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# Nutritive Value

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## Abstract

Nature has blessed the human and animal beings with great food diversity in terms of cereal grains to maintain their health status. Among the cereal grains, wheat, rice and maize (*Zea mays*) are the major ones that are considered as stable food across the globe due to their high nutritional significance enriched with abundant amount of macronutrients like starch, fibre, protein and fat along with micronutrients like B-complex vitamins,  $\beta$ -carotene and essential minerals, i.e. magnesium, zinc, phosphorus, copper, etc. Maize is also considered as low-cost-high-benefit ratio for human beings that help in the prevention of metabolic syndrome due to the presence of different antioxidants like phenols and phytosterols in it. Maize or corn can be consumed only after processing into different food items such as popcorn, flour, tortillas, cornflakes, corn germ oil, etc. Maize products are also used in supplementary nutritional programmes to feed the malnourished children and to improve their health status. However, the quality of maize products depends upon the agronomic practices and climatic conditions.

**Keywords:** maize, nutritional value, health, quality

## 1. Brief overview

The cereal grains, wheat, rice and maize (*Zea mays*), are considered as stable food across the globe and contribute to 50–60% of daily human energy requirements. Maize as a third leading cereal grain around the world due to its high yield and nutritive value is also known as the queen of cereal crops. The largest producer of maize is the United States of America (USA) contributing about 35% of the total world maize production. It is also known as the mother grain of Americans and it is the driver of the US economy [1]. Maize is a stable cereal very popular due to its high nutritional significance enriched with abundant amount of macronutrients like starch, fibre, protein and fat along with micronutrients like vitamin B complex,  $\beta$ -carotene and essential minerals, i.e. magnesium, zinc, phosphorus, copper, etc. Maize also contains a booster of antioxidant that protects from various degenerative diseases. The quality of maize depends upon the agronomic practices and climatic conditions. Maize contains 11% of protein but is deficient in amino acids like tryptophan and lysine. However, new fortified varieties are also being produced in the American region. Maize has to undergo different food processing methods like grinding, alkali processing, boiling, cooking, fermentation, etc. so that it can be used in the development of variety of food items, that is, flour, flakes, popcorn, tortillas, etc. Nutritional quality of maize also depends upon the processing method used for food preparations. Maize like wheat and rice is also used in supplementary nutrition programmes and

integrated child development service programmes to feed malnourished children [2]. Maize kernel is an edible and nutritive part of the plant. Maize is a major cereal crop for both livestock feed and human nutrition.

## 2. Food processing techniques for maize

There are three major processes utilised in the production of maize for food usage as discussed below.

### 2.1 Dry milling

Grinding of the whole grain stone or roller mill to produce flour or meal is a simple method used around the world when the ground products are to be consumed shortly after processing. The stability of such products is limited owing to the presence of crushed germ in the flour. Oil from broken germ cells is easily oxidised to produce rancid odour and flavour. The large as well as small grits are used in the production of cornflakes and breakfast cereals. Dry milling germ can be pressed or solvent extracted to recover the valuable oil. The major advantages of maize dry milling are the lower capital costs as compared to wet milling [3].

### 2.2 Wet milling

In developed countries like the USA, the major utilisation has been wet milling. The two most important products of wet milling are high-fructose corn syrup and ethanol.

### 2.3 Alkali processing

In this process, maize is cooked with water and lime at 90°C for 50 minutes then steeped for 14 hours before being washed with fresh water to remove residual alkali and other waste materials from maize.

## 3. Products of maize

There are varieties of products that can be derived after application of food processing methods like dry milling, wet milling and alkali processing to make it consumable for human beings as discussed above. Commonly, maize is used to make flour, oil, starch, grits, flakes, popcorn, etc. [4]. Few very popular products derived from maize are discussed below.

### 3.1 Degerminated flour

This consists mostly of the endosperm and has content of B vitamins. It is used by brewers as a starch medium for the action of barley malt in the preparation of wort for the production of beer. It is also used to make chapatti or bread in the northern region of India. The flour is supplemented with green leafy vegetables to make it more nutritious and healthy. The chapatti is famous around the Punjab as '*makki di roti*' that is served with well-cooked mustard leaves along with butter.

### 3.2 Corn germ oil

It can be obtained by solvent extraction. Maize oil has become a highly desired vegetable oil owing to its relatively high level of linolenic fatty acid and its excellent

flavour. The fat content of maize is 3.6%, and oil extracted from it can be refined to produce a high-quality vegetable oil for cooking or food use.

### **3.3 Popcorn**

A particular variety of corn is used to make popcorn and most famous food items derived from maize. To make popcorn a hard corneous endosperm is desirable. Other desirable traits of popcorn are good flavour, tenderness, the absence of objectionable hulls and high popping expansion. Moreover, the moisture content recommended is 13.5% for the best popping expansion. The popping of corn is a method of starch cookery. As the kernels of popcorn are heated, the water vapour within them expands, increasing the pressure until it is sufficient to make the kernels explode or 'pop' [5]. Popping can be done with or without fat as well. Ready-to-cook popcorns are also easily available that are enriched with both nutrition and taste. Thus it can be added as supplementary snacks in the diet of malnutrition children.

### **3.4 Corn starch**

It is the most widely used product obtained from maize. It is made by a process of wet milling in which the hull and germ are removed and the corn ground and mixed with water. The semi-liquid material is separated by passing it over sieves or centrifuging it. The starch settles out while most of the proteins are suspended. The starch is then washed, dried and powdered. Corn starch is widely used because it is inexpensive, lacks characteristic flavour and cooks to a smooth and almost clear paste in water or other clear liquids and is superior to wheat flour or potato starch. Corn starch flavoured with vanilla and containing edible colours is solid as custard powder.

### **3.5 Cornflakes**

The whole grain is crushed between the large metal rollers to remove the bran from the outer layer and then mixed with seasoning agents (salt, sugar, flavours and fortified minerals) and water in a large rotating pressure cooker. The physiochemical properties like time, temperature and speed of rotation vary with the type of grain being cooked. The cooked grain is moved to a conveyor belt which passes through a drying oven. In this process, soft and solid mass is obtained which can be moulded into desired shapes. Then these cooked grains are allowed to cool, and stabilising the moisture content is known as 'tempering'. Then the tempered grains are flattened between large metal rollers under tons of pressure, and the resulting flakes are further conveyed to ovens with blast of very hot air to remove remaining moisture and to toast them to desirable flavours. Cornflakes are also processed from extruded pellets in a similar way.

## **4. Nutritive value of maize**

### **4.1 Macronutrients**

Maize provides approximately 1400 Kcal/100 g (on a dry basis) of energy that is sufficient to maintain the equilibrium. This energy is also used to perform different types of physiological task. Maize or corn can be consumed as a source of energy in the form of breakfast cereals as cornflakes, chapattis, tortillas, etc. Maize also contains an appreciable amount of fat content that helps in the carrier of fat-soluble vitamins A, D, E and K. The presence of fat in maize or corn is responsible for much of the texture and flavour of food. Thus it helps in increasing the palatability.

The fat content beneath the skin known as the subcutaneous fat also serves as an insulating material for the body and is effective in preventing heat loss. Moreover, fat content also acts as a body reservoir for energy conservation purpose.

Another important component in maize after fat is dietary fibre and is defined as the portion of food derived from plant cell, which is resistant to hydrolysis or digestion by the elementary enzyme system in human beings. However, some of the bacteria in the large intestine can degrade some components of fibre releasing products that can be absorbed into the body and also used as a source of energy. Crude fibre is the residue remaining after the treatment with hot sulphuric acid, alkali and alcohol. The major component of crude fibre is a polysaccharide called cellulose and a part of dietary fibre. Insoluble fibres are indigestible and insoluble in water, while soluble fibres are indigestible but soluble in water. Total fibre is the sum of insoluble and soluble fibres. Dietary fibre is isolated and extracted from a synthetic fibre that has proven health benefits. Resistant starch also functions as dietary fibre [6–8].

$$\text{Total fibre} = \text{dietary fibre} + \text{functional fibre}$$

The effect of fibre on the gastrointestinal tract (**Table 1**) is influenced by the characteristics of the fibre itself, the particle size, the interaction between fibre and other dietary components and the bacteria flora. Maize also contains a significant quantity of insoluble fibre found in the cell wall of the constituent [9].

The insoluble fibre present in maize or corn has a physiological effect in preventing constipation, diverticulitis and even cancer of the large intestine as presented in **Table 2**.

Maize is also considered as a booster of nutrient like carbohydrates, fats, proteins and insoluble fibres that helps in providing sufficient energy to meet the human daily dietary requirements [10]. The proximate composition of maize is presented in **Table 3**.

#### 4.1.1 Protein

Maize contains 8–11% of protein that is made from different components like albumin, globulin, nonnitrogen substance, prolamin, etc. The quality of maize protein depends upon its agronomic practices and genotype as well. The quality of maize protein is not of good quality as compared to other cereal grains like rice, wheat, barley, etc. Recent researches have shown that with genetic modification, the quality of maize protein can be improved. The maize protein is known as zein that is lack of essential amino acids tryptophan and lysine. The opaque-2 gene is also helpful in reducing the concentration of zein up to 30% and improves the quality protein maize (QPM). The protein content present in maize helps in the growth

Site	Activity
Mouth	Stimulate saliva secretion
Stomach	Dilutes contents, delays gastric emptying
Small intestine	Dilutes content, delay absorption
Large intestine	Dilutes contents, forms substrate for bacteria, traps water, binds cation, soften stools, prevents straining

Source: Raninen et al. [9].

**Table 1.**  
Influence of dietary fibre on the gastrointestinal tract.



Disease	Physiological mechanism
Constipation Diverticulitis Irritable bowel syndrome Varicose veins Haemorrhoids	<ul style="list-style-type: none"> <li>• Increase the water-holding capacity</li> <li>• Increases the stool weight</li> <li>• Reduces the transit time</li> <li>• Enhances gastric motility</li> <li>• Volatile fatty acids which are released by bacteria having a laxative effect</li> <li>• Faster bowel emptying due to increased intraluminal mass bulk</li> <li>• Decreases intracolonic pressure</li> </ul>
Cancer of the large intestine	<ul style="list-style-type: none"> <li>• Changes in the population of microbes in the GI tract</li> <li>• Increases binding of intestinal bile acids</li> <li>• Food residues remain in the colon for less time for carcinogen to be absorbed</li> <li>• Increases stool weight and volume</li> <li>• Increases frequency of defaecation</li> <li>• Bulk and water of the faeces may dilute the carcinogen to a nontoxic level</li> <li>• Fibre-induced effects on faecal enzymes</li> <li>• Production and distribution of short-chain fatty acids in the colon resulting in pH modifications</li> <li>• Increases on bile acids and mutagens in the colon</li> <li>• Adsorbing cancer-producing hydrocarbons</li> </ul>

Source: Raninen et al. [9].

**Table 2.**  
 Role of dietary fibre in preventing and managing diseases.

S. no.	List of nutrients	Nutritive value*
1	Moisture	9.26 ± 0.55
2	Protein (g)	8.80 ± 0.49
3	Ash (g)	1.17 ± 0.16
4	Fat (g)	3.77 ± 0.48
5	Total fibre (g)	12.24 ± 0.93
6	Insoluble fibre (g)	11.29 ± 0.85
7	Soluble fibre (g)	0.94 ± 0.18
8	Carbohydrates (g)	64.77 ± 1.58
9	Energy (KJ)	1398 ± 25

Source: Longvah et al. [6], Indian Food Composition Tables, Government of India.  
 \*All the values are presented as per 100 grammes of edible portion.

**Table 3.**  
 Nutritive value of proximate content of maize, dry (*Zea mays*).

and maintenance of tissues, formation of essential body compounds, transport of nutrients, regulation of water balance, maintenance of appropriate pH, defence and detoxification as well.

#### 4.1.2 Essential amino acids

These amino acids cannot be synthesised by the body at a sufficient rate to meet the body requirement for optimum growth and development. The human body has certain limited powers of converting one amino acid into another. This is

Essential amino acids		Conditionally essential amino acids		Non-essential amino acids	
Amino acids	Nutritive value*	Amino acids	Nutritive value	Amino acids	Nutritive value*
Histidine	2.70 ± 0.21	Arginine	4.20 ± 0.24	Alanine	7.73 ± 0.46
Isoleucine	3.67 ± 0.22	Cysteine	1.55 ± 0.14	Asparagine	—
Leucine	12.24 ± 0.57	Glycine	3.27 ± 0.15	Aspartic acid	6.55 ± 0.59
Lysine	2.64 ± 0.18	Proline	7.88 ± 0.71	Glutamic acid	19.39 ± 0.70
Methionine	2.10 ± 0.17	Tyrosine	3.71 ± 0.18	Glutamine	—
Phenylalanine	5.14 ± 0.29			Serine	4.58 ± 0.44
Threonine	3.23 ± 0.29			Selenocysteine	—
Tryptophan	0.57 ± 0.12			Pyrrolysine	—
Valine	5.41 ± 0.71				

Source: Longvah et al. [6], Indian Food Composition Tables, Government of India.  
\*All the values are presented as per 100 grammes of edible portion.

**Table 4.**  
Essential and non-essential amino acid profile (g) of maize, dry (*Zea mays*).

achieved in the liver by the process of transamination, whereby an amino group is shifted from one molecule to another under the influence of amino transferases, the coenzyme of which is pyridoxal phosphate. The inability to synthesize the carbon skeleton of these amino acids is the probable reason why they are dietary essentials. There are nine essential amino acids that are required for a human body to perform various functions (**Table 4**).

#### 4.1.3 Conditionally essential amino acids

These are needed in the diet unless abundant amounts of their precursors are available for their synthesis. The newborn may not have enzymes in adequate amounts to synthesise non-essential amino acid, or in intestinal metabolic dysfunction, arginine may not be synthesized. Hence it becomes a conditionally essential amino acid. Amino nitrogen is not freely interchanged between all amino acids. The precursors of conditionally essential amino acids are mentioned in **Table 4**.

#### 4.1.4 Non-essential amino acids

Non-essential amino acids are the ones that the body can make in adequate amount if nitrogen is available in the diet. They are non-essential only in the sense that they are not essential components of the diet as discussed in **Table 4**.

#### 4.1.5 Starch

The main portion of maize grain is starch that provides more than 70% weight to its cereal kernel. Starch in maize is composed of two glucose polymers mainly amylose that contributes to 30% of its starch content and the rest of the content is made from amylose pectin (70%). Waxy maize is composed of 100% amylopectin content. Due to the pectin content, maize has a branch-type structure. The monosaccharide present in maize is comprised of glucose and fructose, and the disaccharide is comprised of sucrose in a little amount. The starch and sugar content of maize is presented in **Table 5**.

S. no.	List of nutrients	Nutritive value*
1	Total available CHO	61.01 ± 0.76
2	Total starch	59.35 ± 0.83
3	Fructose	0.16 ± 0.03
4	Glucose	0.80 ± 0.01
6	Sucrose	0.70 ± 0.03
6	Total free sugars	1.66 ± 0.04

Source: Longvah et al. [6], Indian Food Composition Tables, Government of India.

\*All the values are presented as per 100 grammes of edible portion.

**Table 5.**  
Starch and sugar content (g) of maize, dry (*Zea mays*).

S. no.	List of nutrients	Nutritive value*
1	Thiamine (B1) (mg)	0.35 ± 0.039
2	Riboflavin (B2) (mg)	0.14 ± 0.014
3	Niacin (B3) (mg)	2.10 ± 0.09
4	Pantothenic acid (B5) (mg)	0.27 ± 0.02
5	Total B6 (mg)	0.28 ± 0.023
6	Biotin (B7) (mg)	0.70 ± 0.06
7	Total folates (B9) (mg)	39.42 ± 3.13

Source: Longvah et al. [6], Indian Food Composition Tables, Government of India.

\*All the values are presented as per 100 grammes of edible portion.

**Table 6.**  
B-complex nutritive content of maize, dry (*Zea mays*).

## 4.2 B-complex vitamins

Maize is also enriched with B-complex vitamins that play a vital role in growth, healthy skin, heart, hair, brain, digestion, nails and dementia as well. Maize products can be used in the daily diet of coeliac patients to improve their health status [11]. People with coeliac disease cannot absorb gluten due to an abnormal immune reaction that occurs in the small intestine. So the only cure is consumption of gluten-free diet that helps in improving the gastrointestinal function [12]. Maize is enriched with thiamine, riboflavin, niacin, pantothenic acid, pyridoxine and folic acid as well. The nutritional content of B-complex vitamin present in maize is discussed in **Table 6**.

The B-complex vitamin present in maize is of water-soluble nature and found in the aleurone layer of the kernel. The processing method has significant direct relationship with the amount of vitamin present in maize. Moreover, niacin deficiency causes pellagra that is also directly related with maize.

## 4.3 Fat-soluble vitamins

Maize contains fat-soluble vitamins that is comprised of provitamin A, carotenoids, lutein, zeaxanthin, ergocalciferol, tocopherol, phyloquinones (**Table 7**), etc. that have a unique role in preventing both ageing and cancer. These fat-soluble vitamins (A, D, E, K) act as antioxidants and scavenge the free radicals that help in protection against different types of cancer. The content of fat-soluble vitamin



S. no.	List of nutrients	Nutritive value*
1	Lutein (µg)	186 ± 19.4
2	Zeaxanthin (µg)	42.4 ± 15.7
3	B-Cryptoxanthin (µg)	110 ± 10.1
4	β-Carotene (µg)	186 ± 19.2
5	Total carotenoids (µg)	893 ± 154
6	Ergocalciferol (µg)	33.60 ± 2.82
7	Tocopherol-alpha (mg)	0.21 ± 0.04
8	Tocopherol-gamma (mg)	1.29 ± 0.17
9	Tocopherol-delta (mg)	0.38 ± 0.05
10	Tocotrienol-alpha (mg)	0.05 ± 0.00
11	α-Tocopherol, vitamin E (mg)	0.36 ± 0.03
12	Phylloquinones (vitamin K (µg)	2.50 ± 0.76

Source: Longvah et al. [6]s, Indian Food Composition Tables, Government of India.

\*All the values are presented as per 100 grammes of edible portion.

**Table 7.**  
Nutritive content of fat-soluble vitamin in maize, dry (Zea mays).

S. no.	List of fatty acids	Nutritive value*
1	Palmitic (C16:0)	363 ± 4.6
2	Stearic (C18:0)	42.45 ± 2.76
3	Arachidic (C20:0)	7.14 ± 0.95
4	Oleic (C18:1)	700 ± 17.9
5	Eicosaenoic (C20:1)	6.62 ± 0.74
6	Linoleic (C18:2)	1565 ± 18.2
7	α-Linolenic (C18:3)	40.76 ± 2.43
8	Total saturated fatty acids (TSFA)	413 ± 5.6
9	Total monounsaturated fatty acids (TMUFA)	706 ± 17.4
10	Total polyunsaturated fatty acids (TPUFA)	1606 ± 18.5

Source: Longvah et al. [6], Indian Food Composition Tables, Government of India.

\*All the values are presented as per 100 grammes of edible portion.

**Table 8.**  
Essential fatty acid profile (mg) of maize, dry (Zea mays).

depends upon the genotype of maize whether it is fortified or not, that is, yellow maize is enriched with different types of carotenoid pigment due to its genotype, while white maize is deficient in carotenoid content due to absence of this genotype.

Majority of the carotenoid contents are present in the hard endosperm of maize kernel and the rest in small quantity in the germ. The ergocalciferol content present in maize helps in the bone formation and tocopherol (α, β, γ) in anti-ageing and cosmetic products. As an antioxidant, tocopherol (vitamin E) helps in protecting different types of skin cancer. Phylloquinone (vitamin K) helps in the blood clotting when an accident or injury happens. It has anticoagulating properties. The following tables discussed the nutritive value of fat-soluble vitamin content present in maize (**Tables 7–12**).

S. no.	List of nutrients	Nutritive value*
1	Aluminium (Al)	2.82 ± 0.16
2	Calcium (Ca)	8.91 ± 0.61
3	Chromium (Cr)	0.010 ± 0.006
4	Cobalt (Co)	0.010 ± 0.003
5	Copper (Cu)	0.45 ± 0.23
6	Iron (Fe)	2.49 ± 0.32
7	Lithium (Li)	0.002 ± 0.001

Source: Longvah et al. [6], Indian Food Composition Tables, Government of India.  
\*All the values are presented as per 100 grammes of edible portion.

**Table 9.**  
Minerals and trace content (mg) of maize, dry (Zea mays).

S. no.	List of nutrients	Nutritive value*
1	Total oxalate	15.26 ± 1.78
2	Insoluble oxalate	14.19 ± 1.30
3	Soluble oxalate	2.73 ± 1.34
4	Fumaric acid	0.66 ± 0.20
5	Malic acid	0.93 ± 0.50
6	Quinic acid	0.84 ± 0.07
7	Succinic acid	1.50 ± 0.23
8	Tartaric acid	0.94 ± 0.05

Source: Longvah et al. [6], Indian Food Composition Tables, Government of India.  
\*All the values are presented as per 100 grammes of edible portion.

**Table 10.**  
Total organic acid content (mg) of maize, dry (Zea mays).

#### 4.3.1 Essential fatty acids (EFA)

The oil content of maize is extracted from the germ part which is genetically modified with an average range of 3–18%. Three classes of fatty acids are described according to the number of double bonds between the carbon atoms as described in **Table 8**. In saturated fatty acids, there are none; in an unsaturated fatty acid, there may be one (monoenoic or monounsaturated fatty acids) or two or more (polyenoic or polyunsaturated fatty acids) double bonds. Corn oil is enriched with PUFA (polyunsaturated fatty acid) and MUFA (monounsaturated fatty acid) while having low content of SFA (saturated fatty acid). SFA comprises of palmitic, stearic and arachidic acids. PUFA contains linoleic,  $\alpha$ -linolenic, arachidonic and eicosaenoic acids that help in maintaining healthy skin and vision, strong immune system and optimum growth and development. Moreover, it has also anti-inflammatory properties and reduces the production of interleukin-1 and tumour necrosis factor (TNF) by downregulating inflammatory response. It is also responsible for the formation of prostaglandins that are found in every single cell of the body and helps in regulating cell activities including transmission of genetic information from generation to generation.

This is rare in human beings that deficiency of fatty acid occurs. It has been reported, however, in patients fed solely by vein (total parenteral nutrition (TPN))

S. no.	List of nutrients	Nutritive value*
<b>Phenols</b>		
1	3,4-Dihydroxybenzoic acid	0.07 ± 0.02
2	Protocatechuic acid	2.93 ± 0.42
3	Vanillic acid	2.96 ± 0.44
4	p-Coumaric acid	2.84 ± 0.36
5	Caffeic acid	2.91 ± 0.32
6	Chlorogenic acid	1.01 ± 0.45
7	Ferulic acid	1.43 ± 0.09
8	Total polyphenols	32.92 ± 3.85
<b>Phytosterol</b>		
1	Campesterol	12.49 ± 0.24
2	Stigmasterol	4.22 ± 0.18
3	β-Sitosterol	87.70 ± 2.61
<b>Phytate</b>		646 ± 19.4

Source: Longvah et al. [6], Indian Food Composition Tables, Government of India.  
\*All the values are presented as per 100 grammes of edible portion.

**Table 11.**  
Total polyphenol, phytosterol and phytate contents (mg) of maize, dry (Zea mays).

S. no.	Nutrients	Deficiency
1	Energy, protein	Underweight, marasmus, kwashiorkor
2	Fibre	Constipation, diverticulitis
3	Calcium	Rickets, osteomalacia
4	Iron	Anaemia
5	Vitamin A	Night blindness
6	Thiamine	Pain in the calf muscle, weakness of the heart muscle
7	Niacin	Dementia, diarrhoea, dermatitis
8	Pyridoxine	Angular stomatitis
9	Folic acid	Megaloblastic anaemia
10	Antioxidants	Decreased immunity

Source: Srilakshmi, [17], Text Book on Nutrition Science.

**Table 12.**  
Nutrient deficiency symptoms related to maize.

for long times without fat emulsions. EFA deficiency can occur in fat malabsorption and occasionally in protein-calorie malnutrition, where there is a deficiency of fat calories.

#### 4.4 Mineral and trace element

The majority of minerals and trace elements of maize is present in germ portion and very few in endosperms. Phosphorus is found in the embryo portion of the maize. Environmental factors strongly influence the quality and quantity of mineral

content present in maize. Maize is having a low content of mineral and trace element (**Table 9**) as compared with other cereal grains. The minerals present in maize have a vital role in bone development, tooth formation, haemoglobin formation, growth regulation, regulation of acid–base balance of the body, facilitation of energy transactions, absorption and transport of nutrients and metabolism of carbohydrates, proteins and fats. These minerals also act as a cofactor and regulator of biochemical reactions for blood clotting, contraction of muscles, releases of insulin and parathyroid and calcitonin hormones as well. Furthermore, these minerals play vital role in the growth, development and formation of red blood cells in human system. The chromium content of an adult body is estimated to be 6 mg and potentiates insulin action. The mineral and trace element content of maize is discussed below.

#### 4.5 Organic acid content

There are a number of organic acids present in nature like formic, malic, succinic, etc. Organic acids help in building the carboxylic acids which can alter the physiology of bacteria and cause metabolic disorders that prevent their proliferation and death. Organic acids are not fixed in one state, and supplementation of its higher doses in animal feed helps them to gain body weight and improves feed conversion ratio by reducing the colonisation of pathogens in the intestine. The total organic content of maize is discussed in **Table 10**.

#### 4.6 Antioxidants

Food polyphenols (**Table 11**) are ubiquitous components and have an antioxidant mechanism involved in fighting free radical damage by interaction of ascorbic acid and glutathione (GSH) with oxidants and oxidising agents. Scavenging of free radicals and single oxygen through food polyphenols (Vitamin E, ascorbic acid,  $\beta$ -carotene and superoxide dismutase) by reduction of hydroperoxides, glutathione peroxidases (GSHPx) and catalase enzymes as well. Food polyphenols also act as chelating agent by binding with transition metals that cause cellular damage [13]. Thermal processing deteriorates the quality of maize grains due to leaching of water-soluble polyphenols into brine or sugar solution. The effects of processing method cause alteration in the structure, chemical composition and nutritional value of the food products like canned sweet corn, tortillas, chips, etc. [14].

Recently, the industry has focused attention to plant matrices rich in phytosterols and phytostanols for their ability to reduce serum cholesterol levels. Therefore, the objective of this study was to examine the phytosterol and phytostanol contents of different fractions (endosperm, pericarp, germ) of corn kernel. The phytosterols are found in the endosperm, pericarp and germ portion of corn kernel. The germ portion contains 25–31% of oil as compared to other fractions. Corn oil is enriched with  $\beta$ -sitosterol (62–69%), followed by campesterol (11–18%) and stigmasterol (5–13%). Processing of maize, especially during roasting, results in the loss of phytate content and increase of the availability of minerals. For example, baking chapattis from maize helps in the reduction of phytates and improves the nutritional quality of maize. Due to the emerging field of nutraceuticals, the phytochemicals derived from maize have achieved great attention. The antioxidant capacity in terms of DPPH radical scavenging activity of maize (139 mg/100 g) is quite high as compared to other cereal and pulse grains except finger millet (173 mg/100 g). This antioxidant activity of maize helps in protecting different types of degenerative diseases [15].

#### 4.7 Relationship of maize with health

Being comparatively inexpensive, maize as a staple diet contributes to most of the caloric requirement. It is also an excellent source of starch and B-complex vitamins along with antioxidants such as different types of polyphenols [16]. It also contributes to satiety and is used as a main dish in the diet. No meal can be prepared from cereals. Maize is also used as a thickening agent as a corn flour in custards and puddings. Maize as a thickening agent used in the preparation of different types of sausages as well.

Maize is also consumed as a ready-to-eat food in the form of cornflakes with milk as a healthy breakfast [17]. The fibre present in the maize helps to lower cholesterol levels and reduce the risk of colon cancer (**Table 12**). Moreover, it is also useful for anaemic, haemorrhoid, cardiac and diabetic patients due to significant nutritional value of macro- and micronutrients in it. It is also helpful in the metabolism of carbohydrates due to the presence of thiamine in it [18].

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