicinal significance of medicinal plants is usually based on their antioxidant phytochemical composition. Antioxidants are the substances which have the ability to prevent the oxidation reactions in living and nonliving systems. They possess hydrogen-donating ability due to which they reduce other species and are themselves oxidized. These substances perform their action by reducing the reactive oxygen or nitrogen species or metals in their oxidized forms. These substances have the ability to terminate the free radical chain reactions occurring in the living system. Owing to their antiradical and reducing properties, the antioxidant phytochemicals play a key role in the preparation of pharmaceutical formulations against various diseases. The diversity in the phytochemical quality and high content of bioactive antioxidant phytochemicals make corn a valuable candidate for pharmaceutical application. Among various parts of corn, the corn silk is a rich source of antioxidant compounds and possesses strong antioxidant potential. The antioxidant properties of various parts of corn studied in terms of total antioxidant activity, ferric reducing, iron chelating, copper-reducing properties, and free radical-scavenging capacities are presented in **Tables 3–5**. The corn extracts have been also reported to improve the antioxidant status of various organs by affecting the activity of antioxidant enzymes [38].

Corn part	Extracting solvent	TAOA	β -CABC	References
Corn silk	Water	73–44.19%		[87]
	Methanol		66.05%	[87]
	Ethanol	5.61–9.98 mg FeSO ₄ /g dw	52.92%	[87]
	Ethyl acetate	2.15–2.735 mg GAE/g dw	38.65%, 26.33%	[87, 89]
Corn seed	Methanol acidified with citric acid	1827.5–2429.3 μ mol TE/100 g dw, 61.15%, 3.1 μ mol TE/g fw, 3.8 μ mol TE/g dw, 17.9–32.19%		[61, 82, 91]
	Methanol acidified with HCl	18–100 μ mol AAE/100 g		[95]
	Ethanol acidified with citric acid	22.95% TE		[41]
Corn cob	Methanol	0.3–10.2 μ mol/g dw		[67]
	Methanol acidified with citric acid	31.10%		[91]
Corn husk	Methanol acidified with citric acid	11.85%		[91]

TAOA, total antioxidant activity; β -CABC, β -carotene-bleaching capacity; GAE, gallic acid equivalent; TE, Trolox equivalent; AAE, ascorbic acid equivalent; fw, fresh weight; dw, dry weight.

Table 3. Total antioxidant activity and β -carotene-bleaching capacity of extracts from various parts of corn.

Corn part	Extracting solvent	FRAP	CRC	References
Corn silk	Water	35.01%		[87]
	Methanol	56.41%		[87]
	Ethanol	51.16%, 38.90–65.46%		[87, 93]
	Ethyl acetate	27.21%		[87]
Corn kernel	Methanol	6.4–12.7 37 µM TE/g dw		[95]
	Methanol acidified with citric acid	0.09 µmol Fe(II) E/g fw		[61, 82, 98]
		0.10 µmol Fe(II)/g dw		
		13.1–26.1 µM TE/g		
	Methanol acidified with HCl	9 ± 2 mmol TE/100 g dw		[95]
Corn cob	Various polarity solvents	35.81–41.39%	EC ₅₀ (218.1–735.0 µg/ml)	[93, 97]
Corn leaves	Various polarity solvents		EC ₅₀ (152.3–248.8 µg/ml)	[97]
Corn husk	Various polarity solvents		EC ₅₀ (205.7–723.4 µg/ml)	[97]

FRAP, ferric-reducing antioxidant power; CRC, cupric-reducing capacity; EC₅₀, effective concentration required for 50% inhibition; TE, Trolox equivalent.

Table 4. Metal-reducing capacity of extracts from various parts of corn.

Corn part	Extracting solvent	DPPH	ABTS	References
Corn silk	Water	63.5%		[89]
		IC ₅₀ (195.21 µg/ml)		[99]
	Methanol	81.7%		[89]
	Methanol	IC ₅₀ (0.10–0.18 mg/ml)		[18]
	Methanol	41–76%		[19]
	Methanol	IC ₅₀ (140.89 µg/ml)		[99]
		81.7–71.5%		[89]
	Ethanol	84%, 68–75.6%		[78]
		68.4–75.6%		[57]
		IC ₅₀ (140.89 µg/ml)		[87]
Corn seed	Ethanol	IC ₅₀ (143.55 µg/ml)		[99]
	Ethanol-water	92.6% with IC ₅₀ (0.56 mg/ml)		[6]
	Ethyl acetate	IC ₅₀ (411.69 µg/ml)		[99]
	Methanol	IC ₅₀ (66.3–79.8 µg/ml) IC ₅₀ (52–177 mg/ml)	IC ₅₀ (219–799 µg/ml)	[40, 98]
	Methanol acidified with citric acid	13.15%, 28.7% fw, 34.2% dw, 10.48–13.46%		[61, 91]
	Methanol acidified with HCl		5–14 µM TE/g dw 11 ± 2 mmol TE/100 g dw	[95],
	Ethanol acidified with citric acid	49.2 µM ET/g		[41]

Corn part	Extracting solvent	DPPH	ABTS	References
Corn cob	Methanol	4–22 $\mu\text{mol/g dw}$		[67]
	Methanol acidified with citric acid	21.01%		[91]
	Various polarity solvents	IC_{50} (11.8–154.4 $\mu\text{g/ml}$)		[97]
Corn husk	Methanol acidified with citric acid	10.25%		[91]
	Various polarity solvents	IC_{50} (34.1–170.9 $\mu\text{g/ml}$)		[97]
Corn leaves	Various polarity solvents	IC_{50} (9–78 $\mu\text{g/ml}$)		[97]

DPPH, 2,2-diphenyl-1-picrylhydrazyl radical-scavenging ability; IC_{50} , inhibitory concentration required for 50% inhibition; ABTS, azino-bis-tetrazolium sulfate.

Table 5. Free radical-scavenging capacity of extracts from various parts of corn.

5. Biological activities

Epidemiological studies have demonstrated a relationship between the consumption of food with high quantities of phenolic compounds and a reduction in the risks of chronic and degenerative diseases, such as cancers and cardiovascular disease. Corn seed possesses antidiabetic, antioxidant, antiproliferative, and anti-cataractogenic activities [18, 39–41].

Corn part	Extracting solvent	Activity	Reference
Corn silk	Water	Diuretic and kaliuretic activity with reduced glomerular function, anti-hepatocarcinomic, antiadipogenic, antiobesitic, antihyperglycemic, antidiabetic, lipid lowering, hematinic, anti-inflammatory, and analgesic activity	[43, 55, 59, 99, 100]
	Hot water	Antioxidant activity and inhibition of IgE antibody formation in mice	[48, 101]
	Methanol	Antioxidant, antimicrobial, anti-hyperthyroidism, inhibition of lipid peroxidation, immunomodulatory activity by enhancing the innate immunity, lipid lowering, and cardioprotective activity	[19, 47, 49, 102, 103]
	Ethanol	Inhibition of tumor necrosis factor- α and adhesion of leukocytes to cell surface, activation of human peroxisome proliferator activator receptors, induction of antioxidant enzymes, and reduction of oxidative stress, antioxidant and free radical-scavenging, urease inhibitory, anti-hyperlipidemic, and diuretic activity	[34, 38, 44, 46, 50, 76, 104]
	Aqueous alcohol	Anti-fatigue, hepatoprotective, and renal protective activity in terms of inhibition of lipid peroxidation	[10, 37, 105–108]
	Aqueous acetone	Antioxidant activity	[20]
	Various polarity solvents	Antioxidant activity in terms of free radical-scavenging, metal-reducing and beta-carotene-bleaching capacities and antimicrobial activity	[24, 87, 109]
	Corn silk powder	Antioxidant and immunostimulatory activity in fish	[110]

Corn part	Extracting solvent	Activity	Reference
Corn seed	Methanol	Antioxidant activity in terms of free radical-scavenging and metal-reducing capacity	[18, 40]
	Aqueous alcohol	Antioxidant and anti-cataractogenic activity against diabetic cataract	[39]
Corn stem	Methanol	Anti-inflammatory, neuroprotective, hepatoprotective, and antioxidant	[81, 84]
Corn husk	Ethanol	Nephroprotective activity by dose-dependent increase antioxidant enzymes in diabetic rat	[111]

Table 6. Biological activities of extracts from various parts of corn.

Corn silk has been traditionally used for the treatment of several ailments due to various pharmacological activities exhibited by its extracts. It has been found to possess antioxidant, antidiabetic, antiproliferative, antimutagenic, anticoagulant, antifungal, antiadipogenic, anti-obesitic, antihypertensive, antihyperlipidemic, antilithiatic, antibiotic, antibacterial, antiseptic, anti-inflammatory, antidepressant, and anti-fatigue activities [6, 11, 34, 38, 42, 43]. It has been also reported to possess antihyperglycemic, antihyperlipidemic, diuretic, neuroprotective, hepatoprotective, and uricosuric activities [44, 45]. Corn silk has been investigated to activate the receptors for the binding of human peroxisome proliferator activators used in the treatment of diabetes [46]. Its methanolic extract has been found to be effective in thyroid dysfunction [47]. Corn silk extracts contain certain bioactive compounds which show immunomodulation activity [33, 48, 49]. Corn silk extracts have been also found to be effective in inhibition of tumor necrosis factor- α and adhesion of leukocytes to cell surface and induction of nitric oxide synthase and cyclooxygenase in macrophages [50–52]. The chemically modified corn silk polysaccharides have been reported to show antioxidant and amylase inhibitory activities [14]. Recently, the studies have shown that corn silk has no cytotoxic effect, but the excessive use of corn silk may be cardiotoxic particularly in patients with compromised cardiac health [4]. The biological activities of various extracts of different parts of corn are presented in **Table 6**.

6. Medicinal importance

Corn seed kernel is commonly used as nutritional purpose, but owing to its good phytochemical composition and biological properties, it has great medicinal value. The toxicological assessment of corn at various doses against various clinical parameters has proven it clinically nontoxic and can be used for nutritional and medicinal purposes [53]. Anthocyanins in purple waxy corn have been reported to be effective against diabetic cataract [39]. Corn silk is usually discarded as waste and not used for nutritional purpose. However, it has a great medicinal importance due to the presence of valuable bioactive phytochemical compounds. It has been traditionally used as an effective herbal remedy for the treatment of hyperglycemia, diabetes, obesity, hypercholesterolemia, hyperthyroidism, rheumatism, arthritis, gout,

tumors, hepatitis, heart problems, jaundice, malaria, inflammation, asthma prostatitis, cystitis, nephritis, kidney stones, bed wetting, renal conditions, and other kidney-related diseases. Corn silk is also known to be urine laxative, antihypertensive, and immune enhancer. Corn silk tea has been used as diuretic for the treatment of urinal irritation. In combination with other herbs, corn silk has been found to be effective against mumps or inflammation of the bladder. It has been also reported to be useful in gonorrhea, acute and chronic cystitis, and bladder irritation due to uric acid and phosphate gravel [11, 14, 37, 38, 42–44, 46, 47, 51, 54–59]. Recently, corn silk polysaccharides have been suggested to be a good choice as functional food or medicine for the treatment of type 2 diabetes mellitus due to its hypoglycemic activity [60].

7. Factors affecting the phytochemical profile and antioxidant potential of corn

There are several factors which have been reported to affect the phytochemical quality and antioxidant potential of various parts of corn. The phytochemical composition and antioxidant profile of maize have been observed to be different in different varieties and at various stages of maturity [18, 61–63]. The phytochemical content of corn silk has been found to be enhanced by treatment with red algae [64]. The location, climatic, water stress, irrigation method, and plant density significantly affect the growth, metabolism, and physiological characteristics of corn plant [65–67]. The spraying of salicylic acid and collection period have been found to increase the growth rate and phytochemical content of corn silk [68]. The fermentation of corn samples has been found to result in an increase in carotenoid and ascorbic acid content with a slight decrease in antioxidant activity [69]. The germination conditions between light and dark periods have been also found to affect the morphological structures, biochemical and phytochemical composition, and antioxidant activity of corn sprouts [70]. The storage conditions, processing techniques, and cooking methods have been also found to affect the phytochemical content and free radical-scavenging activity of maize [21, 71]. Recently, studies in our laboratory have shown that high-dose gamma irradiation results in a decrease in antioxidant properties of corn flour [72].

8. Conclusion

All parts of corn plant are good sources of phytochemical compounds which possess antioxidant potential. Corn seed have a valuable role in human nutrition, while corn silk has a great medicinal importance due the presence of a variety of bioactive phytochemical compounds. The principal phytochemicals present in corn silk include polyphenols, phenolic acids, flavonoids, anthocyanins, glycosides, carotenoids, and some water-soluble vitamins. The presence of these phytochemicals makes corn a medicinal plant which shows various biological activities particularly the antioxidant activity. On the account of its high antioxidant potential, all parts of corn plant can be used for the management of oxidative stress and the treatment of various diseases.

Conflict of interest

I confirm that there are no conflicts of interest.

Author details

Haq Nawaz^{1*}, Saima Muzaffar², Momna Aslam¹ and Shakeel Ahmad³

*Address all correspondence to: haqnawaz@bzu.edu.pk

1 Department of Biochemistry, Bahauddin Zakariya University, Multan, Pakistan

2 Department of Chemistry, University of Education, Vehari, Pakistan

3 Department of Agronomy, Faculty of Agriculture, Bahauddin Zakariya University, Multan, Pakistan

References

- [1] Vaughan JG, Geissler CA. The New Oxford Book of Food Plants. Oxford: Oxford University Press; 1997. ISBN 0-19-854825-7
- [2] Purohit SS, Sharma AK, Prajapati ND, Kumar T. A Handbook of Medicinal Plants: A Complete Source Book. 2nd ed. Jodhpur, India: Agrobios; 2009. pp. 352-353
- [3] Nuss ET, Tanumihardjo SA. Maize: A paramount staple crop in the context of global nutrition. *Comprehensive Reviews in Food Science and Food Safety*. 2010;**9**:417-436
- [4] Ishak WRW, Ali SM. Assessment of Malaysian cornsilk bioactive compounds and its cytotoxicity test on brine shrimp (*Artemia salina*). *Health (N Y)*. 2016;**7**:124-138
- [5] Naqvi S, Ramessar K, Farré G, Sabalza M, Miralpeix B, Twyman RM, et al. High-value products from transgenic maize. *Biotechnology Advances*. 2011;**29**:40-53
- [6] Ebrahimzadeh MA, Pourmorad F, Hafezi S. Antioxidant activities of Iranian corn silk. *Turkish Journal of Biology*. 2008;**32**:43-49
- [7] Shad MA, Nawaz H, Noor M, Ahmad HB, Hussain M, Choudhry MA. Functional properties of maize flour and its blends with wheat flour: optimization of preparation conditions by response surface methodology. *Pakistan Journal of Botany*. 2013;**45**:2027-2035
- [8] Nawaz H, Shad MA, Mehmood R, Rehman T, Munir H. Comparative evaluation of functional properties of some commonly used cereal and legume flours and their blends. *International Journal of Food and Allied Sciences*. 2015;**1**:67-73
- [9] Voca N, Varga B, Kricka T, Curic D, Jurisic V, Matin A. Progress in ethanol production from corn kernel by applying cooking pre-treatment. *Bioresource Technology*. 2009; **100**:2712-2718

- [10] Karami M, Shokerzadeh M, Naghshvar F, Ala S, Fezbakhsh R, Nosrati A, et al. Comparison the renal protective activity of corn silk and Feijoa extracts by using insitu rat renal perfusion system. *Iranian Journal of Toxicology*. 2014;**8**(25)
- [11] Hasanudin K, Hashim P, Mustafa S. Corn silk (*Stigma maydis*) in healthcare: A phytochemical and pharmacological review. *Molecules*. 2012;**17**:9697-9715
- [12] Wang C, Zhang T, Liu J, Lu S, Zhang C, Wang E, et al. Subchronic toxicity study of corn silk with rats. *Journal of Ethnopharmacology*. 2011;**137**:36-43
- [13] Gwendlin V, Induja TA, Manoj J, Shivasamy MS. Recent trends in effective utilization of by-product of corn. *Indian Journal of Science*. 2015;**22**:18-26
- [14] Chen S, Chen H, Tian J, Wang Y, Xing L, Wang J. Chemical modification, antioxidant and α -amylase inhibitory activities of corn silk polysaccharides. *Carbohydrate Polymers*. 2013;**98**:428-437
- [15] Rosli W, Nurhanan AR, Solihah MA, Mohsin SSJ. Cornsilk improves nutrient content and physical characteristics of beef patties. *Sains Malays*. 2011;**40**:155-161
- [16] Aukkanit N, Kemngoen T, Ponharn N. Utilization of corn silk in low fat meatballs and its characteristics. *Procedia—Social and Behavioral Sciences*. 2015;**197**:1403-1410
- [17] Ebrahimzadeh MA, Pourmorad F, Bekhradnia AR. Iron chelating activity, phenol and flavonoid content of some medicinal plants from Iran. *African Journal of Biotechnology*. 2008;**7**(18):3188-3192
- [18] Nawaz H, Shad MA, Batool Z. Inter-varietal variation in biochemical, phytochemical and antioxidant composition of maize (*Zea mays* L.) grains. *Food Science and Technology Research*. 2013;**19**:1133-1140
- [19] Emmanuel SA, Olajide O, Abubakar S, Akiode SO, Etuk-Udo G. Chemical evaluation, free radical scavenging activities and antimicrobial evaluation of the methanolic extracts of corn silk (*Zea mays*). *Journal of Advances in Medical and Pharmaceutical Sciences*. 2016;**9**:1-8
- [20] Jana ŽS, Janković M, Basić Z, Vančetočić J, Maksimović V. Antioxidant activity, phenolic profile, chlorophyll and mineral matter content of corn silk (*Zea mays* L): Comparison with medicinal herbs. *Journal of Cereal Science*. 2016;**69**:363-370
- [21] Cabrera SG, Perez IFR, Aguilar LJL, Caringal MC, Dado AG, Evangelista DM. Determination of properties of selected fresh and processed medicinal plants. *Asia Pacific Journal of Multidisciplinary Research*. 2015;**3**
- [22] Guevara P, Perez-Amador MC, Zuniga B, Snook M. Flavones in corn silks & resistance to insect attacks. *Phyton*. 2000;**69**:151-156
- [23] Silva MM, Santos MR, Caroco G, Rocha R, Justino G, Mira L. Structure-antioxidant activity relationships of flavonoids: A re-examination. *Free Radical Research*. 2002;**36**:1219-1227
- [24] Nessa F, Ismail Z, Mohamed N. Antimicrobial activities of extracts and flavonoid glycosides of corn silk (*Zea mays* L). *International Journal of Biotechnology for Wellness Industries*. 2012;**1**:115-120

- [25] Matsuda H, Wang T, Managi H, Yoshikawa M. Structural requirements of flavonoids for inhibition of protein glycation and radical scavenging activities. *Bioorganic & Medicinal Chemistry*. 2003;**11**:5317-5323
- [26] Wu C-H, Yen G-C. Inhibitory effect of naturally occurring flavonoids on the formation of advanced glycation endproducts. *Journal of Agricultural and Food Chemistry*. 2005;**53**:3167-3173
- [27] Toufektsian M-C, De Lorgeril M, Nagy N, Salen P, Donati MB, Giordano L, et al. Chronic dietary intake of plant-derived anthocyanins protects the rat heart against ischemia-reperfusion injury. *The Journal of Nutrition*. 2008;**138**:747-752
- [28] Wang L-S, Stoner GD. Anthocyanins and their role in cancer prevention. *Cancer Letters*. 2008;**269**:281-290
- [29] He J, Giusti MM. Anthocyanins: Natural colorants with health-promoting properties. *Annual Review of Food Science and Technology*. 2010;**1**:163-187
- [30] Abdel-Aal EM. Anthocyanin-pigmented grain products. In: *Advances in Cereal Science: Implications to Food Processing and Health Promotion*. Washington DC, USA: ACS Publications; 2011. pp. 77-109
- [31] Kaur S, Grover IS, Singh M, Kaur S. Antimutagenicity of hydrolyzable tannins from *Terminalia chebula* in *Salmonella typhimurium*. *Mutation Research. Genetic Toxicology and Environmental Mutagenesis*. 1998;**419**:169-179
- [32] Kong J-M, Chia L-S, Goh N-K, Chia T-F, Brouillard R. Analysis and biological activities of anthocyanins. *Phytochemistry*. 2003;**64**:923-933
- [33] Luhong T, Xiaolin D, Lifen Y, Weier G, Furong Y. Bio-active substances from corn silk corn silk polysaccharide (CSPS) and its immunological enhancing function. *Journal of Wuxi University of Light Industry*. 1995;**4**
- [34] Liu J, Wang C, Wang Z, Zhang C, Lu S, Liu J. The antioxidant and free-radical scavenging activities of extract and fractions from corn silk (*Zea mays* L.) and related flavone glycosides. *Food Chemistry*. 2011;**126**:261-269
- [35] Lewer P, Bandurski RS. Occurrence and metabolism of 7-hydroxy-2-indolinone-3-acetic acid in *Zea mays*. *Phytochemistry*. 1987;**26**:1247-1250
- [36] Yang Z, Zhai W. Identification and antioxidant activity of anthocyanins extracted from the seed and cob of purple corn (*Zea mays* L.). *Innovative Food Science & Emerging Technologies*. 2010;**11**:169-176
- [37] Hu Q-L, Zhang L-J, Li Y-N, Ding Y-J, Li F-L. Purification and anti-fatigue activity of flavonoids from corn silk. *International Journal of Physical Sciences*. 2010;**5**:321-326
- [38] Hu QL, Deng ZH. Protective effects of flavonoids from corn silk on oxidative stress induced by exhaustive exercise in mice. *African Journal of Biotechnology*. 2011;**10**:3163-3167

- [39] Thiraphatthanavong P, Wattanathorn J, Muchimapura S, Thukham-Mee W, Wannanon P, Tong-Un T, et al. Preventive effect of *Zea mays* L. (purple waxy corn) on experimental diabetic cataract. *BioMed Research International*. 2014;**2014**:1-8
- [40] Ganie AH, Yousuf PY, Ahad A, Pandey R, Ahmad S, Aref IM, et al. Quantification of phenolic acids and antioxidant potential of inbred, hybrid and composite cultivars of maize under different nitrogen regimes. *Journal of Environmental Biology*. 2016;**37**:1273
- [41] Herrera-Sotero MY, Cruz-Hernández CD, Trujillo-Carretero C, Rodríguez-Dorantes M, García-Galindo HS, Chávez-Servia JL, et al. Antioxidant and antiproliferative activity of blue corn and tortilla from native maize. *Chemistry Central Journal*. 2017;**11**:110
- [42] Grases F, March JG, Ramis M, Costa-Bauzá A. The influence of *Zea mays* on urinary risk factors for kidney stones in rats. *Phytotherapy Research*. 1993;**7**:146-149
- [43] Min O-J, Sharma BR, Park C-M, Rhyu D-Y. Effect of myadis stigma water extract on adipogenesis and blood glucose in 3T3-L1 adipocytes and db/db mice. *Korean Journal of Pharmacognosy*. 2011;**42**:201-208
- [44] Cáceres A, Girón LM, Martínez AM. Diuretic activity of plants used for the treatment of urinary ailments in Guatemala. *Journal of Ethnopharmacology*. 1987;**19**:233-245
- [45] Chen G, Wang H, Zhang X, Yang S-T. Nutraceuticals and functional foods in the management of hyperlipidemia. *Critical Reviews in Food Science and Nutrition*. 2014;**54**:1180-1201
- [46] Rau O, Wurglics M, Dingermann T, Abdel-Tawab M, Schubert-Zsilavecz M. Screening of herbal extracts for activation of the human peroxisome proliferator-activated receptor. *Pharmazie*. 2006;**61**:952-956
- [47] Bhaigyaabati T, Ramya J, Usha K. Effect of methanolic extract of sweet corn silk on experimentally induced hyperthyroidism in Swiss albino rats. *International Research Journal of Pharmacy*. 2012;**3**:241-245
- [48] Namba T, Xu H, Kadota S, Hattori M, Takahashi T, Kojima Y. Inhibition of IgE formation in mice by glycoproteins from corn silk. *Phytotherapy Research*. 1993;**7**:227-230
- [49] Lee J, Kim S-L, Lee S, Chung MJ, Park YI. Immunostimulating activity of maysin isolated from corn silk in murine RAW 264.7 macrophages. *BMB Reports*. 2014;**47**:382
- [50] Habtemariam S. Extract of corn silk (Stigma of *Zea mays*) inhibits tumour necrosis factor- α -and bacterial lipopolysaccharide-induced cell adhesion and ICAM-1 expression. *Planta Medica*. 1998;**64**:314-318
- [51] Kim KA, Choi S-K, Choi H-S. Corn silk induces nitric oxide synthase in murine macrophages. *Experimental & Molecular Medicine*. 2004;**36**:545
- [52] Kim KA, Shin H-H, Choi SK, Choi H-S. Corn silk induced cyclooxygenase-2 in murine macrophages. *Bioscience, Biotechnology, and Biochemistry*. 2005;**69**:1848-1853

- [53] Sabiu S, O'Neill FH, Ashafa AOT. Toxicopathological evaluation of a 28-day repeated dose administration of *Zea mays* L. (Poaceae), *Stigma maydis* aqueous extract on key metabolic markers of Wistar rats. Transactions of the Royal Society of South Africa. 2017;**72**:225-233
- [54] Barter P, Gotto AM, LaRosa JC, Maroni J, Szarek M, Grundy SM, et al. HDL cholesterol, very low levels of LDL cholesterol, and cardiovascular events. The New England Journal of Medicine. 2007;**357**:1301-1310
- [55] Zhao W, Yin Y, Yu Z, Liu J, Chen F. Comparison of anti-diabetic effects of polysaccharides from corn silk on normal and hyperglycemia rats. International Journal of Biological Macromolecules. 2012;**50**:1133-1137
- [56] Nessa HA, Muchtar H. Efek Diuretik dan Daya Larut Batu Ginjal Dari Ekstrak Etanol Rambut Jagung (*Zea mays* L.). Pros Semin Nas Perkemb Terkini Sains Farm Dan Klin III Sumat Utara Fak Farm Univ Andalas; 2013
- [57] Sarepoua E, Tangwongchai R, Suriharn B, Lertrat K. Relationships between phytochemicals and antioxidant activity in corn silk. International Food Research Journal. 2013;**20**:2073
- [58] Sukandar EY, Sigit JI, Adiwibowo LF. Study of kidney repair mechanisms of corn silk (*Zea mays* L. Hair)-Binahong. International Journal of Pharmacology. 2013;**9**:12-23
- [59] Yang J, Li X, Xue Y, Wang N, Liu W. Anti-hepatoma activity and mechanism of corn silk polysaccharides in H22 tumor-bearing mice. International Journal of Biological Macromolecules. 2014;**64**:276-280
- [60] Pan Y, Wang C, Chen Z, Li W, Yuan G, Chen H. Physicochemical properties and anti-diabetic effects of a polysaccharide from corn silk in high-fat diet and streptozotocin-induced diabetic mice. Carbohydrate Polymers. 2017;**164**:370-378
- [61] Khampas S, Lertrat K, Lomthaisong K, Suriharn B. Variability in phytochemicals and antioxidant activity in corn at immaturity and physiological maturity stages. International Food Research Journal. 2013;**20**:3149
- [62] Tian J, Chen H, Chen S, Xing L, Wang Y, Wang J. Comparative studies on the constituents, antioxidant and anticancer activities of extracts from different varieties of corn silk. Food & Function. 2013;**4**:1526-1534
- [63] Sarepoua E, Tangwongchai R, Suriharn B, Lertrat K. Influence of variety and harvest maturity on phytochemical content in corn silk. Food Chemistry. 2015;**169**:424-429
- [64] Al-Saman MA, Farfour SA, Hamouda RA. Effects of some red algae on antioxidant and phytochemical contents of maize (*Zea mays* L.) plants. International Journal of Agriculture Sciences. 2015;**5**:393-398
- [65] Bahadori A, Mobasser HR, Ganjali HR. Influence of water stress and plant density on some characteristics in corn. Biological Forum – An International Journal. Research Trend. 2015;**7**:673

- [66] Ghanati F, Mohamadalikhani S, Soleimani M, Afzalzadeh R, Hajnorouzi A. Change of growth pattern, metabolism, and quality and quantity of maize plants after irrigation with magnetically treated water. *Electromagnetic Biology and Medicine*. 2015;**34**:211-215
- [67] Khampas S, Lertrat K, Lomthaisong K, Simla S, Suriharn B. Effect of location, genotype and their interactions for anthocyanins and antioxidant activities of purple waxy corn cobs. *Turkish Journal of Field Crops*. 2015;**20**:15-23
- [68] MH A-M. Effect of spraying salicylic acid and collection dates of corn silk (*Zea mays* L.) on growth, yield and content of some antioxidant compounds. *Journal of Global Pharma Technology*. 2017;**9**:98-103
- [69] Oladeji BS, Akanbi CT, Gbadamosi SO. Effects of fermentation on antioxidant properties of flours of a normal endosperm and quality protein maize varieties. *Journal of Food Measurement and Characterization*. 2017;**11**:1148-1158
- [70] Xiang N, Guo X, Liu F, Li Q, Hu J, Brennan CS. Effect of light-and dark-germination on the phenolic biosynthesis, phytochemical profiles, and antioxidant activities in sweet corn (*Zea mays* L.) sprouts. *International Journal of Molecular Sciences*. 2017;**18**:1246
- [71] Song J, Liu C, Li D, Meng L. Effect of cooking methods on total phenolic and carotenoid amounts and dpph radical scavenging activity of fresh and frozen sweet corn (*Zea mays*) kernels. *Czech Journal of Food Sciences*. 2013;**31**(6):607-612
- [72] Nawaz H, Shad MA, Rehman T, Ramzan A. Influence of high-dose gamma radiation and particle size on antioxidant properties of maize (*Zea mays* L.) flour. *Brazilian Journal of Pharmaceutical Sciences*. 2016;**52**:771-780
- [73] Liu RH. Potential synergy of phytochemicals in cancer prevention: mechanism of action. *The Journal of Nutrition*. 2004;**134**:3479S-3485S
- [74] Yu TT, Lu XX, Lian XJ, Zhang YQ. Composition analysis of flavonoids from corn silk with thin-layer chromatography and ultraviolet spectrophotometry. *Food Science*. 2008;**29**:477-481
- [75] Ren S-C, Liu Z-L, Ding X-L. Isolation and identification of two novel flavone glycosides from corn silk (*Stigma maydis*). *Journal of Medicinal Plants Research*. 2009;**3**:1009-1015
- [76] Ismael RH, Ahmed SA, Mahmoud SS. Detection of rutin, kaepferol, and quercetin based crude from corn silk and studying their effects on the inhibition of pure urease enzyme and urease of *Klebsiella* species. *International Journal of Current Microbiology and Applied Sciences*. 2017;**6**:2676-2685
- [77] Snook ME, Widstrom NW, Wiseman BR, Byrne PF, Harwood JS, Costello CE. New C-4"-hydroxy derivatives of maysin and 3'-methoxymaysin isolated from corn silks (*Zea mays*). *Journal of Agricultural and Food Chemistry*. 1995;**43**:2740-2745
- [78] El-Ghorab A, El-Massry KF, Shibamoto T. Chemical composition of the volatile extract and antioxidant activities of the volatile and nonvolatile extracts of Egyptian corn silk (*Zea mays* L.). *Journal of Agricultural and Food Chemistry*. 2007;**55**:9124-9127

- [79] Rahman NA, Wan Rosli WI. Nutritional compositions and antioxidative capacity of the silk obtained from immature and mature corn. *Journal of King Saud University – Science*. 2014;**26**:119-127
- [80] Xie L, Yu Y, Mao J, Liu H, Hu JG, Li T, et al. Evaluation of biosynthesis, accumulation and antioxidant activity of Vitamin E in sweet corn (*Zea mays* L.) during kernel development. *International Journal of Molecular Sciences*. 2017;**18**:2780
- [81] Jung Y-J, Park J-H, Cho J-G, Seo K-H, Lee D-S, Kim Y-C, et al. Lignan and flavonoids from the stems of *Zea mays* and their anti-inflammatory and neuroprotective activities. *Archives of Pharmacal Research*. 2015;**38**:178-185
- [82] Bacchetti T, Masciangelo S, Micheletti A, Ferretti G. Carotenoids, phenolic compounds and antioxidant capacity of five local Italian corn (*Zea mays* L.) kernels. *Journal of Nutrition & Food Sciences*. 2013;**3**:1
- [83] Edelman M, Colt M. Nutrient value of leaf vs. seed. *Frontiers in Chemistry*. 2016;**4**:1-5 Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4954856/>
- [84] Jung Y-J, Park J-H, Seo K-H, Shrestha S, Lee D-S, Kim Y-C, et al. Phenolic compounds from the stems of *Zea mays* and their pharmacological activity. *Journal of Korean Society for Applied Biological Chemistry*. 2014;**57**:379-385
- [85] Ahmed HM. Phytochemical screening, total phenolic content and phytotoxic activity of corn (*Zea mays*) extracts against some indicator species. *Natural Product Research*. 2018;**32**:714-718
- [86] Li P, Lapčík L, Lapčíková B, Kalytchuk S. Physico-chemical study of flavonoids from different matureness corn silk material. *Potravinárstvo Slovak Journal of Food Sciences*. 2018;**12**:347-354
- [87] Nurhanan AR, WR WI. Evaluation of polyphenol content and antioxidant activities of some selected organic and aqueous extracts of cornsilk (*Zea mays* hairs). *Journal of Medical and Bioengineering*. 2012;**1**:48-51
- [88] Solihah MA, Rosli WW, Nurhanan AR. Phytochemicals screening and total phenolic content of Malaysian *Zea mays* hair extracts. *International Food Research Journal*. 2012;**19**:1533
- [89] Muda RJ, Nurhanan AR, Rosli W, Mohsin S. Total polyphenol content and free radical scavenging activity of cornsilk (*Zea mays* hairs). *Sains Malays*. 2012;**41**:1217-1221
- [90] Singh NK, Sahu AN, Singh SK. Free radical scavenging and hepatoprotective activities of standardized methanolic extract of *Maydis stigma*. 2009
- [91] Simla S, Boontang S, Harakotr B. Anthocyanin content, total phenolic content, and anti-radical capacity in different ear components of purple waxy corn at two maturation stages. *Australian Journal of Crop Science*. 2016;**10**:675

- [92] Cevallos-Casals BA, Cisneros-Zevallos L. Stoichiometric and kinetic studies of phenolic antioxidants from Andean purple corn and red-fleshed sweetpotato. *Journal of Agricultural and Food Chemistry*. 2003;**51**:3313-3319
- [93] Ho YM, Wan Amir Nizam WA, Wan Rosli W. Antioxidative activities and polyphenolic content of different varieties of malaysian young corn ear and cornsilk. *SAINS Malays*. 2016;**45**:195-200
- [94] Laeliocattleya RA, Prasiddha IJ, Estiasih T, Maligan JM, Muchlisiyah J. The potential of bioactive compounds from corn silk (*Zea mays* L.) that result from gradual fractionation using organic solvents for the use as a natural sunscreen. *Jurnal of Teknologi Pertanian*. 2014;**15**(3):175-184
- [95] Ku KM, Kim HS, Kim SK, Kang Y-H. Correlation analysis between antioxidant activity and phytochemicals in Korean colored corns using principal component analysis. *The Journal of Agricultural Science*. 2014;**6**:1
- [96] Lopez-Martinez LX, Oliart-Ros RM, Valerio-Alfaro G, Lee C-H, Parkin KL, Garcia HS. Antioxidant activity, phenolic compounds and anthocyanins content of eighteen strains of Mexican maize. *LWT-Food Science and Technology*. 2009;**42**:1187-1192
- [97] Fidrianny I, Eriani Wulandari RH. In Vitro Antioxidant Activity of Different Organs Extracts of Corn Grown in Cimahi-West Java-Indonesia
- [98] Ramos-Escudero F, Muñoz AM, Alvarado-Ortíz C, Alvarado A, Yáñez JA. Purple corn (*Zea mays* L.) phenolic compounds profile and its assessment as an agent against oxidative stress in isolated mouse organs. *Journal of Medicinal Food*. 2012;**15**:206-215
- [99] Adedapo AA, Babarinsa OS, Ogunshe AAO, Oyagbemi AA, Omobowale TO, Adedapo AD. Evaluation of some biological activities of the extracts of corn silk and leaves. *Tropical Veterinarian*. 2013;**31**:12-32
- [100] Velazquez DVO, Xavier HS, Batista JEM, de Castro-Chaves C. *Zea mays* L. extracts modify glomerular function and potassium urinary excretion in conscious rats. *Phytomedicine*. 2005;**12**:363-369
- [101] Kılıç C, Can Z, Yılmaz A, Yıldız S, Turna H. Antioxidant properties of some herbal teas (green tea, senna, corn silk, rosemary) brewed at different temperatures. *International Journal of Secondary Metabolite*. 2017;**4**:142-148
- [102] Maksimović ZA, Kovačević N. Preliminary assay on the antioxidative activity of Maydis stigma extracts. *Fitoterapia*. 2003;**74**:144-147
- [103] Ozuruoke DF, Olaniyan MF, Temitope F. Changes in plasma level of LDH, CKMB and lipid profile in rabbits administered with corn silk extract. *American Journal of Biomedical Sciences*. 2016;**8**
- [104] Wu J, Ye M, Wang Z. Extraction, purification and anti-hyperlipidemic activities of total flavonoids from corn silk. *Pakistan Journal of Zoology*. 2017;**49**

- [105] Karami M, Saeidnia S, Naghshvar F. The hepatoprotective effects of corn silk against dose-induced injury of ecstasy (MDMA) using isolated rat liver perfusion system. *Iranian Journal of Toxicology*. 2013;7:808-815
- [106] Karami M, Saeed Nia S, Ebrahimzadeh MA, Amali Amiri M, Karami N. Study of therapeutic and histopathologic effects of corn silk's aqueous and metanolic extract against dosage induced by MDMA in isolated rat liver perfusion system. *ISMJ*. 2014;17:21-32
- [107] Karami M, Shokerzadeh M, Naghshvar F, Ala S, Fezbakhsh R, Nosrati A, et al. The renal protective effects of corn silk and feijoa by using in situ rat renal system. *Iran Journal of Toxicology*. 2014;8:1060-1067
- [108] Zhao H, Zhang Y, Liu Z, Chen J, Zhang S, Yang X, et al. Acute toxicity and anti-fatigue activity of polysaccharide-rich extract from corn silk. *Biomedicine & Pharmacotherapy*. 2017;90:686-693
- [109] Morshed S, Islam SS. Antimicrobial activity and phytochemical properties of corn (*Zea mays* L.) silk. *SKUAST Journal of Research*. 2015;17:8-14
- [110] Catap ES, Jimenez MRR, Tumbali MPB. Immunostimulatory and anti-oxidative properties of corn silk from *Zea mays* L. in Nile tilapia, *Oreochromis niloticus*. *International Journal of Fisheries and Aquaculture*. 2015;7:30-36
- [111] Okokon JE, Nyong ME, Essien GE, Nyong E. Nephroprotective activity of husk extract and fractions of *Zea mays* against alloxan-induced oxidative stress in diabetic rats. *Journal of Basic Pharmacology and Toxicology*. 2017;1:1-10