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Health benefits of Maize phytochemicals

KAMALJEET KAUR MANN
Lecturer in Food and Nutrition
Ch. BRG. Govt. Girls College, Sriganganagar (Rajasthan) India

ABSTRACT

Objective: Maize also known as golden grain, contains lots of nutrients and phytochemicals. These phytochemicals derived from the maize and their health benefits have recently become the major cause of research studies. Thus, main objective of this Review is to discuss the major phytochemical compounds in maize and their health promoting effects, in order to better understand the nutritional and health benefits of maize and consequently improve the consumption.

Conclusion: Maize is considered as magic golden grain rich in many nutrients, phytochemicals and phytosterols. These phytochemicals possess antioxidant characteristics. Along with nutritional importance, another important part of maize plant, known as maize silk has a great medicinal importance due to presence of various bioactive compounds. These phytochemicals make maize plant a medicinal plant which shows various biological properties particularly the antioxidant activity. Due to high oxidant potential, all parts of the maize can be used for the management of oxidative stress and treatment of cancer, cardiovascular disease & diabetes mellitus and various other diseases.

Key Words : *Zea mays*, Phytochemicals, RS (Resistant starch), Phytosterolsanthocyanins, Antioxidants, Zein, Fiber, Flavonoids, Phenolic acids

INTRODUCTION

Maize is a monocotyledonous plant cultivated widely around the world and has constituted itself in one very common staple food. Maize and its wild variant , teosinte , belongs to the Poaceaefamily, of the Maydeas tribe; species of the Tripsacumgenus are wild variants of maize, also originating in the American continent, but without any direct trade value. This family also includes important agricultural crops, such as wheat, rice, sorghum,barley, and sugarcane. Based on the characteristics of the ear or male inflorescence, the Zea genus divides into two sections, luxurians and annuals. (1) Although the consumption of Maize can be traced back to the fifteencenturies, maize has drawn increasing attention globally due to its nutritional composition, bioactive compounds, and phytochemicals along with potential health promoting benefits found in the most recent decades. Most phytochemicals in maize present in bran and germ fractions instead of the endosperm fraction. Human clinical trials, epidemiological studies, and some animal studies have implicated that regular consumption of maize and its derived whole grain products is associated with reduced risk of developing chronic diseases such as cardiovascular disease, type 2 diabetes mellitus and obesity. The high amylose content in maize contributes to the digestive health by its nature of resistance to digestion thus bringing bioactive

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compounds to the colon. Therefore, dietary modifications of increasing maize and other whole grains and millets consumption is a practical strategy to optimize health and reduce the risk of chronic diseases.

Table 1 : Fatty acid content of Guatemalan maize varieties and Nutricta QPM (%)

Maize variety	C16:0 Palmitic	C18:0 Stearic	C18:1 Oleic	C18:2 Linoleic	C18:3 Linolenic
QPM Nutricta	15.71	3.12	36.45	43.83	0.42
Azotea	12.89	2.62	35.63	48.85	-
Xetzoc	11.75	3.54	40.07	14.65	
Tropical white	15.49	2.40	34.64	47.47	-
Santa Apolonia	11.45	3.12	38.02	47.44	-

Table 2 : Soluble and insoluble dietary fibre in common and quality protein maize (%)

Maize type	Dietary fibre		
	Insoluble	Soluble	Total
Highland	10.94±1.26	1.25±0.41	12.19±1.30
Lowland	11.15±1.08	1364±0.73	12.80±1.47
QPM Nutricta	13.77	1.14	14.91

Table 3 : Neutral and acid detergent fibre, hemicellulose and lignin in five maize varieties (%)

Maize No.	Neutral detergent fibre	Acid detergent fibre	Hemicellulose	Lignin	Cellular walls
1.	8.21	3.23	4.98	0.14	9.1
2.	10.84	2.79	8.05	0.12	10.8
3.	9.33	3.08	6.25	0.13	12.0
4.	11.40	2.17	9.23	0.12	13.1
5.	14.17	2.68	11.44	0.14	14.2
Average	10.79±2.27	2.79±0.44	8.00±2.54	0.13±0.01	11.8±2.0

Source : Bressani, Breuner and Ortiz, 1989

Table 4 : Mineral content of maize (Average of five sample)

Mineral	Concentration (mg/100 g)
P	299.6+57. 8
K	324.8+33.9
Ca	48.3+12.3
Mg	107.9+9.4
Na	59.2+4.1
Fe	4.8+1.9
Cu	1.3+0.2
Mn	1.0+0.2
Zn	4.6+1.2

Source : Bressani, Breuner and Ortiz, 1989

Table 5 : Protein quality of maize and other cereal grains

Cereal	Protein quality (% casein)
Common maize	32.1
Opaque-2 maize	96.8
QPM	82.1
Rice	79.3
Wheat	38.7
Oats	59.0
Sorghum	32.5
Barley	58.0
Pearl Millet	46.4
Finger millet	35.7
Teff	56.2
Rye	64.8

Table 6 : Vitamin content of raw maize and tortillas (mg/100 g)

Product	Thiamine	Riboflavin	Niacin	Folic acid	Panthothenic acid	Vitamin H	Carotene	Total carotenoids
Raw maize								
White	0.38	0.19	2.00	-	-	-	-	-
Yellow	0.48	0.10	1.85	-	-	-	0.30	1.32
White	0.34	0.08	1.64	-	-	-	0.15	-
Tortillas								
White	0.10	0.014	1.01	-	-	-	-	-
Yellow	0.11	0.05	1.01	-	-	-	0.12	0.41
White	0.19	0.09	0.96	-	-	-	0.06	-
Industrial	0.13	0.08	1.11	-	-	-	-	-
Industrial	0.07	0.04	1.61	0.014	0.24	0.12	-	-
Industrial	0.08	0.05	2.11	0.015	0.16	0.27	-	-

Source : Bressani, Paz y Paz and Scrimshaw, 1958; Cravioto et al., 1945; Ranhotra, 1984; Saldana and Crown, 1984.

Maize is rich in phytochemicals including phenolic acids, flavonoids, fiber, and resistant starch that are complementary to those in fruits, vegetables and other whole grains when consumed together. (2) The benefits of resistant starch in maize have been well studied, and a moderate intake of RS (about 10 gm/ day) from maize starch has benefits on reducing glucose and insulin response, and a higher intake of RS (20gm / day) from maize starch promotes the digestive health. There is a lack of research on many othermaize phytochemicals such as phenolic acids and flavonoids. Further Research on the health benefits of phytochemicals in maize and sweet corn are warranted. Whole grain has a wide range of phytochemicals exhibiting health benefits of lowering risk of chronic diseases.

Nutritional value: As commonly consumed grain product, maize has unique profiles of nutrients and phytochemicals when compared with other whole grains. Maize nutrients and phytochemicals include vitamins (A, B, E, K) ,minerals(Mg, P,& K) ,phenolic acids (ferulicacid, coumaric acid, and syringicacid), carotenoids & flavonoids (anthocyanins), and dietary fiber. More and more scientific evidences have shown that regular consumption of whole grain maize lowers the risk of developing chronic diseases such as cardiovascular disease, type 2 diabetes, and obesity and improves digestive

Table 7 :

Corn part	Class of phytochemicals	Phytochemical compounds
Corn silk	Polyphenols	Tannins, saponins, flavonoids, alkaloids, steroids, cardiac glycosides, allantoins, anthocyanins, hesperidin, and reins
	Phenolic acids	Para-aminobenzoic acid (PABA), vanillic aicd, p-coumaric acid, chlorogenic acid, protocatechuic acid, caffeic aicd, ferulic acid, maizenic acid, hydroxycinnamic acid ester, and 3-O-caffeoylquinic acid
	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-deoxyglucosyle-3-methoxy luteolin and 6,4-dihydroxy-3-methoxyflavone-7-O-glucoside. Isoorientin-2-2-O- α -rhamnoside, cardiac glycosides 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-6-C-(6-deoxy-xylo-hexos-4-ulosyl)-luteolin-3'-methylether, kaempferol Maysins: Rhamnosyl-6-C-(4-ketofucosy)-5, 7, 3'4'-tetrahydroxylflavone, 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, cis-sabinene hydrate, 6,11-oxidoacor-4-ene, citronellol, trans-pinocamphone, cis-sabinene hydrate, cis-R-terpineol, and neo-iso-3-thujanol
	Vitamins	Vitamin C, vitamin K, vitamin E
	Sugars	Dextrose, xylose
	Miscellaneous compounds	Polysaccharides (galactan), geraniol, limonene, terpenoids, α -terpineol, citronellol, Trans-pinocamphone, formononetin, apigenin, pelargonidin, anthraquinones, hordenine, Xanthoproteins,
Cron seeds	Polyphenols	Tannins, saponins, rutin, allantoins, 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
	Flavonoids	Anthocyannins, quercetin, and catechin
	Carotenoids	Cartotenes inclding lutein, cyclosadol, β-cryptoxanthin, zeaxanthin, α -and β -carotene, α and β -cryptoxanthin
	Anthocyanins	Cyanogenic glycosides including pelargonidin-3-glucoside, cyaniding-3-glucoside, and peonidin-3-glucoside

Table 7 contd..

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	Vitamins	Vitamin E (tocopherols), vitamin B (biotin, riboflavin, pantothenic acid, folic acid, niacin, pyridoxine, thiamine), vitamin C
	Miscellaneous compounds	Polysaccharide, sugars, proteins, inositols, resins, hexaphosphoric and maizenic acids, 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

Source : www.intechopen.com

Table 8 : Gross chemical composition of different types of maize (%)

Maize type	Moisture	Ash	Protein	Crude fibre	Ether extract	Carbohydrate
Salpor	12.2	1.2	5.8	0.8	4.1	75.9
Crystalline	10.5	1.7	10.3	2.2	5.0	70.3
Floury	9.6	1.7	10.7	2.2	5.4	70.4
Starchy	11.2	2.9	9.1	1.8	2.2	72.8
Sweet	9.5	1.5	12.9	2.9	3.9	69.3
Pop	10.4	1.7	13.7	2.5	5.7	66.0
Black	12.3	1.2	5.2	1.0	4.4	75.9

Source : Cortez and Wild-Altamirano, 1972

health. Further research on bioactive compounds of maize related to health are needed. (3)

Different maize (*Zea mays* L.) varieties including pigmented maize have been used for centuries as a healthy food source all around the world. Maize ingestion could contribute to the reduction in the rate of non – communicable diseases and, in turn, to its function as an adjuvant in their management. These diseases are mainly associated with oxidative stress, which is characterized by a redox cell imbalance produced due to pro – oxidant molecules accumulation, including irreversible damages. Although the endogenous antioxidant defense system is efficient, exogenous antioxidants are necessary to help to prevent this damage. Bioactive compounds, like anthocyanins, contained in dietary plants exert a major activity against oxidative stress. Studies shows that the maize anthocyaninsplay a curative, preventive or complementary role in the management of chronic diseases.

Maize is rich source of dietary fiber specifically maize kernels consists mainly of fiber, ranging from 61 to 86 %, depending on the variety of the plant. Approximately 99% of the fiber is found in the endosperm and consists of starch (approximately 73% of the total weight), and the rest of resistant starch. The kernel also contains non – starch polysaccharides such as cellulose, hemicellulose, and, to a lesser extent, lignin (approximately 10 % of the total weight), location mainly in the bran. Depending on the variety 6 to 12 % protein present in maize, calculated on the dry basis, while lipids represent around 3 to 6 %. Out of these 81 to 85 % is stored in the germ.

Maize main protein is known as Zein, considered as a low quality protein because absence of essential amino acids. Due to the water insolubility of maize proteins, its potential health benefits are limited; however, late technological advances have allowed to obtain peptides by hydrolysis in order to improve their bioavailability. (3)

All maize types are rich in dietary fiber, vitamins, minerals, phenolic acids and flavonoids, plant sterols and other phytochemicals (lignin and bound phytochemicals). However, different varieties of maize contain significantly different phytochemical profiles in terms of flavonoids and carotenoids.

Blue, red and purple maize possess higher concentration of anthocyanidins (up to 325mg/100gm DW) including cyanidin derivatives (75- 90 %), peonidin derivatives (15 – 20 %) and pelargonidinderivatives (5 – 10 %). Yellow maize is rich in carotenoids (up to 823microgm/ 100gm) including lutein (50%), Zeaxanthin (40%),Beta -cryptoxanthin (3%), Beta- carotene (4%), and alpha- carotene (2%).High amylose maize is rich in amylose (up to 70% of all carbohydrates)(4) Therefore, the consumption of combined different maize varieties provides wide range of phytochemicals with optimum nutritional benefits from maize.

Like all other cereal crops, maize protein, even though possess at reasonably high level is deficient in essential amino acids like lysine and tryptophan content. In more recent years opaque 2 hybrids and composite varieties developed in several countries have been shown to have twice the lysine and tryptophan content. In India, also three nutritionally superior opaque- 2 composite varieties (Shakti, Ratan, and Protima) developed in India were released for commercial cultivation in 1970.

Under poor storage condition, maize grain develop mold which upon eating are extremely harmful to the consumer and may even prove fatal. Unlike local maize varieties, Shaktiand Ratanwas shown to be resistant to the production of toxin even if it was infected with the fungus. The opaque strains thus in addition to avoiding the hazards of toxins would also promote better growth and development.

Maize phytochemicals:

Phytochemicals are chemicals of plant origin. This word is derived from Greek word phyto, meaning “plant”. Phytochemicals are chemicals produced by plants through primary or secondary metabolism. They generally have biological activity in the plant host and play a role in plant growth or defense against competitors, pathogens, or predators. Maize contain wide variety of phytochemicals, some of them act as antioxidants, neutralizing free radicals and removing their power to create damage. These phytochemicals reported to provide various biological functions in humans. In particular, plant pigment phytochemicals, carotenoids, and flavonoids, are the most extensively studied phytochemicals for their antioxidant functions as well as potential preventive medicinal benefits such as maintaining inflammation balance, reducing the risk of certain cancers, and promoting cardiovascular, neurocognitive, eye, and bone health in humans.(5)All parts of corn plant are good source of a variety of bioactive phytochemical compounds which possess antioxidant potential. The principal phytochemicals present in maize 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 maize 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 maize plant can be used for the management of oxidative stress and the treatment of various diseases.(6)

Maize Phytochemicals are bioactive chemicals naturally present in maize plant and have the potential for reducing the risk of major chronic diseases. Maize contains various major phytochemicals such as carotenoids, phenolic acids and phytosterols.

Carotenoids: Carotenoids belong to a family of red, orange, and yellow pigments. Yellow maize grain contains large amounts of carotenoids pigments. These pigments are divided into two classes: Carotenes, which are purely hydrocarbons containing no oxygen, and Xanthophylls(Lutein and Zeaxanthin)which are hydrocarbons containing oxygen. Carotenoids plays important role in vision process.

Xanthophylls: Unlike other carotenoids, Xanthophylls(Lutein and Zeaxanthin) cannot be converted into Vitamin A.

Vitamin E: Maize contains both tocopherol and tocotrienols. Tocotrienolshave stronger function

in preventing cancer and cardiovascular diseases as compared to tocopherols. Vitamin E also improves immune system function and repairs DNA function. (12)

Phenolic Compounds: These compounds are specified as phenolic acids, flavonoids, stilbenes, coumarins, and tannins. (7) These compounds are present in bran of maize grain. Maize contains two main phenolic compounds ferulic acid and anthocyanins. Anthocyanins collectively known as flavonoids. They are Reddish to purple colourwater soluble plant pigments. Maize has the highest concentration of anthocyanins.

Phytosterols: They are present in maize plant cell wall. More than 250 different phytosterols have been found so far. Maize oil is very rich in phytosterols. The most common phytosterols in maize oil are sitosterol, stigmasterol, and campesterol. Their distribution varies in different fractions of maize kernel such as endosperm, pericarp, and germ.(8) The endosperm of maize contains highest level of phytostanols. High intake of plant sterols (1.6 mg per day) can lower serum LDL and total cholesterol levels in humans.(13) The proposed mechanism is that phytosterols and cholesterol compete for the micelle formation in the intestine, thus inhibiting the absorption of cholesterol. (14)

Maize has various health benefits. Maize contains appreciable amounts of vitamin B complex, which are good for heart, brain, skin, hair and digestive system. These B complex vitamins play important role in joint mobility, hence they believe to prevent the symptoms of rheumatism. Maize contains Appreciable amounts of vitamin A, C, K, beta carotene and selenium. These nutrients improves immune system and thyroid function. Maize is a rich source of potassium, which act as a powerful diuretics. In different countries including India, maize silk is used as a medicine in treating Kidney stones, urinary tract infections, jaundice and oedema. It also has a potential to improve blood pressure, support liver functioning, and produce bile. It acts as a good emollient for wounds , swelling and ulcers. Decoction of silk, roots, and leaves are used for bladder problems, nausea, and vomiting, while decoction of cob is used for stomach complaints.(9)

Previously, phytochemicals of maize have received less attention than these of fruits and vegetables. The consumption of maize and other whole grains has been linked to the reduced risk of chronic diseases including cardiovascular disease, diabetes, obesity, carcinoma and gastrointestinal disorders. The health benefits of maize is not only due to basic macronutrients and micronutrients, but also from their unique phytochemical profile such as phenolic acids and phytosterols. The major components of maize kernel include endosperm, germ and bran, and each part contains different phytochemical compounds. Along with the health promoting compounds such as amylase in maize endosperm, a wide range of phenolic acids such as vannilicacid, syringic acid, courmaric acid,ferulic acid and caffeic acid are found in maize bran and germ. Approximately 87% of total phenolic content present in bran and germ. Thus endosperm and bran contains higher bioactive compounds than refined corn starch and refined corn oil.(10) Maize has the highest antioxidant activity among all common grains such as rice, wheat, and oats.(10) phytochemicals are the major contributors to the total antioxidant activity in maize. Principal phenolic acids are flavonoids and ferulic acid.87% of them are present in bound form as niacin present in bound form .Thermal processing increases the antioxidant activity of sweet corn by releasing bound form phytochemicals.(11)

Conclusion:

Maize is considered as magic golden grain rich in many nutrients , phytochemicals and phytosterols. These phytochemicals possess antioxidant characteristics. Along with nutritional importance, another important part of maize plant, known as maize silk has a great medicinal importance due of pressure of various bioactive compounds. These phytochemicals present in maize silk are phenolic acids, polyphenols, flavonoids, anthocyanins, glycosides, carotenoids, and some water soluble vitamins. These phytochemicals make maize plant a medicinal plant which shows various biological properties particularly the antioxidant activity. Due to high oxidant potential, all parts of the

maize can be used for the management of oxidative stress and treatment of cancer, cardiovascular disease & diabetes mellitus and various other diseases. More and more scientific researches have shown that regular consumption of whole grain maize lowers the risk of developing chronic degenerative diseases such as type 2 diabetes mellitus and cardiovascular disease &cancer. It also helps in reducing weight and improves digestive health. Further studies on phytochemicals of maize related to health are needed.

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