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Assessment of essential and non-essential metals in popcorn and cornflake commercially available in Ethiopia

Adane Abebe, Bhagwan Singh Chandravanshi* and Ayalew Debebe

Department of Chemistry, College of Natural Sciences, Addis Ababa University, P.O. Box 1176, Addis Ababa, Ethiopia
*Corresponding author's E. mail: bscv2006@yahoo.com

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ABSTRACT

The levels of essential and non-essential metals in popcorn and cornflake were determined in samples collected from an open market and supermarkets in Addis Ababa, Ethiopia. The samples were mineralized by wet digestion method. The volumes of reagents, digestion temperature and digestion time were optimized after proper sample pretreatment. 1 g of the powdered sample was digested with 10 mL of the mixture of HNO_3 (69-72%), $HClO_4$ (60%) and H_2O_2 (30%) in a volume ratio of 6:2:2 (v/v) for 3 hours at 120 ^{0}C on a Kjeldahl digestion apparatus. The levels of metals in the digest were determined by flame atomic absorption spectrometry (for major metals: K, Na, Mg, Ca) and graphite furnace atomic absorption spectrometry (for trace and heavy metals: Cr, Mn, Fe, Co, Ni, Cu, Zn, Pb, Cd). The accuracy of the optimized procedure was evaluated by analyzing the digest of the spiked samples with standard solution and the percentage recoveries varied from 91.2–109%. The level of the metals determined (mg/kg dry weight) were: K 1293±233, Na 148±3, Mg 387±11, Ca 97.9±4.2, Cr 0.68±0.09, Mn (6.17±0.18, Fe 9.5± 2.1, Co 1.41±0.16, Cu 0.09±0.007, Zn 88.3±9.7 and Pb 0.94±0.29 in the popcorn and K 612±70, Na 410±5, Mg 323±11, Ca 196±99, Cr 0.30±0.0.07, Mn 3.0±0.1, Fe 5.5±0.74, Co 0.32±0.03, Cu 0.30±0.01, Zn 40.7±2.5 and Pb 0.36±0.03 in the cornflake while the concentration of Cd and Ni were below the detection limit in both the samples. K and Zn were present at the highest levels among major and trace metals, respectively. The popcorn and cornflake samples purchased from Addis Ababa (Ethiopia) were free from the toxic metals Cd and Ni, but not from Pb.

Capsule Summary: The essential and non-essential metal contents in the popcorn and cornflake commercially available in Ethiopia were determined by flame and graphite furnace atomic absorption spectrophotometry.

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INTRODUCTION

Popcorn (*Zea mays everta*) is a type of maize or corn and is a member of the grass family (Australian Government, 2008). Popcorn is a whole grain and is made up of three components: the germ, endosperm, and pericarp (or hull). Of the other types of corn it is only popcorn that pops! Popcorn differs from other types of corn in that its hull has just the right thickness to allow it to burst open. Each kernel of popcorn contains a small drop of water stored inside a circle of soft starch. Popcorn needs between 13.5-14% moisture to pop. The soft starch is surrounded by the kernel's hard outer surface. As the kernel heats up, the water begins to expand. With increasing temperature the water turns into steam and changes the starch inside each kernel into a superhot gelatinous goop. The pressure inside the grain increases, finally bursting the hull open. As it explodes, steam inside the kernel is released. The soft starch inside the popcorn becomes inflated and spills out, cooling immediately and forming into the odd shape (Smith, 1999; Avey, 2013). Pop maize is able to pop because, unlike other grains, its kernels have a hard moisture-sealing hull and a dense starchy filling. Pop maize is grown on a small scale compared to other types but popped kernels are consumed world-wide as a snack food (Smith, 1999; Avey, 2013).

The health benefits of popcorn are mainly derived from its impressive content of fiber, polyphenolic compounds, antioxidants, vitamin B complex, Mn and Mg. It avoids constipation, reduces the overall level of cholesterol from the body, its fiber regulates the release and management of blood sugar and insulin levels better than people with low levels of the fiber. Reducing these fluctuations in blood sugar is a major bonus for diabetic patients, for cancer prevention, used as anti-aging, and for weight loss, this is because popcorn has low caloric value (Australian Government, 2008). Ethiopians eat popped popcorn mostly during the holidays at the coffee ceremonies, especially in cities and towns.

Cornflakes are small flat pieces of maize that are eaten with milk as a breakfast cereal or toasted flakes made from the coarse meal of hulled corn for use as a breakfast cereal (McKevith, 2004; Leśniewicz, 2012). Cornflakes are good sources of vitamins, minerals, folate, dietary fiber, as well as proteins, and carbohydrates. Cornflakes are very rich in thiamine and have high iron content. Iron helps to keep the brain alert. Corn also contains a carotenoid called beta-cryptoxanthin, which is good for the health of the lungs and also prevents lung cancer. One of the benefits of corn is it provides lutein which the body cannot produce. Lutein is an important nutrient for eye health (McKevith, 2004; Australian Government, 2008).

The following are the health benefits of consuming cornflakes: (i) rich in complex carbohydrate and they offer energy for the body, (ii) enriched in thiamine, riboflavin, iron, niacin and fiber that make it a complete food, (iii) avoids constipation problems, (iv) reduces blood pressure, (v) used to regulate weight, if one takes a bowl of cornflakes in the morning, his/her tummy gets filled with rich fiber and it satisfies his/her hunger, so that there will be no accumulation of excess food in the body (McKevith, 2004; Australian Government, 2008; Swami, 2012; Kapoor, 2015).

Commercially available cornflakes are rich in sugar, salt and fat which make the people unhealthy if consumed in excess quantity. Grains are generally acidic in nature and causes acidic state in the blood and tissues. In case a person suffering from irritable bowel syndrome, the conditions may aggravate further with consumption of cornflake. The major raw materials for the production of cornflakes are maize. Sugar is another raw material used for the manufacture of cornflakes, other ingredients like flavors can also be included in the process (Swami, 2012; Kapoor, 2015).

The technology of cornflake production in Ethiopia is very new and most of the people in Ethiopia are not aware of this technology. As a result of this limitation the production and consumption of cornflake is very limited. In fact very few families in the cities are using this food purchasing from supermarkets which are imported from the abroad. Almost all the rural people in the country have no ideas about cornflakes. In the recent time some private owners are promoting the technology and the production of cornflakes in the cities. In the near future the cornflake producing companies and the consumption rates will be increased.

Several studies have recently been reported on the levels of metals in the different types of Ethiopian foods. Some of these are levels of metals in enset food products (Atlabachew and Chandravanshi, 2008), levels of metals in Ethiopian roasted coffee powder and their infusions (Ashu and Chandravanshi, 2011), levels of metals in vegetables (Weldegebriel et al., 2012), levels of major and trace metals in onion (Kitata and Chandravanshi, 2012), mineral contents of fruits of cactus pear (Aregahegn et al., 2013), levels of major, minor and toxic metals in tubers and flour of *Dioscorea abyssinica* (Aregahegn et al., 2013), levels of essential and non-essential metals in ginger (Wagesho and Chandravanshi, 2015), mineral content and antinutritional factors of yam and taro (Ayele et al., 2015), nutrient composition of niger seed (Syume and Chandravanshi, 2015), assessment of selected nutrients and toxic metals in fruits (Yami et al., 2016) and elemental analysis of Ethiopian coffee (Mehari et al., 2016).

The literature survey revealed that no study has been reported on the levels of metals in Ethiopian popcorn and the data on levels of metals in the popcorn and cornflakes are scarce worldwide. The main objectives of this study were to determine the levels of essential and non-essential metals in popcorn and cornflake commercially available in Addis Ababa, Ethiopia, (ii) to compare the levels of the identified metals in popcorn and cornflakes and (iii) to compare the levels of metals of this study with values reported in the literatures.

MATERIAL AND METHODS

Equipment and apparatus

Electronic blending device (FOSS KNIFETEC 1095, USA) was used for grinding and homogenizing the samples. Electronic series balance (OPTECH, A205EC, Italy) with precision of ±0.0001 g was used for weighing samples. 250 mL round bottom flasks fitted with reflux condenser were used with Kjeldahl (UK) apparatus hot plate to digest the samples. Filtration funnels (Kenutuf, England) and different sizes of filter papers such as Whatman® filter paper 150 mm (Whatman® 541) (Whatman International Ltd Maid-Stone, England) and filter paper 125 mm (from Schleicher & Schuell Micro Science GmbH, Germany) were used for filtration of sample solution after digestion during the optimization and sample preparation processes. Volumetric flasks (50 and 100 mL) were used during dilution and preservation of samples and preparation of metals standard solutions. HTL pipettes with 0.01 mL division with pipette tips and micro pipettes (10-100 µL and 100-1000 µL, USA) were used for measuring reagents during optimization, sample preparation, preparation of standard solutions and spiking solutions. Refrigerator (SANYO Electric Biomedical Co. Ltd, Japan) was used for sample preservation after digestion and before AAS analysis. Flame atomic absorption spectrophotometer (Analytikjena: Model ZEEnit700P, VGP AAS, Germany) equipped with deuterium arc back ground connectors and hollow cathode lamps with air-acetylene flame was used for the determination of the analyte metals (K, Na, Mg, Ca). Graphite furnace atomic absorption spectrophotometer (PerkinElmer, AAnalyst 600, USA) with more than 99.99% pure Argon gas was used for the determination of the trace metals (Cr, Mn, Fe, Co, Ni, Cu, Zn, Pb, Cd).

Chemicals and reagents

HNO_3 (69-72%, Scharlau Chemie S.A., European Union, Spain), $HClO_4$ (60%, BDH Laboratory Supplies AnalaR®, Poole, England) and extra pure H_2O_2 (30%, Scharlau Chemie S.A., European Union, Spain) were used for digestion of the samples. $La(NO_3)_3.6H_2O$ (98%, BDH Chemicals Ltd, Poole, England) was used to minimize the precipitation of Ca and Mg ions in the form of phosphates and sulfates. Stock standard solutions containing 1000 mg/L of the metals K, Na, Mg, Ca, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd and Pb (BDH Chemicals Ltd Spectrosol®, Poole, England) were used for preparation of calibration standards and for the spiking experiments. Deionized water was used for dilution of samples and metal standard solutions prior to analysis.

Sampling and sample preparation

Three packs (500 g each) of cornflakes imported from Egypt were purchased from Addis Ababa supermarkets and thoroughly mixed in a plastic bag. Then a portion of the mixture was crushed in to pieces and ground and homogenized in electronic blending device. A representative portion of about 100 g was transferred in to the cleaned and dried glass bottle till digestion.

About 1 kg of popcorn was purchased from 5 shops (about 200 g from each), thoroughly mixed and a representative portion of about 100 g was prepared. The popcorn was prepared according to the traditional procedure used in Ethiopia. In order to remove some extraneous matter adhering to the surfaces, the popcorn was rubbed with a piece of dry and clean cloth before popping. Then in a clean and dry metal dish about 5 mL of cooking oil was added. The dish containing the oil was transferred to a stove for heating. After about 3 min the popcorn was transferred in to the dish. The dish was covered with its lid. Heating the dish was resumed with frequent swirling by hand holding the dish with a piece of cloth. After the completion of popping, the popped popcorn was allowed to cool to room temperature. The cooled popped popcorn was crushed in to pieces and ground in electronic blending device. The homogenized sample was transferred in to the cleaned and dried sample bottle until digestion.

Digestion of the samples

A known amount (1 g) of powdered and homogenized popped popcorn samples were transferred into 250 mL round bottom flasks and 10 mL of the mixture of HNO_3 (69-72%), $HClO_4$ (60%) and H_2O_2 (30%) with a volume ratio of 6:2:2 (v/v) was added and the mixture was digested on a Kjeldahl digestion apparatus for the optimized period of time (3 hours) at the optimized temperature (120 ^{0}C). After 3 hours of digestion time the digested mixture was allowed to cool to room temperature without dismantling the condenser. The condenser was removed and about 10 mL of deionized water was added to the digest to dissolve the precipitate formed on cooling and to minimize dissolution of filter paper by the digest residue while filtering with Whatman 541 filter paper into 50 mL volumetric flask. About 0.67 g of $La(NO_3)_3.6H_2O$ was added to the solution and diluted to the mark (50 mL) with deionized water. $La(NO_3)_3.6H_2O$ was added to prevent the precipitation of Ca^{+2} and Mg^{+2} with the SO_4^{-2} and PO_4^{-3} if they were present in the samples. Exactly the same digestion procedure was used for the cornflake sample. The digestion was carried out in triplicates for each sample. Digestion of a reagent blank was also performed in parallel with the samples keeping all digestion parameters the same. The digested samples were kept in the refrigerator until the levels of all the metals in the samples were determined.

Metals analysis of popcorn and cornflake samples

For the analysis of the samples calibration of the instrument with the known concentration of standards were done for each metal of interest. First the intermediate (10 mg/L) standard solutions were prepared from the stock solutions (1000 mg/L). The working standards were prepared from intermediate (10 mg/L) standard solutions. All the standards used were AAS grade.

The intermediate standard solutions were diluted with deionized water to obtain four working standards for each metal of interest. K, Na, Mg and Ca were determined with FAAS equipped with deuterium arc background corrector and standard air-acetylene flame system using external calibration curve after the parameters (burner and lamp alignment, slit width and wavelength adjustment) were optimized for maximum signal intensity of the instrument. Cr, Mn, Fe, Co, Ni, Cu, Zn, Pb and Cd concentrations were determined using GFAAS after the necessary optimizations and alignments were made. Three replicate determinations were carried out on each sample. Hallow cathode lamp for each metal operated at the manufacturer's recommended conditions were used at its respective primary source line. All the thirteen metals were determined by absorption/concentration mode and the instrument readout was recorded for each sample and blank solution. The same analytical procedure was employed for the determination of elements in digested blank solutions.

Instrument calibration

Both the FAAS and GFAAS were calibrated using four series of working standards for each metal of interest. The working standard solutions of each metal were prepared freshly by diluting the intermediate standard solutions. The correlation coefficients of the calibration curves were > 0.997 which confirmed a very good positive correlation between the absorbance and the concentration and were linearly fit.

Method performance and validation

Accuracy and precision are the most common terms related to analytical quality procedures to express the extent of errors in analytical measurements (Miller and Miller, 2005). In this study the results of the measurements are expressed as the mean of the measurements together with the standard deviation of the triplicate samples with triplicate measurements of each sample.

The validity of the method used was assessed by spiking experiments (Miller and Miller, 2005). For this purpose standard solution of 1000 mg/L was used and intermediate standards of 100 mg/L and 10 mg/L were prepared. The spiked and non-spiked samples were digested and analyzed in similar conditions using the procedure described above. The percentage recoveries of the analytes were calculated and the results were found within the range 91.2–109%. The percentage recoveries (100 ± 10%) of the metals in the samples are within the acceptable range for all metals.

RESULTS AND DISCUSSION

The mean values of the analysis were determined from triplicate analysis of the sample and the results are reported in terms of mean±SD for all the metals in this study. Among all the determined metals the level of Cd and Ni were below detection limits of the instrument. Results of determined metals in the samples are given in Table 1.

Distribution patterns of metals in the samples

The uptake of metals by plants takes place through different and complex biochemical processes. These up taking processes vary based on the ability of the plants to absorb metals from the soil, the availability of the minerals in the soluble and usable forms, the abundance of particular minerals at the particular areas, the degree of contamination of the soil with heavy metals, etc. The differences in the levels of metals in soil arise mainly due to pollution of the biosphere resulting from the rapid industrialization and modern large scale agricultural activities, i.e. use of different types of fertilizers, pesticides, herbicides and other chemicals. The use of sewage sludge, pesticides, herbicides, irrigation with polluted water and fertilizers on agricultural lands highly affect the quality of food products for humans and animals. The distribution and accumulation of metals in the popcorn and cornflake could be the reflections of the mineral composition of the soil and the degree of mineral pollution of the environment in which the popcorn/corn plant grows. Therefore, the actual metal concentration of cornflakes and popcorns vary considerably according to the geographic origin, the use of fertilizers with different chemical compositions and other characterizing features such as quality water for irrigation and also the storage conditions of the products.

Concentrations of metals in the popcorn and cornflake samples

Metals absorbed by plants from different sources are accumulated in different parts of the plant's body, like roots, stems, leaves, seeds and other parts. The amount of metals accumulated in the plants' body parts is variable. The focus of this study is on the level of metals in seeds (popcorn and the cornflake prepared from corn seeds), the common edible part by human beings.

From Table 1 we can see that the concentration of K is the highest among all the metals and Cu is the lowest in both the popcorn and cornflakes. The order of concentration of the metals determined is K > Mg > Na > Ca > Zn > Fe > Mn > Co > Pb > Cr > Cu in the popcorn and K > Na > Mg > Ca > Zn > Fe > Mn > Co > Pb > Cr ≈ Cu in the cornflakes.

From the nutritional point of view cornflake samples are less preferable than popcorn. As it can be seen from Table 1 all the metals levels in the popcorn is higher than in the cornflake sample except for Na, Ca and Cu. The high value of Na in the cornflake may be resulted from the salt added in the manufacturing process for flavoring purpose. The high values of Ca and Cu in the cornflake could probably be due to the water used (the water used in the process could be hard water), the packaging and storing conditions or due to the metallic materials in the cooking machine in the production processes. The lower values of metals in the cornflakes may probably due to the leaching of the metals in the various steps of the manufacturing process.

Level of micro-essential (trace) metals in maize seeds

From Table 1 we can see that Zn is the highest accumulated trace essential metal determined followed by Fe and Mn with concentration 88.3±9.7, 9.5±2.1 and 6.17±0.18 mg/kg, respectively, in the popcorn and 40.7±2.5, 5.5±0.74 and 3.0±0.1 mg/kg, respectively, in the cornflake. The lower concentration of minerals in the both the popcorn and cornflake may be due to soil pH. Micronutrients are significantly affected by soil pH, decreasing with increasing soil pH. For example solubility of Fe decreases a thousand

Table 1: Metal levels in popcorn and cornflakes from Addis Ababa markets

Metal	Concentration (mg/kg) (mean±SD)	
	Popcorn	Cornflake
K	1293±233	616±70
Na	148±3	410±5
Mg	387±11	323±11
Ca	97.9±4.2	196±9
Cr	0.68±0.09	0.30±0.07
Mn	6.17±0.18	3.0±0.1
Fe	9.5±2.1	5.5±0.74
Co	1.41 ±0.16	0.32 ±0.03
Cu	0.09 ±0.007	0.30 ±0.01
Zn	88.3±9.7	40.7±2.5
Pb	0.94±0.29	0.36±0.03

fold for each unit increase in soil pH in the range of 4 to 9 (Lindsay, 1979).

Levels of non-essential (toxic) metals in popcorn and cornflake samples

According to World Health Organization the dietary exposure to Cd is estimated to be about 1.2 x 10^{-4} to 4.9 x 10^{-4} mg/kg of body weight daily. Intake of dietary Cd should not exceed 0.007 mg/kg of body weight, per week. However, the levels of Cd and Ni in this work were below the instrument detection limits. Therefore, the popcorn and cornflakes studied are safe for human consumption and safe from human health problems due to the accumulation of Cd and Ni.

Pb is a major chemical pollutant of the environment and is highly toxic to man. The levels of Pb determined in this work are given in Table 1. The significant amounts of Pb content in the both the popcorn and cornflake samples may be attributed to agricultural inputs such as fertilizers, herbicides and insecticides containing Pb as an ingredient. Exposure to contamination during storage and transportation by cultivators could be the other causes for the higher values (Eick et al., 1999).

Comparison of metal levels of the present study with literature values

Comparison of levels of metals obtained in this study has been made with the investigations made in other countries by other investigators. Different researches were being made by different researchers in different countries on popcorn and cornflakes, but in the Ethiopian case no studies were made.

For the purpose of comparison, the results of this study on popcorn and results from literature are given in Tables 2-4. As it can be seen from Table 2, the levels of macro-essential metals determined in the popcorn in this work are in good agreement with other studies done in other countries. The concentration of K is in the range 872–2200 mg/kg, Na in the range 11.5–40 mg/kg, Mg in the range 810–2799 mg/kg and Ca 4.5–100 mg/kg dry weight. The results of this study (K 1293±233, Na 148±3, Mg 387±11 and Ca 97.9±4.2 mg/kg) are all in the ranges except for Na and Mg (Na is higher while Mg is lower than the reported values).

The levels of micro-essential metals in popcorn in this study and from the literature are shown in Table 3. The values for Cu, Mn, Co and Cr are not reported in the mentioned literature and hence we cannot compare the results. The results obtained in this study for Cu, Mn, Co and Cr are 0.09±0.007, 6.17±0.18, 1.41±0.16 and 0.68±0.09 mg/kg, respectively. If we look the values from the literatures mentioned Fe is in the range 2.2–11 mg/kg and the value obtained in this study is 9.5±2.1, it is in good agreement with the values in the literature. The value of Ni is not reported by both Ijarotimi et al. (2012) and McKevith (2004) but it is reported as 0.31 mg/kg by Orisakwe et al.

Table 2: Comparison of macro-essential metals concentration (mg/kg, dry weight basis) in popcorn sample with reported values

K	Na	Mg	Ca	Country	Reference
872	11.5	2799	4.5	Nigeria	Ijarotimi et al. (2012)
2200	40	810	100	Britain	Brigid McKevith (2004)
1293±233	148±3	387±11	97.9±4.2	Ethiopia	This study

Table 3: Comparison of micro-essential metals concentration, (mg/kg, dry weight basis) in popcorn sample with reported values

Cr	Mn	Fe	Co	Ni	Cu	Zn	Country	Reference
NR	NR	2.2	NR	NR	NR	3.9	Nigeria	Ijarotimi et al. (2012)
NR	NR	NR	NR	0.31	NR	NR	Nigeria	Orisakwe et al. (2012)
NR	NR	11	NR	NR	NR	17	Britain	McKevith (2004)
0.68±0.09	6.17±0.18	9.5±2.1	1.41±0.16	ND	0.09±0.007	88.3±9.7	Ethiopia	This study

Table 4: Comparison of toxic heavy metals concentration (mg/kg, dry weight basis) in popcorn sample with reported values

Cd	Pb	Country	Reference
ND	0.22	Nigeria	Orisakwe et al. (2012)
NR	NR	Britain	McKevith (2004)
ND	0.94±0.29	Ethiopia	This study

NR = not reported, ND = not detected.

(2012). The level of Ni in this study was below detection limit.

The determination for levels of toxic metals in the popcorn was also carried out in this study. Cd was found to be below the detection limit of the instrument. The level of Pb in this study was found as 0.94±0.29 mg/kg which is higher than the value reported by Orisakwe et al. (2012).

As it can be seen from Table 5, the levels of Na and K in the cornflake are not reported in the mentioned literature, but in this study the levels of Na and K are found to be 410±5 and 616±70 mg/kg, respectively. Mg is reported in the range 70–478 mg/kg and the value in this study is 323±11 mg/kg and the levels of Ca in the literature are in the range 27.8–1061.04 mg/kg and the value obtained in this study is 196±99 mg/kg. The values of both Ca and Mg in this study are in good agreement with those in the above mentioned literature.

Comparison of micro-essential metals in the cornflake is given in Table 6. The levels of Cr, Mn and Zn in the cornflake in this study (0.30±0.07, 3.0±0.1, 40.7±2.7 mg/kg, respectively) are higher than the levels of Cr, Mn and Zn (0.102±0.022, 0.36–1.87, 0.44–9.26 mg/kg, respectively) reported in the literature while the level of Fe (5.5±0.74 mg/kg) found in this study is lower than the reported values (10.9–41.0 mg/kg). The level of Cu (0.30±0.01 mg/kg) found in this study is in good agreement with the levels (0.20-0.81 mg/kg) reported in the literature. The Level of Co found in this study is (0.32±0.03 mg/kg) while it is not reported in the cited literature. Ni is not detected in cornflake studied in present work and its level is not reported in the literature.

Comparison of non-essential toxic heavy metals in the cornflake is given in Table 7. Cd is not detected in the cornflake studied in the present work while Cd is reported at trace level in the literature. In contrast Pb is found at higher level (0.36±0.03 mg/kg) in the cornflake of present study than the reported value (0.195±0.023 mg/kg) in the literature.

Table 5: Comparison of macro-essential metals concentration (mg/kg, dry weight basis) in cornflake sample with reported values

K	Na	Mg	Ca	Country	Reference
NR	NR	466±12	1061±0.04	Poland (M)	Leśniewicz et al. (2012)
NR	NR	73.9±3.9	30.5±2.7	Poland (N)	Leśniewicz et al. (2012)
NR	NR	363±12	54.7±3.1	Poland (H)	Leśniewicz et al. (2012)
616±70	410±5	323±11	196±99	Ethiopia	This study

*(M), (N) and (H) indicate the brand names Mlekolaki, Nestle and Hanne, respectively. NR = not reported, ND = not detected.

Table 6: Comparison of micro-essential metals concentration, (mg/kg, dry weight basis) in cornflake sample with reported values

Cr	Mn	Fe	Co	Ni	Cu	Zn	Country	Reference
0.102±0.02	0.85±0.31	NR	NR	NR	0.81±0.33	2.49±0.77	USA	Garcia et al. (1974)
NR	1.87±0.06	41.0±8.5	NR	NR	0.20±0.06	6.95±0.78	Poland (M)	Leśniewicz et al. (2012)
NR	0.36±0.07	165±2	NR	NR	0.30±0.06	0.44±0.26	Poland (N)	Leśniewicz et al. (2012)
NR	1.57±0.08	10.9±0.8	NR	NR	0.32±0.10	9.26±0.72	Poland (H)	Leśniewicz et al. (2012)
0.30±0.07	3.0±0.1	5.5±0.74	0.32±0.03	ND	0.30±0.01	40.7±2.7	Ethiopia	This study

Explanations as given in Table 5

Table 7: Comparison of toxic heavy metals concentration, (mg/kg, dry weight basis) in cornflake sample with reported values

Cd	Pb	Country	Reference
0.07±0.004	0.195±0.023	USA	Garcia et al. (1974)
ND	0.36±0.03	Ethiopia	This study

Explanations as given in Table 5

Table 8: Comparison of daily intake of metals from popcorn and cornflakes with recommended daily intake and tolerable upper limit of daily intake of metals

Metal	(mg/kg) from popcorn	(mg/kg) from cornflake	(mg/kg) from 5 g popcorn	mg/kg from 5 g cornflake	Daily recommended intake	Tolerable upper limit
Ca	97.9±4.2	196±99	0.4895±0.021	0.98±0.495	1000-1200 mg	2500 mg/day
Mg	387±11	323±11	1.935±0.055	1.615±0.055	320-420 mg	750 mg/day
K	1293±233	616±70	6.465±1.165	3.08±0.35	4700 mg	ND
Na	143±3	410±5	0.715±0.015	2.05±0.025	1500 mg	2300 mg/day
Cr	0.68±0.09	0.30±0.07	0.0034±0.0045	0.0015±0.00035	25-35 μg	120 μg/day
Cu	0.09±0.007	0.30±0.01	0.0045±0.000035	0.0015±0.00005	0.9-2 mg	10 mg/day
Fe	9.5±2.1	5.5±0.74	0.0475±0.0105	0.0275±0.0037	10-15 mg	45 mg/day
Mn	6.17±0.18	3.0±0.1	0.03085±0.0009	0.015±0.00005	1.8-2.3 mg	11 mg/day
Ni	ND	ND	ND	ND	70-170 μg/kg*	1 mg/day
Zn	88.3±9.7	40.7±2.5	0.4415±0.0485	0.2035±0.0125	10-15mg	40 mg/day
Cd	ND	ND	ND	ND	ND	7 μg/kg bw/week
Pb	0.94±0.29	0.36±0.03	0.0047±0.00145	0.0018±0.00015	0.02-3 μg/kg bw	25 μg /kg bw/day
Co	1.41±0.16	0.32±0.03	0.00705±0.0008	0.0016±0.00015	5-40 μg /day*	0.25 mg/day

*Indicates the estimated daily intake, bw = body weight, ND = not determined (not established). Sources: National Research Council, 1989; Food and Nutrition Board, 1997; also from www.frantzmd.info, www.nap.edu, 2015 and www.sparkpeople.com.(minerals), 2015) for Ca, Mg, Na, K, Cr, Cu, Fe, Mn, Zn, Ni and Co, FAO/WHO 2011 for Cd and Pb

Daily intake of metals from popcorn and cornflakes

Daily intake of metals from popcorn and cornflakes has been calculated based on the assumption that an average adult person consumes 5 g dry popcorn and 5 g cornflakes per day on the average. The amount of mineral intake by the person from the popcorn and cornflakes will be as shown in Table 8.

The amount of all the major metals (Ca, Mg, K and Na) that a person can get is well below the daily recommended values. This indicates that consumption of 5 g each of both the popcorn and cornflake are safe for an adult person. It also indicates that both the popcorn and cornflake are good source of the major metals but not sufficient enough needed for the daily requirement. Therefore the person must get supplementary Ca, Mg, K and Na from other sources. The amounts of Mn and Cu that the person can get from the popcorn and cornflake are also below the required amounts. Hence supplementary diet is needed for these two metals too. The amount of Co is sufficient, from the popcorn sample but not from that of cornflake. The values for Fe and Cr are also all below the required limits, here again additional sources of these metals are needed. While the value of toxic metal Pb is below the allowed daily intake which indicates that both the popcorn and cornflake are safe for human consumption as regular diet. Since the levels of Cd and Ni in both samples are below the detection limit, it is possible to conclude that, the person is free from the risks of Cd and Ni as a result of consuming popcorn and cornflakes.

CONCLUSIONS

Both the cornflake and popped popcorn were found to contain appreciable amount of minerals. From the nutritional point of view popcorn is a better source of minerals than the cornflake. From the results of this work it is possible to conclude that both popcorn and cornflake accumulated relatively larger amounts of K and Zn among the determined major and trace metals, respectively. Lower amount of Cu (0.09±0.007 mg/kg in popcorn and 0.30±0.01 mg/kg in cornflake samples) was recorded. Generally, the level of essential metals determined in this study could be put in the following order K > Mg > Na > Ca > Zn > Fe > Mn > Co > Pb > Cr > Cu and K > Na > Mg > Ca > Zn > Fe > Mn > Pb > Co > Cr ≈ Cu in the popcorn and cornflake samples, respectively. Cd and Ni were not detected in both the popcorn and cornflakes. However, Pb was detected in both the samples. This higher value of Pb may be due to the anthropogenic sources or from the ingredients of agricultural inputs, like fertilizers, insecticides and herbicides used. Furthermore high care should be taken during storage and transportation of products to avoid contamination from Pb and other toxic metals (Yemane et al., 2008; Yılmaz et al., 2010).

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