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## FOOD SCIENCE & TECHNOLOGY | REVIEW ARTICLE

# Maize—A potential source of human nutrition and health: A review

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**Abstract:** Maize or corn (*Zea mays* L.) is an important cereal crop of the world. It is a source of nutrition as well as phytochemical compounds. Phytochemicals play an important role in preventing chronic diseases. It contains various major phytochemicals such as carotenoids, phenolic compounds, and phytosterols. It is believed to have potential anti-HIV activity due to the presence of Galanthus nivalis agglutinin (GNA) lectin or GNA-maize. A tablespoon of maize oil satisfies the requirements for essential fatty acids for a healthy child or adult. Decoction of maize silk, roots, leaves, and cob are used for bladder problems, nausea, vomiting, and stomach complaints. Zein an alcohol-soluble prolamine found in maize endosperm has unique novel applications in pharmaceutical and nutraceutical areas. Resistant starch (RS) from maize reduces the risk of cecal cancer, atherosclerosis, and obesity-related complications. This review presents a detailed view on the nutritional and potential health benefits of maize.

**Subjects:** Food Additives & Ingredients; Food Chemistry; Product Development

**Keywords:** *Zea mays* L.; phytochemicals; carotenoids; phenolic compounds; phytosterols; GNA-maize

### 1. Introduction

Maize or corn (*Zea mays* L.) is an important annual cereal crop of the world belonging to family Poaceae. *Zea* is an ancient Greek word which means “sustaining life” and *Mays* is a word from Taino language meaning “life giver.” The word “maize” is from the Spanish connotation “maiz” which is the best way of describing the plant. Various other synonyms like *zea*, silk maize, makka, barajovar, etc. are used to recognize the plant (Kumar & Jhariya, 2013). It is considered as a staple food in many

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### PUBLIC INTEREST STATEMENT

Due to increasing population there is more food demand, therefore maize can satisfy the food requirements as well as provide human nutrition along with number of health benefits. Thus, the aim of the present review was to provide necessary information regarding the nutritive and health benefits of maize so that people will start taking more interest to it and its consumption as a good food source will increase.

parts of the world. It is a third leading crop of the world after rice and wheat (Sandhu, Singh, & Malhi, 2007). The world production of maize was 967 million metric tons (MMT) and in India its production was 23 MMT in 2013–14 (India maize summit, 2014). Due to its highest yield potential among the cereals it is known globally as queen of cereals. The largest producer of maize is United States of America (USA) contributing about 35% of the total world maize production. It is known as mother grain of Americans and it is the driver of the US economy. In India, the major maize growing states are Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Punjab, Haryana, Maharashtra, Andhra Pradesh, Himachal Pradesh, West Bengal, Karnataka, and Jammu and Kashmir, jointly accounting for over 95% of the national maize production (Milind & Isha, 2013). Maize is generally used for animal feed. It is widely processed into various types of products such as cornmeal, grits, starch, flour, tortillas, snacks, and breakfast cereals. Maize flour is used to make chapatis or flat breads which are eaten mainly in a few Northern states of India (Mehta & Dias, 1999). Due to increasing attention being drawn towards the development of nutraceuticals, the phytochemical compounds derived from maize and their health properties have recently become the major focus of studies. Thus, this review aims to discuss the major phytochemical compounds in maize and their health-promoting effects, in order to better understand the nutritional and health potential of maize and consequently improve its consumption.

## 2. Taxonomy of maize

Kingdom: Plantae

Subkingdom: Tracheobionta

Superdivision: Spermatophyta

Division: Magnoliophyta

Class: Liliopsida

Subclass: Commelinidae

Order: Cyperales

Family: Poaceae

Subfamily: Panicoideae

Tribe: Andropogoneae

Genus: *Zea*

Species: *Zea mays*

The genus *Zea* consists of four species of which *Zea mays* L. is economically important. The other *Zea* species, referred to as teosintes, are largely wild grasses native to Mexico and Central America. The number of chromosomes in *Zea mays* is  $2n = 20$ . The tribe Andropogoneae comprises seven genera, namely old and new world groups. Old world comprises *Coix* ( $2n = 10/20$ ), *Chionachne* ( $2n = 20$ ), *Sclerachne* ( $2n = 20$ ), *Trilobachne* ( $2n = 20$ ), and *Polytoxa* ( $2n = 20$ ), and new world group has *Zea* and *Tripsacum* (*Biology of maize*, 2011).

## 3. Nutritional value of maize

Maize kernel is an edible and nutritive part of the plant. The composition of maize kernel is presented in Table 1. It also contains vitamin C, vitamin E, vitamin K, vitamin B<sub>1</sub> (thiamine), vitamin B<sub>2</sub> (niacin), vitamin B<sub>3</sub> (riboflavin), vitamin B<sub>5</sub> (pantothenic acid), vitamin B<sub>6</sub> (pyridoxine), folic acid, selenium, N-p-coumaryl tryptamine, and N-ferrulyl tryptamine. Potassium is a major nutrient present which has a good significance because an average human diet is deficient in it (Kumar & Jhariya, 2013). Roasted maize kernels are also used as coffee substitute (Breadley, 1992).

Maize germ contains about 45–50% of oil that is used in cooking, salads and is obtained from wet milling process (Orthofer, Eastman, & List, 2003). The oil contains 14% saturated fatty acids, 30%

**Table 1. Composition per 100 g of edible portion of maize**

Carbohydrate	71.88 g
Protein	8.84 g
Fat	4.57 g
Fiber	2.15 g
Ash	2.33 g
Moisture	10.23 g
Phosphorus	348 mg
Sodium	15.9 mg
Sulfur	114 mg
Riboflavin	0.10 mg
Amino acids	1.78 mg
Minerals	1.5 g
Calcium	10 mg
Iron	2.3 mg
Potassium	286 mg
Thiamine	0.42 mg
Vitamin C	0.12 mg
Magnesium	139 mg
Copper	0.14 mg

Source: Shah, Prasad, and Kumar (2015); Gopalan, Rama Sastri, and Balasubramanian (2007).

monounsaturated fatty acids, and 56% polyunsaturated fatty acids. The refined maize oil contains linoleic acid 54–60%, oleic acid 25–31%, palmitic acid 11–13%, stearic acid 2–3% and linolenic acid 1% (CRA, 2006). The two main forms of vitamin E present in our diet are alpha ( $\alpha$ ) and gamma ( $\gamma$ ) tocopherols. Maize oil is amongst the rich sources of these tocopherols, especially  $\gamma$ -tocopherol and their reported concentration was 21.3 and 94.1 mg/100 g, respectively (Sen, Khanna, & Roy, 2006). Maize silk contains various constituents essential for our diet such as maizenic acid, fixed oils, resin, sugar, mucilage, salt, and fibers (Kumar & Jhariya, 2013).

#### 4. Phytochemical value of maize

Phytochemicals are bioactive chemical compounds naturally present in plants that provide human health benefits and have the potential for reducing the risk of major chronic diseases (Liu, 2004). Maize is an essential source of various major phytochemicals such as carotenoids, phenolic compounds, and phytosterols (Jiang & Wang, 2005; Kopsell et al., 2009; Lopez-Martinez et al., 2009). The concentration of carotenoids, phenolic compounds, and phytosterols is presented in Table 2.

##### 4.1. Carotenoids

Carotenoids belong to a family of red, orange, and yellow pigments. There is a large quantity of carotenoid pigments present in yellow maize grains, especially in horny and floury endosperm (Liu, 2007). 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.

##### 4.2. Phenolic compounds

Phenolic compounds are most widely distributed category of phytochemicals in the plant kingdom (Saxena, Saxena, Nema, Singh, & Gupta, 2013). They are specified as phenolic acids, flavonoids, stilbenes, coumarins, and tannins (Liu, 2004). These compounds are abundantly present in maize, especially in bran (Zhao, Egashira, & Sanada, 2005). The major phenolic compounds from maize are ferulic acid (FA) or 4-hydroxy-3-methoxycinnamic acid and anthocyanins. Refined corn bran contains the

**Table 2. Concentration of major phytochemical compounds of maize per 100 gm**

Compounds	Concentration (mg/100gm)	References
<b>(1) Carotenoids</b>		
(a) Carotene	2.20	Watson and Ramstad (1987)
(b) Xanthophylls	2.07	Moros, Darnoko, Cheryan, Perkins, and Jerrell (2002)
(i) Lutein	1.50	
(ii) Zeaxanthin	0.57	
<b>(2) Phenolic compounds</b>		
(a) Ferulic acid (FA)	174	Zhao et al. (2005)
(b) Anthocyanins	141.7	Salinas-Moreno, Soto-Hernández, Martínez-Bustos, González-Hernández, and Ortega-Paczka (1999)
<b>(3) Phytosterols</b>		
(a) Sitosterol	9.91	Locatelli and Berardo (2014)
(b) Stigmasterol	1.52	
(c) Campesterol	3.40	

highest FA content, followed by barley and wheat (Zhao & Moghadasian, 2008). Anthocyanins are common class of phenolic compounds collectively known as flavonoids. They are the largest group of water-soluble plant pigments which are reddish to purple in color. Maize has the second highest concentration of anthocyanins (Abdel-Aal, Young, & Rabalski, 2006). The most abundant anthocyanin compounds reported in maize are, pelargonidin-3-glucoside, peonidin-3-glucoside, pelargonidin-3-(6"-malonylglucoside), cyanidin-3-glucoside, cyanidin-3-(3", 6"-malonylglucoside) and cyanidin-3-(3", 6" dimalonylglucoside) (Salinas Moreno, Sanchez, Hernandez, & Lobato, 2005).

#### 4.3. Phytosterols

Phytosterols also called as plant sterols are the essential components of plant cell walls and membranes (Piironen, Lindsay, Miettinen, Toivo, & Lampi, 2000). More than 250 different phytosterols have been found so far which are divided into three classes based on their number of methyl groups at C-4 position: simple sterols or 4-desmethylsterols, 4, 4-dimethylsterols, and 4-monomethylsterols. Maize oil is very rich in phytosterols (Verleyen et al., 2002). The most commonly consumed phytosterols from maize oil are sitosterol, stigmasterol, and campesterol. Their distribution varies in different fractions of maize kernel such as endosperm, pericarp, and germ (Harrabi et al., 2008).

#### 5. Health benefits of maize

Maize has various health benefits. The B-complex vitamins in maize are good for skin, hair, heart, brain, and proper digestion. They also prevent the symptoms of rheumatism because they are believed to improve the joint motility. The presence of vitamins A, C, and K together with beta-carotene and selenium helps to improve the functioning of thyroid gland and immune system. Potassium is a major nutrient present in maize which has diuretic properties. Maize silk has many benefits associated with it. In many countries of the world such as India, China, Spain, France and Greece it is used to treat kidney stones, urinary tract infections, jaundice, and fluid retention. 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 (Kumar & Jhariya, 2013).

The presence of essential fatty acids, especially linoleic acid in maize oil plays an important role in the diet by maintaining blood pressure, regulating blood cholesterol level, and preventing cardiovascular maladies (Dupont et al., 1990; Birringer, Pfluger, Kluth, Landes, & Flohe, 2002; Sen et al., 2006). Moreover a tablespoon of maize oil satisfies the requirements for essential fatty acids for a healthy child or adult (CRA, 2006). Vitamin E in maize oil which is known as a key chain breaking antioxidant

prevents the promulgation of oxidative stresses in biological membranes and prevents the development of atherosclerosis through intervention of maize oil in the diet (Lemcke-Norojarvi et al., 2001; Ricciarelli, Zingg, & Azzi, 2001).

Maize is believed to have potential anti-HIV activity due to the presence of *Galanthus nivalis* agglutinin (GNA) lectin also referred as GNA-maize. Lectins are special proteins that can bind onto carbohydrates or carbohydrate receptors found on cell membranes. In some micro-organisms including the HIV virus, the binding of lectins onto sugars is believed to inhibit activity of the virus. Zein an alcohol-soluble prolamine is an important component found in maize endosperm. It is GRAS (generally recognized as safe), nontoxic, and biodegradable protein. It possesses great potential to provide important health benefits to human beings. It acts as a nanoscale biomaterial that has unique solubility and film-forming properties. It has novel applications in pharmaceutical and nutraceutical areas to coat nanoparticles, develop promising nanocomposite antimicrobial agents, produce novel food packaging, encapsulate nutrients, and provide target delivery with controlled release (Fernandez, Torres-Giner, & Lagaron, 2009; Jin, Davidson, Zivanovic, & Zhong, 2009; Lai & Guo, 2011; Luo, Zhang, Cheng, & Wang, 2010; Luo, Zhang, Whent, Yu, & Wang, 2011; Sanchez-Garcia, Hilliou, & Lagaron, 2010; Zhang et al., 2010).

Resistant starch (RS) from maize, also called as high-amylose maize has various health beneficial effects. Maize endosperm contains 39.4 mg/100 g RS (Jiang, 2010). It escapes digestion and its consumption helps in altering microbial populations, lowering cholesterol and enhancing its fecal excretion, increasing the fermentation and short-chain fatty acid production in large intestine, reducing symptoms of diarrhea, which altogether reduce the risk of cecal cancer, atherosclerosis, and obesity-related complications (Murphy, Douglass, & Birkett, 2008). RS enhances the desirable composition of colonic bacteria in mice therefore might possess potential prebiotic properties (Wang et al., 2002). Its consumption influences cholesterol metabolism, lowers body fat storage therefore reduces the risk of atherosclerosis, hyperlipidemia, diabetes, and obesity (Higgins, 2004). It can significantly shorten the intestinal transit time that leads to elimination of waste material through feces in a quicker time (Kim, Chung, Kang, Kim, & Park, 2003).

RS as dietary fiber helps in weight control as it reduces the food intake by diluting energy density of the diet as well as by modulating certain gene expressions. A study was carried on rats which explained that the inclusion of RS from maize in their diet can affect the energy balance through its effect as a fiber, a stimulator of gut peptide tyrosine-tyrosine (peptide YY), an expressor of glucagon-like peptide-1, as well as other genes in hypothalamic area of brain which are the key factors for maintaining energy homeostasis and reducing the food intake by increasing satiety (Keenan et al., 2006; Shen et al., 2009). Another investigation was carried out to examine the effects of different high-fiber foods on the satiety of healthy human subjects. The results showed that eating muffins containing RS and maize bran had a major impact on satiety compared with foods containing other fibers (Willis, Eldridge, Beiseigel, Thomas, & Slavin, 2009). RS has also been suggested to be potentially beneficial for improving insulin sensitivity in both animal and human subjects (Deng et al., 2010; Johnston, Thomas, Bell, Frost, & Robertson, 2010).

Maize is an essential source of various phytochemicals that play an important role in our health (Kopsell et al., 2009). There is inverse correlation between the consumption of phytochemicals and the development of chronic diseases. The phytochemicals in whole grains have received less attention and sometimes been underestimated. The research has suggested that phytochemicals in grains due to their potent antioxidant activities demonstrate significant beneficial contribution in reducing the risk of many diseases (Liu, 2007; Madhujith & Shahidi, 2007; Shahidi, 2009). Maize grains, especially yellow variety contains large quantities of the carotenoid pigments and has a vital significance in the diet as human beings are not able to biosynthesize carotenoids. These pigments are also beneficial in preventing cancer (Michaud et al., 2000).

Carotene has many health benefits associated with it. Yellow maize, maize silage, and stalklage has carotene content of 22, 17.3, and 6.5 mg/kg, respectively (Watson & Ramstad, 1987). Alpha ( $\alpha$ ) and beta ( $\beta$ ) carotene possess provitamin A activity. High concentration of  $\beta$ -carotene has been observed to act as a pro-antioxidant and induces apoptosis of colon cancer cells, leukemia cells, melanoma cancer cells, and gastric cancer cells, thus rendering potent chemopreventive effect (Jang, Lim, & Kim, 2009; Palozza et al., 2003, 2001). However a diet with a high dose of  $\beta$ -carotene might not be appropriate for smokers because it is believed to increase chances of lung cancer incidences (Alpha-Tocopherol Beta Carotene Cancer Prevention Study Group, 1994; Duffield-Lillico & Begg, 2004).

Xanthophylls (lutein and zeaxanthin) in maize have some pivotal and specific biological functions. Lutein supplementation in food at dose-dependent manner increases tumor latency, inhibits mammary tumor growth, enhances lymphocyte proliferation, lowers the incidence of palpable tumor, and significantly protects cells against oxidant-induced damages (Chew, Wong, & Wong, 1996). Lutein and zeaxanthin are found to be the only carotenoids in the macula of the retina that are responsible for sharp and detailed vision. They also appear to protect humans against phototoxic damage; also play a role in protection against age-related macular degeneration and age-related cataract formation. Supplementing lutein to the subjects diets for a period showed a significant enhancement in macular pigment optical density and notable protection of the macula from light damage (Landrum, Bone, & Kilburn, 1997). Lutein also acts as a cancer chemopreventive suppressing agent by presenting inhibitory actions during promotion of disease (Moreno et al., 2007).

FA has promising health benefits (Zhao et al., 2005). It has potent antioxidant properties and protects the cell membranes against oxidation. The various benefits of FA derived from maize include anticancer, anti-inflammatory, preventive effects against bone loss, anti-diabetic, and hepatoprotective effects (Balasubashini, Rukkumani, Viswanathan, & Menon, 2004; Kawabata et al., 2000; Ou, Kong, Zhang, & Niwa, 2003; Rukkumani, Aruna, Varma, & Menon, 2004; Sassa et al., 2003).

Anthocyanins have been well known for their health-promoting benefits such as anti-carcinogenic, anti-atherogenic, lipid lowering, anti-diabetic, antimicrobial, and anti-inflammatory properties. Due to the potent antioxidant properties they are able to decrease capillary permeability and fragility, immune system stimulation, and inhibit platelet aggregation (Ghosh & Konishi, 2007). The consumption of anthocyanins from purple maize at 5% dietary level during 36-week administration period demonstrated a pronounced inhibition of colorectal carcinogenesis in male rats showing that the lesion development of colon was significantly suppressed (Hagiwara et al., 2001). The dietary administration of purple maize pigment has been reported to have anti-hypertensive effects on spontaneously hypertensive male rats through lowering the systolic blood pressure (Shindo, Kasai, Abe, & Kondo, 2007). The pigments from black glutinous maize cob have shown to possess potent anti-hyperlipidemic effects in high-fat-fed mice by improving the serum lipids profile and reducing the atherogenic index (Zhang et al., 2010).

Phytosterols have many health benefits. Dietary consumption of phytosterol is negatively related to cholesterol absorption, serum total, and LDL cholesterol (Jiang & Wang, 2005). The major mechanism involved in the health benefits of dietary phytosterols is the inhibition of cholesterol absorption through intestine and stimulation of cholesterol synthesis resulting in the enhanced elimination of cholesterol in stools. To test the contribution of phytosterols in maize oil on cholesterol-lowering effect, a study compared cholesterol absorption between the human subjects who consumed original and phytosterol-removed commercial maize oil. The study reported that the cholesterol absorption of healthy subjects was 38% higher in the group consuming the phytosterol-removed commercial corn oil than the group consuming the original commercial corn oil for two weeks. When corn oil phytosterols were added back to phytosterol-removed maize oil the cholesterol absorption was reduced significantly again. Thus, the consumption of corn oil in a long-term period can reduce cholesterol concentrations and prevent atherosclerotic disease (Ostlund, Racette, Okeke, & Stenson, 2002).

## 6. Conclusion

Maize is a healthy food due to the presence of nutrients and phytochemicals. Based on the health benefits of maize discussed in this article, it can be recommended and made a part of our daily diet.

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### Competing interests

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