Compositional variability of nutrients and phytochemicals in corn after processing

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Revised: 2 February 2017 / Accepted: 10 February 2017 / Published online: 18 February 2017
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Abstract The result of various process strategies on the nutrient and phytochemical composition of corn samples were studied. Fresh and cooked baby corn, sweet corn, dent corn and industrially processed and cooked popcorn, corn grits, corn flour and corn flakes were analysed for the determination of proximate, minerals, xanthophylls and phenolic acids content. This study revealed that the proximate composition of popcorn is high compared to the other corn products analyzed while the mineral composition of these maize products showed higher concentration of magnesium, phosphorus, potassium and low concentration of calcium, manganese, zinc, iron, copper, and sodium. Popcorn was high in iron, zinc, copper, manganese, sodium, magnesium and phosphorus. The xanthophylls lutein and zeaxanthin were predominant in the dent corn and the total polyphenolic content was highest in dent corn while the phenolic acids distribution was variable in different corn products. This study showed preparation and processing brought significant reduction of xanthophylls and polyphenols.

Keywords Corn · Proximate · Minerals · Xanthophylls · Polyphenols · Processing

Introduction

Corn (*Zea mays*) is one of the most important cereals cultivated after rice and wheat which is rich in starch. It is utilized as a food source for human nutrition after undergoing various industrial processing and also used for animal feed (Kent and Evers 1994). Corn is well known as a ‘poor man’s nutriceal’ owing to its high carbohydrates, fats, proteins and important vitamins and minerals. In India, maize is a staple food for the lower socioeconomic group of people belonging to Uttar Pradesh, Punjab and Rajasthan (Reddy et al. 1991). Corn is being cultivated worldwide for its demand as a high-energy, micronutrient rich value-added food and it is being utilized by developing countries for food production while developed countries use it for industrial purposes (Mejia 2005).

Corn flour, meals and its products are being processed industrially all over the world using various food technologies to obtain flours which are precooked and refined, dehydrated and nixtamalized, fermented and other products such as cornflakes and corn grits. The vitamin and mineral content of these products vary as they follow different pathways from the raw grain to the consumer’s final product during processing which leads to changes in their nutrient composition. Whole and fractionated products are produced after processing of dry corn which separates bran, germ and endosperm, while starch and protein are separated by wet maize processing. Factors such as maturity, variety/cultivar, climate or season, part of the plant consumed, production practices, post-harvest handling, processing and storage conditions brings about compositional

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Table 1 Corn and corn products and the cooking methods employed

Sample name	Sample type	Method of cooking	Time taken for cooking (min)
Baby corn	Raw	Steamed	8
Sweet corn	Raw	Steamed	10
Dent corn	Raw	Steamed	10
Popcorn with oil	Raw	Popped	6
Popcorn without oil	Raw	Popped	6
Corn grits	Raw	Boiled in water	8
Corn flour	Raw	Boiled in water	3
Corn flakes	Raw	Fried in groundnut oil	5

variability in food. The nutritional composition also varies due various factors such as the structure of the kernel, genetics, environmental conditions, processing effects and various links in the food chain (Fubara 2008). Although, processing has beneficial effects such as destruction of trypsin inhibitors and the liberation of bound niacin in cereals, loss of nutrients and reduction in the nutritional composition is profound in processed foods than in the raw food material. Nutrient loss may occur during harvesting, while handling and transporting, during preparation and processing or storage and distribution (Selinger 1996). Nutritional composition of most cereals which are lower in essential minerals such as calcium, potassium, iron and zinc can be improved by blending with protein rich legumes (Mbata et al. 2009).

Studies have reported maize to be a good source of carotenoids and polyphenols and the consumption of these are associated with lower risk of various degenerative diseases, as antioxidants and regulators of human immune system in preventing cardiovascular diseases, cancer and age-related diseases (Messias et al. 2013). The major constituent of the macular pigment of the human retina are xanthophylls lutein and zeaxanthin (Snodderly 1995). The xanthophylls lutein and zeaxanthin are present in appreciable amounts in corn apart from having minor amounts of α and β -cryptoxanthin and is also a considerable source of polyphenol antioxidants, especially phenolic acids such as ferulic, caffeic and *p*-coumaric acids (Sosulski et al. 1982).

The study was carried out with a view of comparing the effect of processing methods on the nutrient and phytochemical composition of corn varieties and processed corn products after preparation for consumption and to show that maize apart from being rich source of starch has other nutrients and antioxidants which are useful for the health and well being of mankind. In the present study, proximate, minerals, xanthophylls and polyphenolic content were quantified in the raw as well as in prepared and processed corn which includes baby corn, sweet corn, dent corn, popcorn, corn grits, corn flour and corn flakes and also the effects of processing were studied. The implication of the

study will be useful for consumers to select corn as a source of nutrients like other fruits and vegetables.

Materials and methods

Sample preparation

Corn consumed on regular basis as prepared and processed products were purchased from the local markets and the sampling was designed to produce composite samples of corn sold by the five major wholesale food chains in twin cities of Hyderabad and Secunderabad. Four to five sub samples of 0.25 kg in the case of dry corn or 3 cobs of corn in the case of fresh samples were purchased of each item mentioned in the Table 1. Thus, three composite food samples (collected from five major whole sale markets) were analyzed for each selected corn sample either fresh or processed. Composites were prepared in such a way that a homogenous mixture (i.e., aliquots derived from a specific composite were representative of the entire composite) was ensured.

Cooking treatments employed for the study

The domestic cooking methods followed in India for cooking corn are steaming, boiling, popping and frying. In this study baby corn was steamed for 8 min to obtain a texture indicating a well done cooking. The time taken for steam cooking sweet corn and dent corn was 10 min due to the larger ear size. Popcorn (100 g) was popped with groundnut oil (10 ml) and 100 g without groundnut oil in a pressure cooker with its lid toppled over it for about 6 min each. Corn grits (100 g) were boiled with water (500 ml) for 8 min and Corn flour (100 g) was boiled with water (200 ml) for 3 min till done. Cornflakes (100 g) were fried in groundnut oil (100 ml) until crispy flakes were obtained.

All the samples raw and cooked were frozen in liquid nitrogen, ground to a fine consistency using a normal

kitchen blender and portion of the samples were stored at -20 ± 1 °C for analysis of xanthophylls and polyphenols. The remaining portion of the raw and cooked samples was taken for moisture analysis. The dried sample obtained after determination of moisture was further taken for analysis of proximate and mineral parameters.

Determination of the proximate composition

The proximate composition of the samples was determined as follows: the moisture content was determined by using the oven drying method as described by Association of the Official Analytical Chemists (AOAC 2006) method 934.01. Fat content was determined using chloroform and methanol as solvent as described in AOAC (2006) method 920.39. The protein content was determined using macro-Kjeldahl method AOAC (2006) method 984.13. The crude protein was obtained by multiplying the gram nitrogen with 6.25. The total ash was determined as described by AOAC (2006) method 942.05. The dietary fiber was determined according to the procedure of AOAC (2005) method 985.29. The carbohydrate was calculated by difference and the energy value in kilocalories using Atwater factor. Quality control was maintained with certified reference material (CRM) 1546 (Meat Homogenate) for fat and CRM 1515 for nitrogen (Apple leaves) procured from National Institute of Standard Technology (NIST).

Determination of mineral composition

The method described by AOAC (2005) method 985.35 was used for mineral analysis. The samples were digested in CEM Microwave accelerated reaction system using 2 ml suprapur (65%) nitric acid and 1 ml suprapur (30%) hydrogen peroxide. The digested samples were transferred to 25 ml standard flasks and the volume was made up to the mark using Milli-Q (18.2 MΩ cm) water. The minerals were determined from the resulting solution. Phosphorus (P) was determined spectrophotometrically by Modified Fiske and Subbarow method (AOAC 2000) method 931.01 using Analytikjena Specord S600 with KH_2PO_4 as the standard. Iron (Fe), Zinc (Zn), Copper (Cu), Manganese (Mn), Magnesium (Mg), Sodium (Na), Potassium (K) and Calcium (Ca) were determined using Atomic Absorption Spectrophotometer (Varian SpectraAA 220 model). Quality control was maintained using Certified Reference Material 1568a (Rice flour) and 1547 (Peach Leaves) procured from NIST.

Determination of total carotenoids

The method described by Zakaria et al. (1979) was used for the spectrophotometric determination of total carotenoid

content. About 2–5 g of fresh sample was ground using 12% alcoholic KOH and glass powder. Transferred into 250 ml amber conical flask and saponified at room temperature for 30 min and extracted using petroleum ether. The volume noted and further the extract was evaporated using flash evaporator and volume made to 5 ml using chloroform, absorbance was measured at 450 nm using Analytikjena Specord S600 UV/Vis spectrophotometer. Total carotenoids content was calculated and expressed as $\mu\text{g}/100$ g.

Determination of individual xanthophylls

The xanthophylls were quantified by using the method described by Craft (2001) using Spherisorb Waters C18 Column (5 μm , 150×4.6 mm). Xanthophylls were monitored at a wavelength of 450 nm with Dionex Ultimate 3000 Diode array detector. Isocratic mobile phase with Methanol: Acetonitrile: Triethylamine in the ratio 92:8:1 v/v was used with flow rate maintained at 0.5 ml/min and the run time was 25 min at 25 °C with an injection volume of 2 μl . The internal standard used was Echinone. Ten standards—lutein, zeaxanthin, α -cryptoxanthin, β -cryptoxanthin, capsanthin, citrinaxanthin, capsorubin, canthaxanthin, astaxanthin and violaxanthin were separated by using this method. Peak identification in the samples analyzed was based on the comparisons with retention time and absorption spectra of the above mentioned xanthophylls. Xanthophylls were quantified by integrating peak areas in the High performance liquid chromatography (HPLC) chromatograms. Calibration of HPLC systems was done using NIST- CRM 2385 (Slurried Spinach).

Determination of total polyphenolic content

Total polyphenolic content (TPC) of the samples was determined according to the method described by George et al. (2005) using solid phase extraction method. About 2–3 g of fresh samples were ground to a fine paste with 70% acetone and stirred for 30 min using a magnetic stirrer and centrifuged at 5000g for 7 min. The supernatant obtained is known as Raw Extract (RE). 3 ml of Raw extract was passed through SPE-HLB (solid phase extraction, hydrophilic–lipophilic balance) cartridge.

The recovered volume is the Washing Extract (WE). Gallic acid was used as a standard. Results were expressed as mg Gallic acid equivalents per 100 g of food sample (mg GAE/100 g). About 3.5 ml of Folin-Ciocalteu reagent (1 in 10 ml) was added to the Raw extract and the washing extract and incubated for 2 min at room temperature. Further 2.5 ml of sodium carbonate (75 g/l) was added and incubated for 15 min at 50 °C and absorbance was measured at 760 nm.

Determination of individual polyphenolic compounds by RPHPLC

Raw extracts were evaporated in the rotary evaporator and the samples were reconstituted with 3 ml of dimethyl sulphoxide. The extracts were centrifuged at 3372 g for 10 min and filtered through Whatman 0.2 µm syringe filter (polytetrafluoroethylene) before HPLC analysis.

HPLC analysis for determination of the phenolics in samples was done by using the individual standards. Polyphenols were quantified by using the method described by Sakakibara et al. (2003) using a Dionex C18 Column (2.1 µm, 100 × 2.1 mm). Polyphenols were monitored at 4 different wavelengths (250, 280, 320 and 370 nm) with Dionex Ultimate 3000 Diode array detector. Gradient elution was performed with solution A, composed of 50 mM sodium phosphate (pH 3.3) and 10% methanol, and solution B, comprising of 70% methanol, delivered at a flow rate of 0.47 ml/min as follows: initially 100% of Solution A; for the next 0.03 min, 70% A; for another 2.65 min, 65% A; for another 7.9 min, 60% A; for another 11.5 min 50% A and finally 0% A for 13.1 min, again 17 min 100% A and 20.25 min 100% A. The injection volume of the extract was 2 µl maintained at a temperature of 35 °C.

Statistical analysis

The data was analyzed using descriptive statistics to compute mean ± SD in triplicates. Statistical analysis was conducted using SPSS version 19. Multiple comparisons was done and differences among samples and between treatments (methods of processing) were determined by two way ANOVA and wherever there was only 2 groups (corn flakes) student independent sample *t* test was employed. Differences with $p \leq 0.05$ were considered significant as determined by least significant difference (LSD).

Results and discussion

The effects of domestic cooking on the proximate, mineral, xanthophylls and polyphenolic content in fresh, prepared and processed corn varieties were determined to show corn as a good source of nutrients and antioxidants.

Proximate composition

The nutrient component of a typical corn kernel constitutes starch (70–75%), protein (8–10%) and oil (4–5%). The differences in the relative concentration of these nutrient components are due to the structure of the mature kernel

which includes 80% of the endosperm and 10% of the germ on dry basis. Studies by Thakur et al. (2015) reported that particle size and chemical constituents in corn varied during dry milling which was due to differences in the proportion of germ, pericarp, grit and flour. The Table 2 shows the proximate composition of different samples of corn in fresh, cooked and processed corn products, when corn was processed for consumption, significant differences were observed due to the fact that the endosperm is largely starchy while the germ consists of high levels of fat and protein. In our study among the fresh and prepared corn samples, field dent corn was high in protein, fat, ash, carbohydrate and energy when compared to sweet corn and baby corn and significant differences ($p \leq 0.05$) were observed between the corn samples. Significant differences were also observed in the protein, fat, ash and carbohydrate content in grits and flour as shown in the studies by Shevkani et al. (2014) who reported the composition of protein, fat and ash to be higher in grits compared to the flour which was attributed to the particle size or fractions during dry milling. The values of proximate composition of sweet corn in our study were comparable to the data given by Food Standards Australia New Zealand (FSANZ 2006). Also, the data for proximate content of sweet corn in our study is in accordance with the database given by United States Department of Agriculture (USDA 2005) and data from the Brazilian food composition tables.

Significant differences ($p \leq 0.05$) were also observed between samples after using different methods of processing. The concentration of proteins, lipids and fiber is known to be reduced after processing, our study showed significant differences between the fresh and processed products and a decrease after processing. The protein content in popcorn without oil was high with 9.42% in raw and 8.14% in popped corn the reason being in the case of the dry kernel the whole grain is taken for processing which includes both the endosperm and the germ, while in the case of corn flour the protein content was not detectable due to the fact that corn flour is prepared after the removal of the outer hull and germ, only the starchy endosperm is taken for the preparation of the flour. Studies by Singh et al. (2009) reported that the yield and composition of grits and flour varied based on the corn type selected which was due to the differences in the endospermic protein of the corn grain. In the Consensus document on compositional considerations for new varieties of corn key food and feed nutrients, anti-nutrients and secondary plant metabolites, the results for proximate, mineral and vitamin content of various corn samples which includes field dent corn, sweet corn, popcorn, corn grits, flour and meal analyzed by USDA, NEVO (Nederland's Voedingsstoffenbestand) and NRC (National Research Council) have been compared and our data was also in

Table 2 Proximate Composition (g %) of raw and processed corn

Type of corn	Method of processing	Moisture	Protein	Fat	Ash	Dietary Fiber		Carbohydrate	Energy (Kcal)
						Insoluble	Soluble		
Baby Corn	Raw	92.39 ± 0.01 ^{a1}	1.68 ± 0.01 ^{a1}	0.67 ± 0.01 ^{a1}	0.47 ± 0.02 ^{a1}	3.14 ± 0.01 ^{a1}	0.51 ± 0.02 ^{a1}	1.14 ± 0.01 ^{a1}	18 ± 0.05 ^{a1}
	Steamed	92.73 ± 0.01 ^{a2}	1.64 ± 0.02 ^{a2}	0.62 ± 0.01 ^{a2}	0.48 ± 0.02 ^{a1}	3.01 ± 0.02 ^{a2}	0.49 ± 0.01 ^{a2}	1.04 ± 0.07 ^{a2}	17 ± 0.17 ^{a2}
Sweet Corn	Raw	74.70 ± 0.02 ^{b1}	3.67 ± 0.01 ^{b1}	1.63 ± 0.01 ^{b1}	0.80 ± 0.06 ^{b1}	5.44 ± 0.01 ^{b1}	0.38 ± 0.01 ^{b1}	13.39 ± 0.07 ^{b1}	84 ± 0.28 ^{b1}
	Steamed	75.54 ± 0.01 ^{b2}	3.60 ± 0.02 ^{b2}	1.57 ± 0.01 ^{b2}	0.81 ± 0.01 ^{b1}	4.68 ± 0.04 ^{b2}	0.36 ± 0.01 ^{b2}	13.23 ± 0.02 ^{b2}	82 ± 0.05 ^{b2}
Dent Corn	Raw	56.12 ± 0.01 ^{c1}	3.85 ± 0.06 ^{c1}	1.92 ± 0.02 ^{c1}	0.80 ± 0.02 ^{c1}	3.72 ± 0.02 ^{c1}	0.97 ± 0.02 ^{c1}	32.59 ± 0.09 ^{c1}	165 ± 0.05 ^{c1}
	Steamed	57.34 ± 0.01 ^{c2}	4.40 ± 0.01 ^{c2}	1.80 ± 0.03 ^{c2}	0.83 ± 0.03 ^{c1}	3.66 ± 0.01 ^{c2}	0.94 ± 0.01 ^{c2}	31.01 ± 0.06 ^{c2}	160 ± 0.21 ^{c2}
Popcorn with oil	Raw	7.62 ± 0.01 ^{d1}	7.16 ± 0.01 ^{d1}	8.46 ± 0.01 ^{d1}	1.92 ± 0.02 ^{d1}	21.18 ± 0.03 ^{d1}	2.88 ± 0.04 ^{d1}	50.80 ± 0.02 ^{d1}	314 ± 0.06 ^{d1}
Popcorn without oil	Popped	0.10 ± 0.01 ^{d3}	6.93 ± 0.02 ^{d3}	9.71 ± 0.25 ^{d3}	1.86 ± 0.02 ^{d1}	20.83 ± 0.03 ^{d1}	2.64 ± 0.03 ^{d3}	57.92 ± 0.20 ^{d3}	352 ± 1.32 ^{d3}
	Raw	5.01 ± 0.01 ^{e1}	9.42 ± 0.11 ^{e1}	2.69 ± 0.03 ^{e1}	1.01 ± 0.02 ^{e1}	11.40 ± 0.06 ^{e1}	1.01 ± 0.02 ^{e1}	69.42 ± 0.05 ^{e1}	342 ± 0.11 ^{e1}
Corn Grits	Popped	0.03 ± 0.01 ^{e3}	8.14 ± 0.03 ^{e3}	2.47 ± 0.09 ^{e3}	1.03 ± 0.01 ^{e1}	11.75 ± 0.04 ^{e1}	0.98 ± 0.03 ^{e3}	73.52 ± 0.06 ^{e3}	359 ± 0.40 ^{e3}
	Raw	8.05 ± 0.01 ^{f1}	8.61 ± 0.01 ^{f1}	2.62 ± 0.02 ^{f1}	0.53 ± 0.01 ^{f1}	6.10 ± 0.02 ^{f1}	2.46 ± 0.02 ^{f1}	71.64 ± 0.03 ^{f1}	350 ± 0.22 ^{f1}
Corn Flour	Boiled	79.67 ± 0.01 ^{f4}	1.88 ± 0.04 ^{f4}	0.53 ± 0.01 ^{f4}	0.10 ± 0.01 ^{f4}	1.22 ± 0.02 ^{f4}	0.51 ± 0.02 ^{f4}	16.09 ± 0.04 ^{f4}	78 ± 0.12 ^{f4}
	Raw	5.66 ± 0.01 ^{g1}	ND	1.25 ± 0.01 ^{g1}	0.08 ± 0.01 ^{g1}	2.97 ± 0.03 ^{g1}	1.61 ± 0.02 ^{g1}	88.48 ± 0.04 ^{g1}	368 ± 0.22 ^{g1}
Corn flakes*	Boiled	62.72 ± 0.01 ^{g4}	ND	0.46 ± 0.01 ^{g4}	0.02 ± 0.02 ^{g4}	1.17 ± 0.03 ^{g4}	0.63 ± 0.03 ^{g4}	35.04 ± 0.04 ^{g4}	146 ± 0.18 ^{g4}
	Raw	5.83 ± 0.01 ¹	7.54 ± 0.01 ¹	4.58 ± 0.02 ¹	0.70 ± 0.01 ¹	3.22 ± 0.03 ¹	0.86 ± 0.03 ¹	77.21 ± 0.03 ¹	382 ± 0.19 ¹
	Fried in oil	0.04 ± 0.01 ⁵	5.42 ± 0.03 ⁵	18.27 ± 0.16 ⁵	0.50 ± 0.02 ⁵	2.44 ± 0.02 ⁵	0.69 ± 0.04 ⁵	72.63 ± 0.18 ⁵	478 ± 0.82 ⁵

Data are represented as mean ± SD of triplicate measurement (fresh weight basis). Values designated with different letters and numbers in each column are significantly different at 5% level ($p \leq 0.05$) determined by least significant difference (LSD) using two way ANOVA

The alphabets a, b, c, d, e, f, g given as superscripts denotes type of corn sample while the numbers 1, 2, 3, 4, 5 denotes the methods of cooking employed

ND not detectable

* Student independent sample *t* test was applied

accordance with it. Apart, from this, our data also showed the effect of processing on fresh and other processed corn products. The fat content in popcorn with oil and corn flakes fried in oil were highest (9.71 and 18.27%) due to the addition of oil during the preparation of the corn products while it was least in boiled corn flour and corn grits (0.46 and 0.53%) which was due to the addition of water during cooking. Corn is an important food crop for human and high energy feed for animals. Corn compares favorably with root and tuber crops as a staple food and as a good source of vitamin, mineral, fiber and has energy similar to dried legumes. Popcorn being a complement of nutrition benefits such as dietary fiber, protein and B-complex vitamins is consumed as versatile and nutritious snacks (Donkeun et al. 2000). Our studies also revealed similar values for popcorn in protein, ash, dietary fiber, carbohydrate and energy. Although, corn flour in its raw form showed the highest carbohydrate content, reduction was observed after processing by boiling with water. The conversion of corn into various products is a process which is affected by the type of corn used, as well as other variables, such as water, heat treatments, washing, steeping times, grinding and final cooking which influences functional characteristics, chemical composition and nutritive value due to the changes in the structure. Among the processed corn products, ready for consumption the soluble and insoluble dietary fiber was found to be high in popcorn, popped with oil (2.64 and 20.83%). Fiber can be lost during peeling, filtration, and stem removal or during processing. Studies have suggested that the solubility and physiochemical properties of fibre changed during heat processing as seen in our study too. The energy content was highest in corn flakes fried in oil with 478 kcal while it was lowest in steamed baby corn with 17 kcal.

Mineral composition

In our study the mineral composition of corn and its products showed higher concentrations of magnesium, phosphorus, potassium, and low concentrations of calcium, manganese, zinc, iron, copper, and sodium. The low concentration of calcium and zinc recorded in this study tallies with the findings of Asiedu et al. (1993), who found that cereal are poor in these minerals. However, the observed differences in mineral composition in these products may be due to genetic factor and environmental factors like irrigation frequency, soil composition and fertilizer used (Ikram et al. 2010). The mineral contents of fresh, prepared and processed corn products are given in Table 3. In our study among the ready to eat products, popcorn, popped without oil showed higher iron (1.81 mg/100 g), zinc (1.89 mg/100 g), copper (0.27 mg/100 g), manganese (0.72 mg/100 g), magnesium (103.57 mg/100 g) and

phosphorus (179.22 mg/100 g) content when compared to other corn products while corn grits and corn flour boiled with water were lower in all the elements analyzed. This finding showed that popcorn is a good source of these essential minerals, particularly for the iron and zinc which are of public health significance and this further enhanced the nutritional values of the popcorn products hence, its utilization in the production of various corn products or any other cereal-based meal products would not have any detrimental effects on the consumers. Significant differences were observed ($p \leq 0.05$) among the various corn samples and its products analyzed while no significant differences ($p > 0.05$) were observed when the different method of processing were compared the reason being minerals are heat stable under normal processing conditions. Processing conditions such as addition of salt, leaching during blanching can bring about a gain or loss of minerals in food products. The loss of minerals such as potassium and calcium can be nutritionally detrimental compared to sodium by leaching into the cooking liquid during cooking process. The mineral composition of sweet corn raw and boiled in our study is comparable to the data given by FSANZ (2006). The sodium levels in popcorn with oil were high due to addition of salt in these products. Potassium content was high in raw and steamed dent corn with 296.16, 327.27 mg/100 g, respectively.

Total carotenoids and individual xanthophylls

The total carotenoid and individual xanthophyll content of raw corn and its processed products is given in Table 4. The xanthophylls identified in the corn samples were lutein, zeaxanthin, α -cryptoxanthin and β -cryptoxanthin. Among the xanthophylls, zeaxanthin was predominant in all the prepared and processed corn products and this is supported by the study which showed that corn and corn products were major sources of dietary zeaxanthin (Perry et al. 2009). Dent corn contained relatively higher amount of zeaxanthin (993.29 $\mu\text{g}/100\text{ g}$ in raw and 891.66 $\mu\text{g}/100\text{ g}$ in steamed) while in baby corn it was not detectable. Leaching of carotenoids into the oil used in cooking during stir frying is attributed to the reduction of xanthophylls when compared with boiling (Rodriguez-Amaya and de Sa 2004) hence in the case of corn flakes, there were significant differences ($p \leq 0.05$) between the raw and fried samples. Lutein concentration was highest in yellow prepared and processed corn (394.38 $\mu\text{g}/100\text{ g}$ in raw and 313.66 $\mu\text{g}/100\text{ g}$ in steamed) which was also reported by de la Parra et al.(2007), while it was not traceable in corn flour which can be attributed to the fact that corn flour is a processed product obtained from milling the endosperm of the maize germ after the removal of germ and outer layer which results in the loss of nutrients while yellow dent corn

Table 3 Mineral composition (mg/100 g) of raw and processed corn

Type of corn	Method of processing	Fe mg/100 g	Zn	Cu	Mn	Na	Mg	K	P	Ca
Baby Corn	Raw	0.41 ± 0.01 ^{a1}	0.40 ± 0.01 ^{a1}	0.10 ± 0.01 ^{a1}	0.56 ± 0.01 ^{a1}	0.22 ± 0.02 ^{a1}	22.73 ± 0.52 ^{a1}	140.88 ± 1.25 ^{a1}	48.76 ± 1.56 ^{a1}	12.27 ± 0.28 ^{a1}
	Steamed	0.44 ± 0.01 ^{a1}	0.44 ± 0.01 ^{a2}	0.09 ± 0.02 ^{a1}	0.59 ± 0.02 ^{a1}	0.24 ± 0.03 ^{a1}	24.22 ± 1.28 ^{a1}	144.59 ± 2.52 ^{a2}	50.43 ± 0.35 ^{a2}	13.22 ± 0.02 ^{a1}
Sweet Corn	Raw	0.60 ± 0.01 ^{b1}	0.79 ± 0.01 ^{b1}	0.12 ± 0.02 ^{b1}	0.32 ± 0.01 ^{b1}	0.49 ± 0.04 ^{b1}	37.31 ± 0.88 ^{b1}	298.22 ± 2.64 ^{b1}	119.61 ± 0.51 ^{b1}	3.80 ± 0.62 ^{b1}
	Steamed	0.55 ± 0.04 ^{b1}	0.74 ± 0.03 ^{b2}	0.13 ± 0.02 ^{b1}	0.31 ± 0.01 ^{b1}	0.42 ± 0.03 ^{b1}	37.15 ± 0.29 ^{b1}	287.63 ± 2.11 ^{b2}	102.68 ± 1.58 ^{b2}	3.20 ± 0.12 ^{b1}
Dent Corn	Raw	0.75 ± 0.01 ^{c1}	0.84 ± 0.03 ^{c1}	0.11 ± 0.07 ^{c1}	0.24 ± 0.01 ^{c1}	0.63 ± 0.02 ^{c1}	43.52 ± 0.20 ^{c1}	296.16 ± 1.50 ^{c1}	155.46 ± 3.92 ^{c1}	5.38 ± 2.15 ^{c1}
	Steamed	0.81 ± 0.02 ^{c1}	0.94 ± 0.03 ^{c2}	0.20 ± 0.02 ^{c1}	0.25 ± 0.03 ^{c1}	0.66 ± 0.03 ^{c1}	44.13 ± 3.0 ^{c1}	327.27 ± 2.76 ^{c2}	164.53 ± 0.61 ^{c2}	5.96 ± 1.25 ^{c1}
Popcorn with oil	Raw	1.65 ± 0.03 ^{d1}	1.81 ± 0.18 ^{d1}	0.26 ± 0.01 ^{d1}	0.64 ± 0.04 ^{d1}	456.04 ± 11.8 ^{d1}	81.30 ± 1.62 ^{d1}	185.90 ± 0.63 ^{d1}	193.15 ± 1.19 ^{d1}	5.63 ± 0.86 ^{d1}
	Popped	1.60 ± 0.01 ^{d3}	1.85 ± 0.02 ^{d1}	0.24 ± 0.02 ^{d1}	0.60 ± 0.01 ^{d3}	489.04 ± 1.63 ^{d3}	83.35 ± 3.20 ^{d3}	163.58 ± 2.17 ^{d1}	175.91 ± 8.30 ^{d3}	4.82 ± 1.14 ^{d1}
Popcorn without oil	Raw	1.92 ± 0.06 ^{e1}	1.95 ± 0.03 ^{d1}	0.24 ± 0.01 ^{d1}	0.73 ± 0.01 ^{e1}	2.39 ± 0.02 ^{e1}	95.37 ± 1.83 ^{e1}	253.67 ± 0.71 ^{e1}	199.71 ± 1.87 ^{d1}	11.71 ± 6.31 ^{e1}
	Popped	1.81 ± 0.02 ^{e3}	1.89 ± 0.02 ^{d1}	0.27 ± 0.01 ^{d1}	0.72 ± 0.02 ^{e3}	2.64 ± 0.21 ^{e3}	103.57 ± 4.82 ^{e3}	283.63 ± 11.5 ^{e3}	179.22 ± 7.49 ^{d3}	11.86 ± 3.56 ^{e3}
Corn Grits	Raw	1.00 ± 0.05 ^{f1}	1.23 ± 0.06 ^{f1}	0.23 ± 0.23 ^{f1}	0.24 ± 0.01 ^{f1}	0.57 ± 0.02 ^{f1}	44.09 ± 2.54 ^{f1}	143.42 ± 2.31 ^{f1}	169.07 ± 3.02 ^{f1}	7.84 ± 1.02 ^{f1}
	Boiled	0.22 ± 0.03 ^{f4}	0.26 ± 0.02 ^{f4}	0.11 ± 0.01 ^{f1}	0.05 ± 0.01 ^{f4}	0.13 ± 0.02 ^{f4}	9.66 ± 0.01 ^{f4}	32.59 ± 2.15 ^{f4}	36.19 ± 0.76 ^{f4}	2.51 ± 0.63 ^{f4}
Corn Flour	Raw	1.65 ± 0.01 ^{g1}	0.09 ± 0.01 ^{g1}	0.03 ± 0.02 ^{f1}	0.08 ± 0.01 ^{g1}	19.46 ± 0.01 ^{g1}	6.36 ± 0.04 ^{g1}	5.47 ± 0.58 ^{g1}	12.20 ± 0.87 ^{g1}	18.50 ± 0.22 ^{g1}
	Boiled	0.63 ± 0.02 ^{g4}	0.03 ± 0.02 ^{g4}	0.04 ± 0.05 ^{f1}	0.03 ± 0.01 ^{g4}	7.60 ± 0.04 ^{g4}	2.60 ± 0.08 ^{g4}	2.36 ± 0.01 ^{g4}	4.41 ± 0.21 ^{g4}	5.79 ± 0.59 ^{g4}
Corn flakes*	Raw	1.15 ± 0.04 ¹	0.57 ± 0.02 ¹	0.13 ± 0.03 ¹	0.26 ± 0.03 ¹	6.19 ± 0.03 ¹	31.55 ± 0.97 ¹	207.87 ± 0.68 ¹	133.26 ± 1.36 ¹	1.6 ± 0.09 ¹
	Fried	0.89 ± 0.028 ⁵	0.43 ± 0.02 ⁵	0.14 ± 0.01 ¹	0.21 ± 0.01 ¹	4.64 ± 0.03 ⁵	21.22 ± 0.31 ⁵	144.52 ± 3.46 ⁵	89.83 ± 4.70 ⁵	1.21 ± 0.02 ⁵

Data are represented as mean ± SD of triplicate measurement (fresh weight basis). Values designated with different letters and numbers in each column are significantly different at 5% level ($p \leq 0.05$) determined by least significant difference (LSD) using two way ANOVA

The alphabets a, b, c, d, e, f, g given as superscripts denotes type of corn sample while the numbers 1, 2, 3, 4, 5 denotes the methods of cooking employed

* Student independent sample *t* test was applied

Table 4 Total carotenoids and xanthophylls ($\mu\text{g}/100\text{ g}$) in raw and processed corn

Type of corn	Method of processing	Total carotenoids	Lutein	Zeaxanthin	Alpha-cryptoxanthin	Beta-cryptoxanthin
Baby corn	Raw	$394.3 \pm 1.80^{\text{a1}}$	$224.58 \pm 0.90^{\text{a1}}$	ND	ND	ND
	Steamed	$355.20 \pm 5.10^{\text{a2}}$	$233.49 \pm 43.06^{\text{a1}}$	ND	ND	ND
Sweet corn	Raw	$1016.8 \pm 84.30^{\text{b1}}$	$136.76 \pm 9.57^{\text{b1}}$	$652.42 \pm 37.46^{\text{b1}}$	$25.39 \pm 0.79^{\text{b1}}$	$91.56 \pm 0.56^{\text{b1}}$
	Steamed	$967.80 \pm 68.70^{\text{b2}}$	$128.92 \pm 3.45^{\text{b1}}$	$573.37 \pm 18.20^{\text{b2}}$	$20.30 \pm 0.93^{\text{b2}}$	$89.03 \pm 4.12^{\text{b2}}$
Dent corn	Raw	$987.67 \pm 46.95^{\text{c1}}$	$394.38 \pm 2.75^{\text{c1}}$	$993.29 \pm 2.27^{\text{c1}}$	$93.55 \pm 0.36^{\text{c1}}$	$198.27 \pm 2.73^{\text{c1}}$
	Steamed	$2026.17 \pm 3.25^{\text{c2}}$	$313.66 \pm 36.22^{\text{c1}}$	$891.66 \pm 105.30^{\text{c2}}$	$87.11 \pm 2.82^{\text{c2}}$	$200.02 \pm 19.68^{\text{c2}}$
Popcorn with oil	Raw	$2496.23 \pm 138.05^{\text{d1}}$	$114.20 \pm 2.52^{\text{d1}}$	$385.75 \pm 76.81^{\text{d1}}$	$18.57 \pm 2.33^{\text{d1}}$	$60.50 \pm 9.91^{\text{d1}}$
	Popped	$1959.1 \pm 39.80^{\text{d3}}$	$109.30 \pm 0.70^{\text{d1}}$	$367.61 \pm 6.43^{\text{d1}}$	$16.60 \pm 1.23^{\text{d1}}$	$50.34 \pm 0.67^{\text{d1}}$
Popcorn without oil	Raw	$1615.60 \pm 24.60^{\text{e1}}$	$247.19 \pm 20.25^{\text{e1}}$	$377.70 \pm 58.74^{\text{d1}}$	$114.86 \pm 8.38^{\text{e1}}$	$181.10 \pm 28.58^{\text{e1}}$
	Popped	$1122.53 \pm 63.75^{\text{e3}}$	$225.01 \pm 1.21^{\text{e1}}$	$383.75 \pm 27.49^{\text{d1}}$	$104.40 \pm 3.20^{\text{e1}}$	$169.67 \pm 8.84^{\text{e1}}$
Corn grits	Raw	$2509.70 \pm 86.50^{\text{f1}}$	$177.54 \pm 29.22^{\text{f1}}$	$441.66 \pm 128.68^{\text{f1}}$	$42.76 \pm 0.76^{\text{f1}}$	$59.56 \pm 25.05^{\text{f1}}$
	Boiled	$499.37 \pm 3.95^{\text{f4}}$	$138.61 \pm 3.97^{\text{f4}}$	$277.57 \pm 4.65^{\text{f4}}$	$5.76 \pm 0.93^{\text{f4}}$	$39.74 \pm 6.72^{\text{f4}}$
Corn flour	Raw	$30.93 \pm 1.35^{\text{g1}}$	ND	$44.18 \pm 0.99^{\text{f1}}$	ND	ND
	Boiled	$10.60 \pm 0.50^{\text{g4}}$	ND	$15.79 \pm 0.54^{\text{f4}}$	ND	ND
Corn flakes*	Raw	1992.73 ± 5.75^1	87.28 ± 8.39^1	866.68 ± 22.93^1	290.05 ± 5.59^1	71.56 ± 4.11^1
	Fried	1551.43 ± 8.25^5	71.32 ± 2.33^5	422.43 ± 18.33^5	233.72 ± 3.23^5	ND

Data are represented as mean $\pm$ SD of triplicate measurement (fresh weight basis). Values designated with different letters and numbers in each column are significantly different at 5% level ($p \leq 0.05$) determined by least significant difference (LSD) using two way ANOVA

The alphabets a, b, c, d, e, f, g given as superscripts denotes type of corn sample while the numbers 1, 2, 3, 4, 5 denotes the methods of cooking employed

ND not detectable

* Student independent sample *t* test was applied

is a fresh product which was a prepared product. Studies by Singh et al. (2011) reported the presence of higher levels of xanthophylls in some corn samples to be responsible for the higher yellow pigment content. Further, food preparation did not significantly affect lutein concentration in prepared fresh products such as baby corn, sweet corn, dent corn and processed products such as popcorn with and without oil except for prepared and processed products such as corn grits and corn flakes as it was boiled and fried in oil. Lutein being a lipophilic compound is easily dissolved in heating oil and thereby lost from the vegetables during frying process as shown in the current study (Miglio et al. 2008). Losses in the carotenoids content when the samples were subjected to different culinary processes were also reported. Carotenoids concentration is also influenced by various factors like species/variety, stage of maturity, part of the plant consumed, cultivar, cooking preparation, time of harvesting (Torregrosa et al. 2005). Lower levels of zeaxanthin was reported in pre-cooked corn flour when compared to canned corn (De Oliveira and Rodriguez-Amaya 2007) similar decrease was observed in our study in the corn flour when compared to other corn products and there was significant decrease between the raw and the boiled corn flour. The α -

cryptoxanthin concentration was highest in corn flakes both raw and fried in oil (290.05 and $233.72\text{ }\mu\text{g}/100\text{ g}$) while it was not detectable in baby corn and corn flour. Carotenoid availability is enhanced by domestic cooking (Rock et al. 1998), our study on the contrary has shown significant decrease in the xanthophyll content. β -cryptoxanthin was high in dent corn ($198.27\text{ }\mu\text{g}/100\text{ g}$ raw and $200.02\text{ }\mu\text{g}/100\text{ g}$ steamed) as compared to other corn products followed by popcorn without oil (181.10 , $169.67\text{ }\mu\text{g}/100\text{ g}$) while it was not detectable in baby corn and corn flour.

Total polyphenolic content and individual phenolic acids using RPHPLC

The total polyphenolic content (TPC) and individual phenolic acids in fresh, prepared and processed corn are given in Table 5. Results showed that the total polyphenolic content was more in the raw samples which ranged from 1.26 to $14.53\text{ mg GAE}/100\text{ g}$ as compared to the cooked and processed corn and corn products which ranged from 1.16 to $12.61\text{ mg GAE}/100\text{ g}$. This reduction in the polyphenolic compounds could be attributed to the fact that phenols react with protein forming poorly extractable protein/phenolic complexes. The TPC was high in raw dent

Table 5 Total polyphenolic (GAE mg/100 g) content and phenolic acids ($\mu\text{g}/100\text{ g}$) in raw and processed corn

Samples	Method of processing	Total polyphenolic content	4-OH Benzoic acid	Vanillic acid	Syringic acid	<i>o</i> -coumaric acid	Caffeic acid	<i>p</i> -coumaric acid	Ferulic acid
Baby Corn	Raw	10.7 $\pm$ 0.46 ^{al}	45.17 $\pm$ 0.18 ^{al}	83.36 $\pm$ 0.67 ^{al}	11.66 $\pm$ 0.17 ^{al}	6.43 $\pm$ 0.1 ^{al}	2.34 $\pm$ 0.2 ^{al}	1.25 $\pm$ 0.11 ^{al}	10.34 $\pm$ 0.17 ^{al}
	Steamed	6.57 $\pm$ 0.25 ^{a2}	24.78 $\pm$ 0.58 ^{a2}	57.56 $\pm$ 0.31 ^{a2}	8.19 $\pm$ 0.14 ^{a2}	2.86 $\pm$ 0.11 ^{a2}	1.15 $\pm$ 0.09 ^{a2}	0.34 $\pm$ 0.18 ^{a2}	2.47 $\pm$ 0.15 ^{a2}
Sweet Corn	Raw	8.88 $\pm$ 0.16 ^{b1}	46.88 $\pm$ 0.55 ^{b1}	32.64 $\pm$ 0.22 ^{b1}	15.48 $\pm$ 0.12 ^{b1}	6.17 $\pm$ 0.11 ^{b1}	6.46 $\pm$ 0.11 ^{b1}	1.69 $\pm$ 0.39 ^{b1}	3.45 $\pm$ 0.25 ^{b1}
	Steamed	7.46 $\pm$ 0.33 ^{b2}	24.52 $\pm$ 0.14 ^{b2}	20.23 $\pm$ 0.18 ^{b2}	13.31 $\pm$ 0.23 ^{b2}	3.65 $\pm$ 0.2 ^{b2}	3.62 $\pm$ 0.05 ^{b2}	1.29 $\pm$ 0.06 ^{b2}	1.67 $\pm$ 0.47 ^{b2}
Dent Corn	Raw	14.53 $\pm$ 0.36 ^{c1}	7.47 $\pm$ 0.06 ^{c1}	63.46 $\pm$ 0.08 ^{c1}	10.25 $\pm$ 0.09 ^{c1}	9.48 $\pm$ 0.2 ^{c1}	3.72 $\pm$ 0.1 ^{c1}	2.47 $\pm$ 0.09 ^{c1}	1.5 $\pm$ 0.06 ^{c1}
	Steamed	12.61 $\pm$ 0.25 ^{c2}	4.63 $\pm$ 0.12 ^{c2}	40.68 $\pm$ 0.38 ^{c2}	5.57 $\pm$ 0.09 ^{c2}	3.59 $\pm$ 0.28 ^{c2}	2.53 $\pm$ 0.16 ^{c2}	1.26 $\pm$ 0.11 ^{c2}	1.16 $\pm$ 0.13 ^{c2}
Popcorn with oil	Raw	13.47 $\pm$ 0.56 ^{d1}	45.5 $\pm$ 0.12 ^{d1}	43.26 $\pm$ 0.09 ^{d1}	1.59 $\pm$ 0.28 ^{d1}	6.3 $\pm$ 0.07 ^{d1}	2.21 $\pm$ 0.21 ^{d1}	4.21 $\pm$ 0.08 ^{d1}	1.43 $\pm$ 0.05 ^{d1}
	Popped	7.38 $\pm$ 0.1 ^{d3}	29.47 $\pm$ 0.19 ^{d3}	23.41 $\pm$ 0.15 ^{d3}	1.28 $\pm$ 0.09 ^{d3}	2.33 $\pm$ 0.13 ^{d3}	1.35 $\pm$ 0.03 ^{d3}	0.94 $\pm$ 0.08 ^{d3}	0.87 $\pm$ 0.07 ^{d3}
Popcorn without oil	Raw	11.4 $\pm$ 0.16 ^{f1}	31.13 $\pm$ 0.11 ^{f1}	33.66 $\pm$ 0.23 ^{f1}	1.43 $\pm$ 0.03 ^{f1}	5.25 $\pm$ 0.06 ^{f1}	1.39 $\pm$ 0.03 ^{f1}	3.83 $\pm$ 0.08 ^{f1}	1.15 $\pm$ 0.09 ^{f1}
	Popped	6.88 $\pm$ 0.05 ^{f3}	26.48 $\pm$ 0.13 ^{f3}	16.38 $\pm$ 0.12 ^{f3}	1.1 $\pm$ 0.07 ^{f3}	2.28 $\pm$ 0.28 ^{f3}	1.25 $\pm$ 0.03 ^{f3}	0.5 $\pm$ 0.03 ^{f3}	0.61 $\pm$ 0.03 ^{f3}
Corn Grits	Raw	3.7 $\pm$ 0.17 ^{g1}	55.24 $\pm$ 0.11 ^{g1}	23.69 $\pm$ 0.31 ^{g1}	6.77 $\pm$ 0.18 ^{g1}	2.74 $\pm$ 0.32 ^{g1}	4.8 $\pm$ 0.13 ^{g1}	11.43 $\pm$ 0.08 ^{g1}	3.34 $\pm$ 0.24 ^{g1}
	Boiled	1.72 $\pm$ 0.14 ^{g4}	37.2 $\pm$ 0.09 ^{g4}	19.28 $\pm$ 0.25 ^{g4}	4.69 $\pm$ 0.28 ^{g4}	1.27 $\pm$ 0.07 ^{g4}	2.34 $\pm$ 0.14 ^{g4}	8.68 $\pm$ 0.27 ^{g4}	1.31 $\pm$ 0.04 ^{g4}
Corn Flour	Raw	1.26 $\pm$ 0.11 ^{h1}	23.47 $\pm$ 0.17 ^{h1}	17.62 $\pm$ 0.3 ^{h1}	10.41 $\pm$ 0.17 ^{h1}	0.35 $\pm$ 0.06 ^{h1}	2.32 $\pm$ 0.03 ^{h1}	1.32 $\pm$ 0.09 ^{h1}	1.23 $\pm$ 0.11 ^{h1}
	Boiled	1.16 $\pm$ 0.33 ^{h4}	16.37 $\pm$ 0.14 ^{h4}	15.64 $\pm$ 0.32 ^{h4}	8.39 $\pm$ 0.07 ^{h4}	0.28 $\pm$ 0.06 ^{h4}	0.78 $\pm$ 0.03 ^{h4}	1.16 $\pm$ 0.08 ^{h4}	0.47 $\pm$ 0.05 ^{h4}
Corn flakes*	Raw	11.38 $\pm$ 0.28 ^l	44.82 $\pm$ 0.13 ^l	19.53 $\pm$ 0.07 ^l	15.38 $\pm$ 0.1 ^l	7.26 $\pm$ 0.03 ^l	3.49 $\pm$ 0.07 ^l	1.45 $\pm$ 0.06 ^l	1.45 $\pm$ 0.03 ^l
	Fried	3.56 $\pm$ 0.1 ⁵	30.33 $\pm$ 0.11 ⁵	7.46 $\pm$ 0.03 ⁵	6.72 $\pm$ 0.31 ⁵	5.39 $\pm$ 0.03 ⁵	1.87 $\pm$ 0.05 ⁵	0.37 $\pm$ 0.04 ⁵	1.13 $\pm$ 0.05 ⁵

Data are represented as mean $\pm$ SD of triplicate measurement (fresh weight basis). Values designated with different letters and numbers in each column are significantly different at 5% level ($p \leq 0.05$) determined by least significant difference (LSD) using two way ANOVA

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* Student independent sample *t* test was applied

corn and steamed dent corn with 14.53 mg GAE/100 g and 12.61 mg GAE/100 g respectively and it was less in corn flour raw (1.26 mg GAE/100 g) and boiled (1.16 mg GAE/100 g) which could be due to the degradation of bioactive compounds and absorption of water during boiling resulting in the dilution of active compounds (Podsedeck 2007).

In our study, the individual polyphenols identified in the fresh, prepared and processed corn samples were 4-OH benzoic acid, vanillic acid, syringic acid, o-coumaric acid, caffeic acid, *p*-coumaric acid and ferulic acid. Corn grains are a considerable source of polyphenol antioxidants, especially phenolic acids such as ferulic, caffeic and *p*-coumaric acids (Sosulski et al. 1982) which play an important role as antioxidants and regulators of the human immune system. Significant differences ($p \leq 0.05$) were observed in the TPC as well as individual phenolic acids in the corn and corn products analyzed in this study. Results also showed significant differences between the raw and different methods of cooking employed. The antioxidant activity of corn may be affected during cooking due to the release of more phenolic compounds and destruction or creation of redox-active metabolites (Ruiz-Rodriguez et al. 2008). These phenolic acids protect the human body from free radicals. The phenolic profile of different preparation of corn studied showed that the entire cob of corn is rich in phenolic acids (Pandey et al. 2013) which was in accordance with our study. Some studies showed that thermal treatments, used mainly by industry, tend to change the content of polyphenols as observed in our study too. Among the different phenolic acids identified in our study and in the ready to eat corn products, 4-OH benzoic acid was high in corn grits boiled with water (37.2 µg/100 g), vanillic acid was high in baby corn steamed (57.56 µg/100 g), syringic acid was high in sweet corn steamed (13.31 µg/100 g), o-coumaric acid in corn flakes fried in oil (5.39 µg/100 g), caffeic acid in sweet corn steamed (3.62 µg/100 g), *p*-coumaric acid in corn grits boiled in water (8.68 µg/100 g) and ferulic acid in baby corn steamed (2.47 µg/100 g). The result of thermal process on the level of phenolics depends on the kind of product (Hunter and Fletcher 2002) which is shown in our study too. The phenolic profile of different preparations of corn suggests that the quality and quantity of phenolic acids undergo change during different preparations.

Conclusion

The proximate and mineral composition of corn and its products provides substantive nutritional information on corn, for effective guide on dietetics. The data from the study indicates that eating whole corn which is high in carbohydrate and protein is more beneficial as compared to

flours where removal of the bran or germ resulted in removal of the vital component of the maize. It also indicates that staples such as corn are important mineral sources particularly of Fe, Zn, Cu, Mn, Mg and P if consumed as a whole especially in the form of popcorn and whole corn products will have significant effect on human health and nutrition. This study showed that steaming, boiling, roasting and frying have varying effects on the proximate, mineral, xanthophyll and polyphenol compositions of corn and corn products. Hence, our study supports preferential use of corn and its products for better human health and also suggests the inclusion of corn in the regular diet due to its higher phenolic acid content and xanthophylls lutein and zeaxanthin which are antioxidants and constitutes for the macular pigment. Hence, Corn is a vital food source for much of the world's population and represents a vehicle for sustenance and deficiency intervention and there are several industrial processes which can generate a wide variety of maize products to meet consumer's habits and preferences.

Acknowledgements We acknowledge the continuous support from the Director-in-charge, National Institute of Nutrition and we are also grateful to ICMR, New Delhi for the financial support to carry out the work.

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