بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

Concentration of Macronutrients and Some Undesired Minerals in Some Sudanese Diets

تركيز المغذيات الكبرى و بعض المعادن غير المرغوبه في عينات من بعض الاغذيه السودانية

A Thesis Submitted in Partial Fulfillment for the Requirements of Degree of Master of Science in Chemistry

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بسم الله الرحمن الرحيم

(وَآيَةٌ لَّهُمُ الْأَرْضُ الْمَيْتَةُ أَحْيَيْنَاهَا وَأَخْرَجْنَا مِنْهَا حَبًّا فَمِنْهُ يَأْكُلُون)

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صدق الله العظيم

Dedication

To my beloved parents,
My dear husband;
My Brothers and sisters.

Acknowledgment

My endless praise is due to Allah Almighty for giving me health strength and success to perform this work.

My great thanks go to my supervisor Dr. Omer Adam Mohamed Gibla for his continuous encouragement and help during his supervision of my work.

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Abstract

The aim of this study was to measure the macronutrients and some undesired minerals concentrations in some traditional Sudanese foods. Fifteen samples of different types of food were collected from Al-jazzera and Khartoum states markets. The collected samples included three different types of sorghum (AbAhamaed, Fatarita,Tabat), Millet,Wheat, Gundaila Dates, Roselle ,Tamarindous (Aradaib),Chick peas (Kabkaby), Lupines (Termes),Adansonia (Tabldy) ,Bayrony (Adasia), Haypaene (Doum),Vigna (lupia) and GrewiaTinnas (Godaim). Concentrations of some macro nutrients (K, Mg, Na, Ca, P) and the toxic elements (Be,Ba,Cd,Cr,Al,Pb,As,Sb,Sn,Sr), were determined by inductively coupled plasma (ICP, PQ 9000). Minerals contents were found to be different in all samples; they were ranging from very high to very low contents. Sodium content ranged from (<0.1441 ppm) in Gundaila date to (220 ppm) in Roselle. Magnesium contents were ranged from (13.51ppm) in Lupia to (3245 ppm) in Roselle. Calcium contents were ranged from (0.1999 ppm) in Abahmed to (1966.24 ppm) in Termes. Phosphorus contents were ranged from (638.5 ppm) in tabldy to (3639 ppm) in Adasia. Potassium content were ranged from (4295 ppm) in Fatarita to (27,648ppm) in Doum. Barium concentrations were ranged from (0.320 ppm) in Millet to (3034 ppm) in Roselle. Beryllium concentrations in all samples were ranged between (<0.00003 ppm) to (0.0100 ppm). Cadmium concentrations for all samples were between (<0.000198 ppm) and (0.0499 ppm). Aluminium concentration was ranged from (<0.00033 ppm) in Kabkaby and Adasia to (781.6 ppm) in Tabldy. Chromium concentrations ranged from (<0.000583ppm) in Lupia to (3.416ppm) in Termes. Arsenic concentration was at the lowest detection limit in all samples (<0.00255 ppm) except that of Doum (0.0998 ppm), Tabldy (0.1199 ppm) and Millet (0.02 ppm). Lead concentrations in all samples were (<0.004727 ppm) except in Termes (0.3296 ppm) and Tabldy (0.2298 ppm). Antimony concentrations in most samples were(<0.0006078) ppm)except in Roselle (0.0899 ppm), Kabkaby(0.05 ppm), Adasia(0.1ppm), Doum(0.898 ppm), Lubia(0.1298 ppm) and zero concentration in Aradaib. Tin concentrations ranged from (0.21 ppm) in Gudaim to (2.497 ppm) in Termes. Strontium contents ranged from (1.208 ppm) in Fatirita to (74.35ppm) in Roselle.

المستخلص

الهدف من هذه الدراسة هو قياس تراكيز المغذيات الكبرى وبعض المعادن غير المرغوبة، في بعض الاطعمةالسودانيه التقليديه. جمعت خمسة عشر عينه لانواع مختلفة من الاطعمة من الاسواق بولايتي الجزيرة و الخرطوم . شملت العينات ثلاثة انواع مختلفه من الذرة (اب احمد ، فتريتة ، طابت) الدخن ، القمح ، بلح القنديلة ، الكركديه ،العرديب ،الكبكبي ، الترمس ، التبلدي ، العدسيه، الدوم ، اللوبيا و القضيم . تم تحديد تراكيز بعض المغذيات الكبرى(Na, Ca , Mg . K, P) و بعض العناصر السامة (Be , Ba, Al, Cr, Cd ,As, Sn, Sr, Sb, Pb) بجهازبلازما الحث المزدوج (ICP, PQ 9000)وجد ان المحتوى المعدني مختلف لكل العينات ، حيث يتراوح بين عالي جدا و منخفض جدا . تركيز الصوديوم تراوح بين(0.1442 ppm) في البلح الى (220 ppm) في الكركديه. تركيز المغنيزيوم تراوح بين (13.51ppm) في اللوبيا الى (3245ppm)في الكركديه. محتوى الكالسيوم تراوح بين(0.01999ppm) في اب احمد الى(1966.24ppm) في الترمس.تركيز الفسفور تراوح بين(638.5 ppm) في التبلدي الى (3639 ppm) في العدسيه. محتوى البوتاسيوم كان (4295ppm) في الفتريتا الى (27,648ppm) في الدوم. تركيز الباريوم تراوح بين (0.32ppm)في الدخن الى (30.34ppm) في الكركرديه. تركيز البريليوم في كل العيناتتراوح بين(0.00003ppm>)الى (0.0100ppm). تركيز الكادميوم في كل العينات تراوح بين (0.000198ppm>) الى (0.0499ppm). تركيز الالمونيوم تراوح بين (0.000333ppm >)في الكبكبي و العدسيه الى (781.6 ppm) في التبلدي. تركيز الكروم تراوح بين (0.000583ppm) في اللوبيا الى(3.416ppm)في الترمس. تركيز الزرنيخ في كل العينات كان عند الحد الأدنى للقياس(0.002547ppm >) ما عدا الدوم (0.0998ppm)و التبلدي (0.1199 ppm) و الدخن(0.020ppm). تركيز الرصاص في كل العينات(0.004727ppm >) ما عدا الترمس (0.3296ppm) و التبلدي (0.2298ppm) . تركيز الانتيمون في معظم العينات كان (0.006078ppm >) ما عدا الكركديه (0.0899ppm) و الكبكبي(0.05ppm)و العدسيه (0.1ppm)و الدوم (0.898ppm)و اللوبيا (0.1298 ppm)و العرديب(0.00 ppm). تراوح تركيز القصدير بين (0.2100ppm) في القضيم الى (2.497ppm) في الترمس.محتوى الاسترانشيوم تراوح بين (1.208ppm) في الفتريتا الى (74.35 ppm) في الكركديه.

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CHAPTER ONE

INTRODOUTION

1. Introduction

1.1 Sudanese diet

People's nutrition in Sudan consists of a wide range of food materials. The main species are cereal grains, vegetables, fruits, meat (white and red) and some processed food. Cereal grains may be the most important calorie source in Sudanese diet. Greater numbers of Sudanese people depend on cereals for their nutrition like, whole wheat, sorghum and millet. This study has been focused on some other types of food like dates, vigana, chick peas, lupinuns albus, adanasonia, tamarindus, hyphaene and roselle, as popular types of food, which are, frequently used by children and adults. Cereals are crucial to human survival and are the main components of human diets. Cereal grains provide a major source of energy, protein, and dietary fiber in human nutrition. For example, wheat can provide more than half of the calorie requirements in a healthy daily diet. Wheat is also a major source of protein compared with, other foods and contributes by more than 25 percent of the protein consumed in human diet. Protein contents in sorghum and millet are nearly equal and are comparable to that of wheat and maize (Ali H. Abdelrahman 1998).

1.2 Macro elements and their health effects

Macro elements that are concerned in this study were K, Ca, Mg, Na and P. Potassium, sodium and calcium are considered to be essential, because they play significant physiological roles in human body such as regulation of the electrical and mechanical action of the heart. Abnormal concentrations of these ions, may cause water-electrolyte imbalance, which may result in cardiac arrhythmias, muscle contraction disorders, disturbances of neuronal activity and influences the drugs (Kamil Fijorek, et al 2014)

1.2.1 Potassium

Potassium is an essential macro nutrient; as the most abundant cation in intracellular fluid, where it plays a key role in maintaining cell function, particularly in excitable cells such as muscles and nerves. Because potassium is a major intracellular ion, it is widely distributed in foods once derived from living tissues. Potassium concentration is higher in fruits and vegetables than in cereals and meat. Salting foods and discarding the liquid induces sodium (Na^{+}) for potassium (K^{+}) exchange and reduces the potassium content of foods. Recommended adequate intakes for potassium were set by the Food and Nutrition Board of the Institute of Medicine as 4700 mg/day (Fact Sheet 2005). Potassium requirements may vary with an individual's genetics, blood pressure status, and sodium intake. Benefits of increasing potassium consumption may include improved glucose control, glucose intolerance and insulin resistance. Movement of potassium, within the body may help to improve these health outcomes. Increasing dietary potassium has a potential benefit for lowering the risk of hypertension, the major risk factor for the development of stroke, coronary heart disease, heart failure, and end-stage renal disease. In addition, adequate potassium intake may be extremely influential in glucose control and limiting the risk of diabetes, especially in those under thiazide diuretic treatment, and those already at higher risk from the development of additional co-morbidities. It is well-established as modifiable factor for hypertension. Better understanding of (K^{+}) bioavailability in the diet, will help to determine how it can be used further to improve overall human health (Michael S. Stone, et al 2016). Potassium is a principal cation in intracellular fluid and functions in acid-base balance, regulation of osmotic pressure, conduction of nerve impulse, muscle contraction , cell membrane function and Na^{+}/K^{+} -ATPase. It also helps in the transfer of phosphate from (ATP) to pyruvic acid and probably has a role in many other basic cellular enzymatic reactions. Hyperkalaemia is an increased level in serum potassium and this occurs in Addison's disease, advanced chronic renal failure, shock and dehydration. Hypokalaemia is low level of serum potassium and this occurs in diarrhoea, metabolic alkalosis and familial periodic paralysis. When lactating dairy cows have hypokalaemia, the milk production is markedly lowered. Deficiency disease or symptoms occurs secondary to illness, functional and structural abnormalities including impaired neuromuscular functions of skeletal, smooth, and cardiac muscle, muscular weakness, paralysis, mental confusion . Potassium deficiency affects the collecting tubules of the kidney, resulting in the inability to concentrate urine, and also causes alterations of gastric secretions and intestinal motility .The rapidly growing animals apparently have a higher requirement for potassium, and the increasing protein level, increases the requirement. Plant products contain many times as much potassium as sodium. (K. O. Soetan, et al 2010)

Table (1.1) Some potassium rich types of food

Food	**Serving size**	**potassium content in(mg)**
Banana	1 medium	422
Orange	1	237
Cantaloupe	1 cup	427
Dates	¼ cup	250
Grapefruit	1 half	166
Mango	1 cup	323
Raisins, seedless	¼ cup	250
Black beans	½ cup	400
Lima beans	½ cup	365
Potato	7 ounces	1000
Tomato	1 medium	292
White beans	½ cup	502
Millet	1 cup	266.6
Wheat	1 cup	143
Rossle	1 cup	118.6
Chick peas	1 cup	109
Sorghum	1 cup	672

Source: Ohio State University Wexner Medical Center, (2016), Foods High in Potassium, *Fact Sheet*, 2016 June 24.

1.2.2 Sodium

Munteanu Constantin and Iliuţã Alexandru 2011 reported that, in human body, sodium ions are used, in opposition to potassium ions, to allow the organism build up an electrostatic charge on cell membranes, and thus allow transmission of nerveimpulse when the charge is allowed to dissipate by a moving wave of voltage change. It is classified as a “dietary inorganic macro-mineral” for human body. Sodium is necessary for humans to maintain the balance of the fluids system, and is also required for muscle functioning. High sodium can damage kidneys and increases the chances of high blood pressure. Daily sodium intake varies from individual, to another, and from culture to culture. Some people get as little as 2g/day, some get as much as 20 g/day (Munteanu Constantin, Iliuţã Alexandru 2011). Human body contains about 105 grams of sodium, mainly, in the bones, extracellular fluids and tissues. Bone crystals play a reservoir role, it release sodium in case of serum level deficiency. Sodium ion is the major extracellular cation, responsible for the osmotic pressure of body fluids. In excitable cells, rapidly increasing membrane permeability to sodium ions is responsible for formation of action potential (Vander A, et al 2001). Hyponatremia is associated with symptoms as: confusion, lethargy, fatigue, headache, nausea, vomiting, loss of appetite, spasms, cramps, seizures, depressed neural reflexes and ST elevation on electrocardiogram (ECG). If the serum sodium concentration falls to grade 4, stupor, neuromuscular hyperexcitability, hyperreflexia, seizures and coma appear, which may lead to death. The major symptoms of hypernatremia are connected with brain cell shrinkage. Depending on the duration of the ion abnormal level and on actual blood volume the signs of hypernatremia may include; thirst, neuromuscular excitability, confusion, seizures, coma and cardiopulmonary arrest (Kamil Fijorek, et al, 2014).

Table (1.2) Sodium content in some foods

Food type	**sodium content (mg/100g)**
Apple	2 mg
Dates	5 mg
Banana	1 mg
Lemon	6 mg
Onions	10 mg
Beans	3 mg
Grapefruit	1 mg
Potato	6 mg

Source: (Food data chart – sodium, www.apjcn.nhri.org.tw)

1.2.3 Magnesium

According to Qais Faryadi, (2011) Magnesium is one of the most neglected minerals in human body although it is crucial for a healthy and lasting life. It is responsible for the activation of more than 300 enzymes in the body. It assists to maintain muscle and nerve function. It helps human heart rhythm to function at normal rate and supports healthy immune system. Rude, (1998) and Vormann, (2003) research's indicates that magnesium helps to regulate blood sugar levels and helps blood pressure to function normally. It prevents and manages hypertension, cardiovascular disease, diabetes, and joint pains. Magnesium also helps to produce energy, and transmit energy, nerve signals and assist the muscles to relax. It helps to activate enzymes as thus, helping in digestion and absorption. As well as utilization of proteins, carbohydrates and fats. Magnesium deficiency thus dangerously affects every function of the body. It was estimated that (60-65%) of magnesium is concentrated in teeth and bones, with the remainder, residing in muscles and body fluids. Magnesium plays an important role in assisting the human body to convert food into energy, thus, helps the body to function properly. Magnesium activates adenosine triphosphate (ATP) as vital energy storage molecule. People with low levels of magnesium are quickly tired and need more oxygen and energy. Magnesium is needed in energy metabolism and muscle contraction. It regulates blood sugar levels and blood pressure. Magnesium deficiency certainly qualifies as a principal cause of disease. There is a link between magnesium deficiency and chronic joint pain, because magnesium deficiency results in muscle tension and spasm. Too much calcium without an adequate amount of magnesium irritates the nerve cells in the brain and results in repeated electrical impulses being sent. This creates energy loss and death of the cells. Magnesium regulates sugar levels in the blood, preventing it from rising uncontrollably, and might even resolve the problems of obesity and diabetes by helping to increase glucose metabolism in the body. In fact, magnesium is an anti-diabetic and anti-obesity mineral (Qais Faryadi 2012) .

Table (1.3) Types of foods with high Magnesium content

Type of food	**Size**	**Magnesium content (mg)**
Spinach (cooked)	½ cup	157
Pumpkin seeds	1/8 cup	92
Carrot	1 medium	7
Black beans	½ cup	60
Figs	½ cup	50
Yogurt	1 cup	46.5
Banana	1 medium	32
Sesame seeds	1 ounce	105
Peas	1 cup	48

Source: National Institute of Health, Office of Dietary Supplements, Fact Sheet (2011)

1.2.4 Calcium

It had been reported by Piste Pravina, (2012) that, calcium is very essential in muscle contraction, acolyte activation, building strong bones and teeth, blood clotting, nerve impulse, transmission, regulating heart beat and fluid balance within cells. The requirements are greatest during the period of growth such as childhood, during pregnancy, and breast feeding. The body contains about 2% of Ca and 98% of this is in the bones. The cell and body fluid contains from 10 – 15 mg per 100 gm. Calcium plays an important role to maintain some important body functions such as controls nerve excitability. The effect is mainly on the peripheral neuromuscular mechanism. It is necessary for the maintenance of the integrity of the skeletal muscles. An increase in the ionized (Ca^{+2}) results in an increase in contractility and vice versa. It is very essential for maintaining the tone and contractility of heart. Calcium is an antidotal to the depressant action of K. It aids rennin in the coagulation of milk in the stomach. It is essential for the clotting of food. It decreases cellular permeability. It is therefore used in allergic conditions to diminish exudation which produces wheals and rushes. Calcium appears to serve as a constituent of the intercellular cement. It takes part in the formation of certain tissue and bones. Normally 25 – 35% of calcium is excreted in the urine and the rest in the stools. Hypocalcaemia is a low level of calcium in the blood. It can occur from taking medications, such as diuretics; medical treatments; or disease processes, such as renal failure or hypo-parathyroidism.

An insufficient amount of calcium in your diet will generally not cause hypocalcaemia. This is because normal amounts of calcium in the blood are so critical to many vital body functions of the nerves, muscles, brain and heart, that your body will pull calcium from the bones as needed to maintain normal blood calcium levels. Hypercalcemia is suspected to occur in approximately 1 in 500 adults in the general adult population. Like hypocalcemia, hypercalcemia can be non-severe and present with no symptoms, or it may be severe, with life-threatening symptoms. Hypercalcemia is most commonly caused by hyperparathyroidism and by malignancy, and less commonly by vitamin D intoxication, familial hypocalciuric hypercalcemia and by sarcoidosis.

Hyperparathyroidism occurs most commonly in postmenopausal women. Hyperparathyroidism can be caused by a tumor, or adenoma, in the parathyroid gland or by increased levels of parathyroid hormone due to hypocalcemia.

Approximately 10% of cancer sufferers experience hypercalcemia due to malignancy. Hypercalcemia occurs most commonly in breast cancer,
Lymphoma, prostate cancer, thyroid cancer, lung cancer, myeloma, and colon cancer. It may be caused by secretion of parathyroid hormone-related
peptide by the tumor or may be a result of direct invasion of the bone, causing calcium release. Symptoms of hypercalcemia include anorexia, nausea, vomiting, constipation, abdominal pain, lethargy, depression, confusion, polyurea,
polydipsia and generalized aches and pains (Piste Pravina, et al 2012).

Table (1.4) Foods with high calcium content

Food type	**Size**	**Calcium content in (mg)**
Milk	200 ml	236
Green beans	90 g	50
Carrot	120 g	36
Banana	150 g	12
Orange	150 g	60
Sesame seeds	15 g	22
Tomato	120 g	11

Source: International Osteoporosis Foundation (2017) www.iofbonehealth.org

1.2.5 Phosphorus

Phosphorus is an important mineral found in foods. Phosphorus is a chemical element that is essential to life because of its role in numerous key molecules, including DNA and RNA; indeed, organisms require large amounts of P to grow rapidly. In this regard, phosphorus (P) is far more equal than the other elements involved in living systems, both in terms of its role in biology and its importance as an ecological and evolutionary factor (James J Elser 2012).

Phosphorus represents 1% of total body weight. With both an extracellular and intracellular distribution, phosphorus functions as a structural component of bones and teeth and DNA/RNA and enables the bipolarity of lipid membranes and circulating lipoproteins. Metabolically, phosphorus functions in critical pathways to produce and store energy in phosphate bonds (ATP), buffer blood, regulate gene transcription, activate enzyme catalysis, and enable signal transduction of regulatory pathways affecting a variety of organ functions ranging from renal excretion to immune response. Maintenance of phosphorus homeostasis in adults involves keeping urinary losses equivalent to net phosphorus absorption and equal amounts deposited and resorbed from bone. In the absence of genetic disorders, tumor-related phosphate wasting, or aberrant dietary problems such as re-bound feeding in anorexia or alcoholism, phosphorus deficiency or hypophosphatemia is rare in the healthy population, which is probably due to the widespread availability of phosphorus in most foods. Although phosphorus is an essential nutrient, its excess could be linked to tissue damage by a variety of mechanisms involved in the endocrine regulation of extracellular phosphorus as shown in patients with chronic kidney disease. Disordered regulation of these hormones by high dietary phosphorus intake may be key factors contributing to renal failure, cardiovascular disease, cancer, and osteoporosis in healthy adults (Mona S Calvo, et al2015).

Table (1.5) Some food sources of phosphorus

Food	**Serving size**	**Phosphorus in mg**
Apple	100 g	6
Banana	100 g	30
Dates	100 g	60
Mango	100 g	10
Orange	100 g	20
Tomato	120 g	20

Source: Food data chart, phosphorus apjcn.nhri.org.tw

1.3 Hazardous and undesired elements

Heavy metal toxicity has proven to be a major threat and there is several health risks associated with it. The toxic effects of these metals, even though they do not have any biological role, remain present in some or the other form harmful for the human body and its proper functioning. They sometimes act as a pseudo element of the body while at certain times they may even interfere with metabolic processes. Few metals, such as aluminum, can be removed through elimination activities, while some metals get accumulated in the body and food chain, exhibiting a chronic nature. Various public health measures have been undertaken to control, prevent and treat metal toxicity occurring at various levels, such as occupational exposure, accidents and environmental factors. Metal toxicity depends upon the absorbed dose, the route of exposure and duration of exposure, i.e. acute or chronic. This can lead to various disorders and can also result in excessive damage due to oxidative stress induced by free radical formation. This review gives details about some heavy metals and their toxicity mechanisms, along with their health effects. (Monisha Jaishankar, et al, 2014). Toxic elements, mainly the heavy metals of the periodic table, are normal elements found in the environment, and trace amounts of them are always found in foodstuffs however, foods from contaminated areas may contain higher amounts. Toxic elements primarily enter foodstuffs through contact with the environment (Hajeb,Mahyudin, et al, 2013).

1.3.1 Toxic elements contamination of foods

Toxic elements, are mainly the heavy metals, which are normal elements found in environment, and trace amounts of them are always found in foodstuffs. Toxic elements primarily enter foodstuffs through contact with the environment. Waterways and oceans are contaminated by the discharge of untreated municipal and industrial wastes. Depending upon the exposure route, each food type may become contaminated with different toxic elements, eg, the high levels of arsenic found in groundwater of certain areas, contaminates plants, including vegetables, rice, and other cultivated grains. There are several reports on high arsenic levels in rice, grains, and vegetables from different regions where the fields have been irrigated with arsenic contaminated water (Farid , et al 2003; D´ıaz, et al 2004, Bhattacharya, et al, 2010). Marine organisms, especially fish and seafood, from coastal areas associated with industrial discharge usually contain elevated amounts of toxic elements including mercury, arsenic, cadmium, and lead (Liobet,et al 2003; Falco,et al, 2004; Marti-Cid ,et al 2007). Furthermore, the matrix properties and the chemical structure of some foods also make them more susceptible to contamination with a particular element. Heavy metal toxicity can diminish mental and central nervous system function, elicits damage to blood composition, as well as kidneys, lungs, and liver, and reduce energy levels. Food is one of the main routes of toxic element exposure for humans. P. Hajeb, 2014 reported that common treatments, such as trimming, skinning, removing fat, frying, grilling, cooking, breading, or microwaving, of fish do not effectively remove heavy metals Furthermore, canning and cooking can even increase the mercury content in fish at times (Burger et al, 2003; Rasmussen, et al 2007). However, methods have been developed to remove heavy metals from various foods. Different reagents and media (acidic and alkaline solutions, alcoholic solutions under heating, organic sulfur-complexing agents, ascorbic acid, pectin solutions, and dry crushed shell membranes) and the combined effect of alkaline and acidic solutions with metal-leaching reagents (EDTA, salt, and cysteine) have been used to reduce contamination (P. Hajeb, et al, 2014)

Table (1.6): Cooking and processing methods to reduce heavy metals in different foods.

Food	Heavy metal	Cooking/processing method	Reduction (%)
Fish	Mercury	Frying and roasting	Considerable reduction
String bean and potato	Mercury	Boiling	Considerable reduction
Rice	Arsenic	Precooking wash	57%
Vegetables	Arsenic	Boiling	60%
Vegetables and cereals	Arsenic	Cooking with distilled water	Considerable reduction
Fish	Chromium and nickel	Grilling and microwave cooking	Considerable reduction

Source: P. Hajeb, et al, (2014).

Table (1.7) Food sources of some hazardous elements

Elements	Foods
Cd	Egg, fish, mushroom, garlic, spinach, wheat, rice, oat, corn, soyabean, peanuts ,mushroom
Pb	Egg, cocoa powder, rice, wheat, potato, calcium supplement, smoked food, wine, beer, milk, carrot, raisins
As	Green papaya, rice, tomato, carrot, seafood, Indian mustard, bovine and chicken meat, wine, milk
Hg	Egg, mushroom, seafood, fish oil

Source: (Varsha Mudgal, et al, 2010)

1.3.2 Barium.

Barium is moderately abundant, in earth crust and is used for a variety of industrial purposes. Barium compounds, such as barium-nickel alloys are used for spark-plug electrodes and in vacuum tubes as a drying and oxygen-removing agent. Barium sulfide is used in fluorescent lamps; barium sulfate is used in diagnostic medicine; barium nitrate and chlorate give fireworks a green color. Barium compounds are used in drilling mud's, paint, bricks, ceramics, glass, and rubber. Short term exposure to barium can cause vomiting, abdominal cramps, diarrhea, difficulties in breathing, increased or decreased blood pressure, numbness around the face, and muscle weakness. Barium intake can cause changes in heart rhythm or paralysis and possibly death. Limit is 2.0 ppm (Sabine Martin, 2009)

Barium enters the environment through the weathering of rocks and minerals and through anthropogenic releases. The primary source of barium in the atmosphere is industrial emissions. The primary route of exposure to barium appears to be ingestion from food and drinking water. In most foods, barium content is relatively low (<3 mg/100 g) except in Brazil nuts, were it reaches 150-300 mg/10, according to WHO (1990). Bread is considered the largest source of dietary barium, contributing an estimated 20% of total intake. Barium toxicity is caused by the highly soluble barium compounds wich are more toxic than the insoluble ones, such as barium sulfate. Intentional accidental ingestion of barium compounds causes gastroenteritis, hypokalemia, acute hypertension, cardiac arrhythmias, skeletal muscle paralysis, and death. A chronic dose capable of producing cardiovascular toxicity has not been identified. Increased blood pressure and cardiac arrhythmias have been reported in anesthetized dogs and guinea pigs receiving intravenous infusions of barium chloride. An area of scientific uncertainty concerning the non cancer hazard assessment for barium is identification of the most sensitive endpoint of barium toxicity in humans (Stiven Foster and Harlal Choudhury, 2005).

1.3.3 Beryllium

Beryllium1 is an uncommon metal, with few specific industrial uses. Contact dermatitis is the commonest beryllium related toxic effect. Exposure to soluble beryllium compounds may result in papulovesicular. If contact is made with an insoluble beryllium compound, a chronic granulomatous lesion develops, which may be necrotizing or ulcerative. If insoluble beryllium containing material becomes embedded under the skin, the lesion will not heal and may progress in severity. Use of a beryllium patch test to identify beryllium-sensitive individuals may in itself be sensitizing, so any use of this procedure as a diagnostic test is discouraged. Chronic beryllium disease (CBD) was first described among fluorescent lamp, when workers exposed to insoluble beryllium compounds, particularly beryllium oxide. According to Robert A. Goyer and Thomas W. Clarkson, (1996) chronic beryllium disease is an antigen-stimulated, cell-mediated immune response that leads to granulomatous lung disease. The major symptom is shortness of breath, which in severe cases may be accompanied by cyanosis and clubbing of fingers (hypertrophic osteoarthropathy, a characteristic manifestation of chronic pulmonary disease).

1.3.4 Cadmium

Cadmium occurs naturally in ores together with zinc, lead and copper. Food is the most basic source of cadmium exposure in the general non-smoking population in most countries. Cadmium is present in many foodstuffs, but its concentrations vary greatly, and the individual intake is also varies due to differences in dietary habits. Inhalation of cadmium fumes or particles is life threatening. Although acute pulmonary effects and deaths are uncommon, sporadic cases still occur. Cadmium exposure may cause kidney damage. The international agency for research of cancer (IARC) has classified cadmium as a (group1) human carcinogen on the basis of sufficient evidence in both humans and experimental animals. Cadmium has been associated with prostate cancer, but both positive and negative studies have been published (Lars Järup2003).

1.3.5 Chromium

Monisha Jaishankar, et al, (2014) reported that, chromium occurs in several oxidation states in the environment ranging from (+ii) to (+vi). The most accurring forms are trivalent and hexavalent, with both states being toxic to animals, humans and plants. Chromium occurs naturally by the burning of oil and coal, petroleum from ferrocromate refractory material, pigment oxidants, catalyst, chromium steel, fertilizers, oil well drilling and metal plating tanneries. Anthropogenically, chromium is released into the environment through sewage and fertilizers. According to Willam T, et al (2004), trivalent chromium is found in a wide range of foods, including egg yolks, whole-grain products, high-bran breakfast cereals, coffee, nuts, green beans, broccoli, meat, brewer's yeast, and some brands of wine and beer. Chromium is also present in many multivitamin/ mineral supplements, and there are specific chromium picolinate supplements that contain 200–600 µg chromium per tablet. The U.S. National Academy of Sciences has established the recommended daily Allowances for chromium as 50–200 µg /day for adult men and women. In both experimental animals and humans' chromium is an essential element involved in the action of insulin as demonstrated in the studies of chromium deficiency. Kirti Shekhawat, et al (2015) said that, mostly, all food materials contain some amount of Cr ranging from 20-500µg/Kg. The highest level founds in meats, mollusks and crustacean's. Human health is adversely affected by exposure to chromium and these health effects are categorized in two types, carcinogenic and non-carcinogenic. There has been a vast studies on chromium and its effects on human health. It has been concluded that chromium is responsible for the toxic effects in humans and it cause allergenicity and carcinogenicity in humans and in animals also. Hexavalent chromium is mainly responsible for all carcinogenic activity in comparison to trivalent chromium. Chromium is responsible for dermatitis allergy; perforation in nasal septum and some cases of lung cancer is also evident. Due to the exposure to chromium some genetic alteration also takes place. It has been stated earlier that in mice excess of chromium cause patches on skin and lung cancer. But there is still no clear evidence of activity of chromium ions as an allergen to humans. (Kirti Shekhawat, et al, 2015)

1.3.6 Lead

Lead is not an essential element. It is well known to be toxic and its effects have been more extensively reviewed than the effects of other trace metals.

The toxic effects of lead, like those of mercury, have been principally established in studies on people exposed to lead in the course of their work. Short-term exposure to high levels of lead can cause brain damage, paralysis (lead palsy), anaemia and gastrointestinal symptoms. Longer-term exposure can cause damage to the kidneys, reproductive and immune systems in addition to effects on the nervous system. The most critical effect of low-level lead exposure is on intellectual development in young children and, like mercury, lead crosses the placental barrier and accumulates in the foetus. Infants and young children are more vulnerable than adults to the toxic effects of lead, and they also absorb lead more readily. Even shorten, low-level exposures of young children to lead is considered to have an effect on neurobehavioral development. Consumption of food containing lead is the major source of exposure for the general population as indicated; lead contamination of food arises as a result of environmental emissions, such as mining and the now diminished use of leaded petrol. However, like mercury, lead can accumulate in fish and shellfish and in addition can be found at higher levels in the offal (liver and kidney) of food animals. A further source of lead in the diet is from food containers containing lead, e.g. storage in lead-soldered cans, ceramic vessels with lead glazes and leaded crystal glass. (Fact Sheet 2009) The symptoms of acute lead poisoning are headache, irritability, abdominal pain and various symptoms related to the nervous system. Lead encephalopathy is characterized by sleeplessness and restlessness. Children may be affected by behavioral disturbances, learning and concentration difficulties. In severe cases of lead encephalopathy, the affected person may suffer from acute psychosis, confusion and reduced consciousness. People who have been exposed to lead for a long time may suffer from memory deterioration, prolonged reaction time and reduced ability to understand. (Lars Järup, 2003).

1.3.7 Arsenic

Robert A. Goyer and Thomas W. Clarkson, (1996), reported that arsenic is particularly difficult to characterize as a single element because its chemistry is so complex and there are many different arsenic compounds. It may be trivalent or pentavalent and is widely distributed in nature. The most common inorganic trivalent arsenic compounds are arsenic (iii) oxide, sodium arsenate, and arsenic (iii) chloride. Pentavalent compounds include arsenic pentoxide, arsenic acid, and arsenates, such as lead arsenate and calcium arsenate. Organic compounds may also be trivalent or pentavalent, such as arsanilic acid, or may even occur in methylated forms as a consequance of biomethylation by organisms in soil, fresh water, and seawater. Ingestion of large doses (70 to 180 mg) of arsenic may be fatal. Symptoms of acute illness, possibly leading to death, consist of fever, anorexia, hepatomegaly, melanosis, and cardiac arrhythmia, with changes in electrocardiograph results, that may, point to eventual cardiovascular failure. Other features include upper respiratory tract symptoms, peripheral neuropathy, and gastrointestinal, cardiovascular, and hematopoietic effects. Acute ingestion may be suspected from damage to mucous membranes, such as irritation, vesicle formation, and even sloughing. Anemia and leukopenia, particularly granulocytopenia, occur in a few days following exposure and are reversible.

1.3.8 Strontium

Strontium is a non-essential trace mineral in the body. Because strontium can increase the retention of calcium in the body, it is sometimes used to `prevent bone loss due to osteoporosis. It is known to contribute to the health of bones and teeth it may build stronger teeth, and is being studied as a cavity preventative. Strontium‘s actions in humans body are similar to those of calcium. Because strontium prevents the re-absorption of bone, it helps reduce bone loss. It is found in foods grown in strontium rich soil and in some drinking water (Anupama M., Ashok Kumar K. and Naveena Lavanya Latha J 2001). Strontium content of plants is directly related to the amount of the strontium in the soil in which it is grown. Strontium glucanate seems to be most easily absorbed by the body. Because it is not an essential mineral, there is no defined level of deficiency. There are no identified symptoms of strontium toxicity or strontium overdose. Inhalation of strontium can cause severe respiratory difficulties, anaphylactic reaction and extreme tachycardia, and it can replace calcium in organisms, inhibit normal calcium absorption and induce strontium "rickets" in childhood. (Anupama M., Ashok Kumar K. and Naveena Lavanya Latha J 2001)

1.3.9 Aluminum

Due to its high reactivity, aluminum is not found in the free state in nature. Orally ingested aluminum sources include food products, food additives, utensils and packaging items, water, and pharmaceuticals. Aluminum has been found in small quantities under (0.2 mg) in most foods. According to certain American studies (Greger, 1993), the average adult consumes between 2-25 mg of dietary aluminum daily. Aluminum is present in food additives such as baking powder or flour, as aluminum compounds are sometimes used as pH adjusting agents. It also present in utensils and packaging of foods such as cans. Many human health effects that associated with aluminum are due to intravenous contaminations. The most important health effect is dialysis encephalopathy, which can lead to tumors, convulsions, psychosis, and other related neurological problems. Occupational aluminum exposure has been shown to have carcinogenic effects (Karine LANDRY, 2014). The exact mechanism of absorption of aluminum by the gastrointestinal tract is not understood completely.Based on literature surveys; it is difficult to give a proper time period for aluminum toxicity since some symptoms of aluminum toxicity can be detected in second or in minutes after exposure. Toxicity probably results from the interaction between aluminium and plasma membrane, apoplastic and symplastic targets .In humans Mg^{2+} and Fe^{3+} are replaced by Al^{3+}, which causes many disturbances associated with intercellular communication, cellular growth and secretory functions.The changes that are evoked in neurons by aluminium are similar to the degenerative lesions observed in Alzheimer patients. The greatest complications of aluminium toxicity are neurotoxicity effects such as neuronal atrophy in the locus ceruleus, substantia nigra and striatum (Monisha Jaishankar, et al, 2014).

1.3.10 Tin

Tin is relatively less toxic than mercury, cadmium and lead. The principal concern in relation to tin in food is the possibility of high levels potentially present in canned food, where tin present in the can may be leached into the food, to occur such as in the case of acidic foodstuff like canned tomatoes, and consumption of the affected foodstuff has resulted in gastrointestinal irritation and upsets due to the acute toxic effects of tin. These short-term effects may occur in some individuals at concentrations above 200mg/kg. Only limited data are available on the toxicological effects of inorganic tin present in canned food, resulting from the dissolution of the tin coating (Facts Sheet 2009). Tin may be released to the atmosphere from both natural and anthropogenic sources. Tin is available in many soils and may be released in dusts, roads, and agricultural activities. Other less significant natural sources include forest fires and volcanic emissions. Gases, dusts, and fumes containing tin may be released from smelting and refining processes, industrial uses of tin, waste incineration, and burning of fossil fuels. For the general population, the diet is the main source of exposure to inorganic tin (Peter Watts 2005). Because inorganic tin compounds usually enter and leave the body rapidly after breathing or eating them, they do not usually cause harmful effects. According to Manju Mahurpawar (2015), humans who swallowed large amounts of inorganic tin, in research studies suffered stomachaches, anemia, as well as liver and kidney problems. Studies with inorganic tin in animals have shown similar effects to those observed in humans. There is no evidence that inorganic tin affects reproductive functions, produce birth defects, or cause genetic changes. Inorganic tin is not known to cause cancer. Inhalation, oral (intake), or skin contact to some organotin compounds has been shown to cause harmful effects in humans, but the main effect will depend on the particular organotin. There are some reports of skin, eye, and respiratory irritation, gastrointestinal effects, and neurological problems in humans exposed for a short period of time to high amounts of certain organotin compounds. Some neurological problems have persisted for years after the poisoning occurred. Lethal cases have been reported following ingestion of very high amounts (Manju Mahurpawar 2015)

1.3.11 Antimony

Ross G. Cooper and Adrian P. Harrison (2009) reported that antimony is naturally found in ore deposits. It is widely used in industry and present in all kinds of everyday items .The Principle sources of antimony include milk. Currently antimony has some potential useful medical applications, including its use as a tartar emetic against lung tumor cell lines. Antimony toxicity is dependent on the exposure dose, duration, of breathing, eating, drinking, or skin contact. Other chemical exposures, age, sex, nutritional status, family traits, life style, and state of health (Ross G. Cooper, Adrian P. Harrison, 2009). Most antimony may be absorbed from the lung and gastrointestinal tract (GI). Antimony compounds are gastrointestinal irritants. Trivalent antimony is concentrated in red blood
cells and liver, whereas the pentavalent form is mostly in plasma (A. Goyer and Thomas W. Clarkson2001).The pentavalent form is predominantly excreted in urine, whereas the trivalent is found mainly in feces after injection to animals.. Most informations about antimony toxicity has been obtained from industrial experiences. Occupational exposures are usually by inhalation of dust containing antimony compounds, such as the pentachloride, trichloride, trioxide, and trisulfide. Effects may be acute, particularly from pentachloride and trichloride exposures, producing a rhinitis and even acute pulmonary edema. Chronic exposures by inhalation of antimony compounds result in rhinitis, pharyngitis, tracheitis, and, over the longer term, bronchitis and eventually pneumoconiosis with obstructive lung disease and emphysema. Transient skin eruptions eg,

antimony spots may occur in workers with chronic exposure. Antimony-containing compounds may also produce alterations in cardiac function, and autopsy studies have shown that cardiac toxicity was the cause of death in patients treated with antimonial drugs (A. Goyer and Thomas W. Clarkson2001)

1.4 The studied types of food

1.4.1 Baobab fruits (Tabaldy)

The baobab seed and pulp were analyzed for proximate composition, mineral content, and amino acid composition. The seed oil and protein were evaluated for their fatty acid profile and protein solubility. The seed was found to be a good source of energy, protein, and fat. Both the kernel and the pulp contain substantial quantities of calcium, potassium, and magnesium. Amino acid analyses revealed high glutamic and aspartic acid contents and the sulfur-containing amino acids were being the most limited amino acid. The fatty acid profile showed that oleic and linoleic were the major unsaturated fatty acids, whereas palmitic was the major saturated acid. Of the several solvents tested to solubilize the seed protein, 0.1 M NaOH was found to be the most effective. The protein was more soluble at alkaline than acidic pH, with the lowest solubility at pH 4.0. The seed and fruit pulp are excellent sources of potassium, calcium, and magnesium, but poor sources of iron, zinc, and copper. The fruit pulp mineral contents are comparable to those reported for baobab fruit from Sudan. The pulp showed exceptionally high calcium content. The high calcium contents of the seed and fruit pulp make the baobab fruit attractive as a natural source of calcium supplementation for pregnant and lactating women, as well as for children and the elderly (MAGDI A. OSM AN 2004)

Table (1.8) Baobab content of minerals

Minerals	**concentration in mg/100g**	
	seed	**Fruit pulp**
Potassium	910	1240
Sodium	28.3	27.9
Calcium	410	295
Magnesium	270	90
Iron	6.4	9.3
Copper	2.6	1.6
Zinc	5.2	1.8

Source: (Magdi A Osman 2004)

1.4.2 Chickpeas (Kabkaby)

Consumers of chickpeas and hummus have been shown to have higher nutrient intakes of dietary fiber, polyunsaturated fatty acids, vitamin A, vitamin E, vitamin C, magnesium, potassium, and iron as compared to non-consumers. Emerging research suggests that chickpeas and hummus may play a beneficial role in weight management and glucose and insulin regulation, as well as have a positive impact on some markers of cardiovascular disease (CVD). Raw or cooked chickpeas and hummus also contain dietary bioactive such as phytic acid, sterols, tannins, carotenoids, and other polyphenols such as isoflavones, whose benefits may extend beyond basic nutrition requirements of humans. With chickpeas as its primary ingredient, hummus and especially when paired with vegetables and/or whole grains is a nutritious way for Americans to obtain their recommended servings of legumes. Traditional hummus contains a unique combination of chickpeas, tahini, olive oil, lemon juice, and spices that may provide additional benefits beyond satisfying nutrient requirements. While the scientific literature is emerging, several studies support hummus/chickpea consumption in relation to weight control, glucose, and insulin response, cardiovascular disease, cancer, and gastrointestinal health. Calcium, Iron, Magnesium, Phosphorus, Potassium, Sodium, Zinc, Copper, Manganese and Selenium were detected in chickpea in this study (Taylor C. Wallace 1,*, Robert Murray 2 and Kathleen M. Zelman 2016).

1.4.3 Tamarindus indica (Aaradaib)

Tamarindus indica is a plant used in Nigerian folk medicine for the purpose of food and drugs. The pulp and seed of Tamarindus indica was analyzed for proximate analysis, mineral composition, phytochemical constituents, amino acid and fatty acids. The pulp contained; 15.50±0.5g/100g moisture content, 7.15±0.15g/100g crude protein, 3.00±0.07g/100g crude lipid,4.50±0.2g/100g crudefiber,3.10±0.07g/100gAsh content, 69.90±0.18g/100g Available carbohydrate and 2101.90±19.70kj/100g calorific value. These parameters were also analyzed for the seed respectively. Mineral composition and vitamin C content for the samples were investigated. They are very good sources of mineral element such as; K, Na, Ca, Mg, Zn, Fe and P respectively. Result showed that they both contain essential and non-essential amino acids. The phytochemical analysis revealed the presence of tannins, Saponins, volatile oil and steroids respectively. Results compares well with those of other edible fruits.

In another study two samples of tamarind were used in this study, sample A from Eastern Sudan and B from Western Sudan. They were analyzed for their physical, chemical composition and minerals content. The sodium concentration was found to be 26.64mg/100g, 21.58mg/100g for sample A, B respectively. The calcium concentration in the tamarind pulp was found to be 174.19 mg/100g and 149.13 mg/100g for sample A and B respectively .Potassium in the two samples of tamarind pulp A and B was found to be 112.48 and 142.98 mg/100g, respectively.
In both samples of the pulp, the concentration of the iron was 68.94 mg/100g and 80.67 mg/100g, respectively for sample A and B. Phosphorous was found to be 6.94 mg/100g for sample A. and 8.67 mg/100g for sample B (1Safiya Altuhami Ballal Taha, 1Abd Elazeem Ahmed Mohamed Nour and 2Abd Elmoneim Osman Elkhalifa 2016).

Table (1.9) Some minerals concentrations in Tamarindus indica samples

Minerals	**Concentration in ppm**
P	913.2
Be	0.0086
Ba	16.14
Al	566.8
Na	52.95
Ca	1659
Cr	<0.2600
K	9512
Mg	965.8
Cd	0.2385

Source: Rahma Ismaeil Adam, et al. (2016)

1.4.4 Date fruits (Gundaila)

Date fruits of cultivars: Gondeila, Barakawi, white Gau, Red Gau, and Black Gau were purchased from the local markets of Port Sudan city, Red Sea State, and from Khartoum State, Sudan. The origin of these fruits is the North-ern Region of Sudan. Each sample was collected randomly to assure good representation, and each sample was cleaned by remove foreign matter and taken in polyethylene bags with labels, and stored in a refrigerator till analyses. All date fruits samples were cleaned and pitted. The fruit pulp was ground with electric mincer and the fine sample was kept in a clean polyethylene bag, before being analyzed physically, chemically and microbiologically. Ten minerals namely potassium, sodium, magnesium, manganese, iron, copper, zinc, phosphorous, calcium and cobalt were determined in date palm fruit, using Atomic Absorption Spectroscopy (AAS). The element analysis of date palm extract showed that, the fruit of date palm contains many valuable and useful elements like Calcium, Potassium, Magnesium, Phosphorous, Iron, Cobalt, Copper, Manganese, Zinc, and Sodium. All the five date cultivars were different significantly in their mineral levels. Gondeila had the high-est Zinc (0.46 ppm) whereas, Barakawi had the lowest level. Gondeila showed the highest Manganese level (0.36 ppm) while Black Gau have the lowest (0.19 ppm). The highest Copper content was in Black Gau (0.43 ppm) and the lowest in White Gau (0.17 ppm). The highest Cobalt level was found in Barakawi (0.04 ppm), and the lowest in White Gau. The Calcium highest level was in Gondeila (59.09 ppm) and the lowest was recorded in Black Gau (39.38 ppm). Black Gau had the highest level of Iron (33.94 ppm), while, White Gau has the lowest level (2.52 ppm). Magnesium was highest in Barakawi (50.24 ppm), and lowest in Red Gau (36.09 ppm). Sodium was highest in Black Gau (60.00 ppm) and low-est in White Gau (15.00 ppm). The highest level of Potas-sium was recorded in Barakawi (726.97 ppm), whereas, White Gau has the lowest level (558.99 ppm). The high-est level of Phosphorous was in Gondeila (16.201 ppm) and the lowest level was in Red Gau (10.75 ppm).

These results are in accordance with many previous reports which revealed that the date palm contains a suitable concentration of elements which are very important for human body and metabolic operations in the human cells (Abdel Moneim E. Sulieman, et al, 2012).

1.4.5 Millet

Millets are a major food source in arid and semi-arid parts of the world. Millets are good sources of energy. They provide protein, fatty acids, minerals, vitamins, dietary fibre and polyphenols. Typical millet protein contains high quantity of essential amino acids especially the sulphur containing amino acids (methionine and cysteine). Processing millet by milling removes the bran and germ layers that are rich in fibre and phytochemicals, causing significant loss. The millets are source of antioxidants, such as phenolic acids and glycated flavonoids. Millet foods are characterized to be potential prebiotic and can enhance the viability or functionality of probiotics with significant health benefits. The nutritional significance of millets demands for an examination of the nutritional characteristics and functional properties of different millet cultivars as well as developing value added products from millets (Issoufou Amadou, et al, 2013)

Nine millet varieties with 3-kg portions of each finger millet seeds were collected and used for this study. Mean values for protein content and mineral composition of finger millet varieties were ranged from 6.26 g/100 g to 10.5 g/100g; calcium; iron; zinc; magnesium; manganese; phosphorus; chromium and copper. The proximate composition data analyses of improved and local finger millet varieties were also show significance variations within the varieties. Millet is more than just an interesting alternative to the more common grains. The grain is also rich in phytochemicals, including phytic acid, which is believed to lower cholesterol, and phytate, which is associated with reduced cancer risk. These health benefits have been partly attributed to the wide variety of potential chemopreventive substances, called phytochemicals, including antioxidants present in high amounts in foods such as millets. Millet is gluten-free, therefore an excellent option for people suffering from celiac diseases often irritated by the gluten content of wheat and other more common cereal grains. It is also useful for people who are suffering from atherosclerosis and diabetic heart disease (Shimelis Admassu, et al, 2009)

Table (1.10) Mean concentrations of minerals in the millet.

Mineral	Mean concentration in mg/100g
Calcium	50.66 mg/100g to 319 mg/ 100g
Iron	4.59 mg /100g to 53.39 mg/100g
Zinc	0.97mg/100g to 2.56 mg/100g
Magnesium	78 mg/100g to 201mg/100g
Manganese	17.61 mg/100g to 48.43 mg/100g
Phosphorus	3.46 mg/100g to 147mg/100g
Chromium	0.12 mg/100g to 3.47 mg/100g
Copper	0.18 mg/100g to 0.79 mg /100g

Source: (Shimelis Admassu, et al, 2009)

1.4.6 Grewia (Gudaim)

Analysis of the nutritional composition of fruits of three species of *Grewia* (G. *tenax, G. flavescens* and *G. villosa*) was carried out. This study was conducted on October 2008. Fruits of G. villosa and G. flavescens were collectedfrom Kordofan (Western Sudan) and those of G. tenax were collected from the campus of University of Khartoum. All species were authenticated at the Herbarium of Botany Department, University of Khartoum where voucher specimens were deposited. The proximate composition as well as the content of amino acids, mineral elements (K, Ca, Mn, Fe, Cu and Zn), tannin and pectic substances was determined. The predominant mineral in the three species was potassium, which ranged from 817 mg/100 g (G. tenax) to 966 mg/100 g (G. villosa). The three Grewia spp contained remarkably high amounts of iron with values ranged from 20.8 mg/100 g (G. tenax) to 29.6 mg/100 g (G. villosa). This finding supports the traditional use of Grewia in the treatment of anaemia (G.O. Mohammed Elhassan and S.M. Yagi, 2010).

Table (1.11) Mineral contents in Grewia samples

Minerals	Concenteration in mg/100 g		
	G. tenax	*G. flavecence*	*G. villosa*
Potassium	817	877	966
Calcium	790	269	536
Manganese	5.1	0.1	0.1
Iron	20.8	26.9	29.6
Copper	1.5	1.1	1.2
Zinc	1.9	1.1	2.5

Source: G.O. Mohammed Elhassan and S.M. Yagi (2010)

1.4.7 Roselle

According to Rahma Ismaeil Adam, et al. (2016) Sudanese use Roselle, Adansonia digitata, and Tamairndus indica as juices almost daily at home, especially, during fasting month “Ramadan”. The juices are popular even in some restaurants and hotels. Roselle is used as a hot drink after boiling. Roselle locally known as “karkade” Belong to the family Malvaceae, it was believed to be domesticated in western Sudan before 4000 B.C. Samples were collected from many local markets in Khartoum state. Mineral content analysis showed high potassium concentration in the three crops with significantly higher value in Roselle. Calcium concentration is higher in Adansonia compared to the other two. Roselle showed high concentration of magnesium and sodium. Toxic minerals showed high concentration in the three samples. Arsenic and Silver were of low concentrations in the three fruits. Barium and beryllium concentration are considerable in Roselle, which is dangerous. Aluminum content is high in the three samples. Trace elements Samples showed relatively high Iron concentration, Silicon also shows High concentration in all samples. Boron, Molybdenum, Chromium, Manganese, Titanium, and Vanadium shows considerable concentrations. Many of these trace elements are required by human body as nutrients. Some of them are undesired such as strontium and Boron.

Table (1.12) Some minerals concentrations in Roselle samples

Minerals	**Concentration in ppm**
P	1238
B	56.17
Ba	63.53
Al	369
Na	93.92
Mn	53.76
Be	0.0243
Ca	1311
Cr	<0.2600
K	24138
Mg	3790
Sr	99.82
Pb	1.162
Cd	<0.1800

Source: Rahma Ismaeil Adam, et al. (2016)

1.4.8 lupin (Lubia)

White lupin (Lupinus albus) seeds collected from the local markets of Debretabor (DT) and Dembecha (DB) in Ethiopia were studied for their chemical composition, physicochemical and functional properties. Moisture, total ash, crude protein, crude fat, crude fiber and minerals were determined. Mean values for protein, crude fat, total carbohydrates, crude fiber, and crude ash content of the two samples were 40.22, 8.92, 47.73, 10.08 and 3.15 g/100g, respectively on dry weight basis. The mean values of minerals such as phosphorus, iron, zinc and calcium contents for the samples were 248.90, 12.51, 4.68 and 82.56 mg/100g, respectively on dry weight basis (Tizazu H1 and SA Emire 2010).

1.4.8 Sorghum

Noha A. Mohammed, et al. (2011) published that sorghum is one of the cereals that constitute a major source of proteins, calories, minerals for millions of people in Africa and Asia. This cereal is mainly considered as subsistence crop because of its unique tolerance to drought and adaptation to dry tropical and subtropical ecosystems throughout the world. The crop is rich in minerals but with bioavailability vary from less than 1% for some forms of iron to greater than 90% for sodium and potassium. The reasons for this are varied and complex, since many factors interact to determine the ultimate bioavailability of a nutrient.Like other grains, sorghum protein is generally low in the essential amino acids such as lysine and therionine. Sorghum, like legume and oil seed meals has some limitations, due to the presence of antinutritional factors, such as trypsin and amylase inhibitors, phytic acid, and tannins. These compounds are known to interfere with protein, carbohydrates and mineral metabolism.

Table (1.13) Concentration of some minerals in Sorghum

Minerals	**Concentration in mg/100g**
Calcium	3.75
Phosphorus	100.6
Iron	2.24
Magnesium	75.02
Zinc	0.75
Copper	0.61

Source: Noha A. Mohammed, et al. (2011)

CHAPTER TWO

Materials and methods

2. Materials and methods

2.1 Collection of samples

Fifteen different samples of food materials, which are mainly consumed by almost all Sudanese people were collected from the local markets of Al-Jazeera and Khartoum states . The samples included Millet , Wheat , Dates (Gundaila), Roselle , different types of Sorghum (abahamed ,fatarita and tabat) ,Tamarindous (Aradaib) ,Chick peas (Kabkaby), Lupines (Termes) Adansonia (Tabldy), Bayrony (Balilla Adasia) , Haypaene (Doum) ,Vigna (lupia) and Tinnas grewia (Godaim).

2.2 Chemicals

Nitric acid conc (%65)

Hydrogen peroxide (%30)

2.3 Instruments

1. Inductively coupled plasma mass spectrometer (ICP-MS – PQ9000)

2. Microwave digestion system (milestone)

2.4 Method of analysis

2.4.1 Preparation of samples

0.5 g of each sample was ashed and weighed accurately in clean vessel, 8 ml of HNO_3 and 2 ml of H_2O_2 were added. The mixture was then placed in the microwave in 200 C^o for 30 minutes to digest the sample. The mixture was transferred to 50 ml volumetric flask and the volume was completed to the mark by the deionized water. This process was repeated for every sample. The samples were processed by the ICP-MS and the obtained results were tabulated.

CHAPTER TWO

Materials and methods

3. Results and discussion

Table (3.1) Cereal grains contents of macro minerals (in ppm)

Mineral	Food type				
	Fatarita	**Abahmed**	**Tabat**	**Millet**	**Wheat**
Na	0.4991	11.67	24.86	53.76	58.49
K	4295	4563	4375	5882	4587
Mg	1595	1244	1217	1508	1300
Ca	34.44	.01999	11.70	235.8	462.2
P	3164	2574	2260	3571	2667

Macro minerals contents of cereal grains was found to be relatively high (table 3.1). Sodium showed clearly different concentrations in Sorghum samples. The lowest sodium contents was in Fatarita (0.4991ppm) followed by (11.67ppm) in Abahmed and (24.86ppm) in Tabat. Millet and Wheat showed almost similar sodium contents. All the five cereal samples may be described as rich sources of potassium, phosphorus and magnesium. Calcium concentrations were different. They showed lower values in sorghum samples (34.44, 0.01999 and 11.70 ppm). In Millet and wheat Calcium concentrations were relatively high or moderate. Low sodium contents may be a good property in food, because sodium is always related to blood pressure. The macro concentrations in this study agree with those obtained by Shimelis Admassu, et al, 2009 and Noha A. Mohammed, et al. 2011.

Table (3.2) Cereal grains contents of undesired minerals (in ppm)

Mineral	Food type				
	Fatarita	Abahmed	Tabat	Millet	Wheat
Be	0.0100	0.0100	0.0100	0.0100	0.0100
Sr	1.208	1.419	1.369	1.380	5.601
Ba	0.3793	0.1999	0.1899	0.320	2.845
Cr	0.0599	0.1099	0.0900	0.930	0.190
Cd	$<198\times10^{-7}$	$<198\times10^{-7}$	$<198\times10^{-7}$	$<198\times10^{-7}$	$<2547\times10^{-7}$
Al	1.817	5.007	6.098	35.72	23.53
Sn	.7187	0.6896	0.5998	0.350	0.6190
Pb	$<4727\times10^{-7}$	$<4727\times10^{-7}$	$<4727\times10^{-7}$	$<4727\times10^{-7}$	$<4727\times10^{-7}$
As	$<2547\times10^{-7}$	$<2547\times10^{-7}$	$<2547\times10^{-7}$	0.020	$<2547\times10^{-7}$
Sb	$<6078\times10^{-7}$	$<6078\times10^{-7}$	$<6078\times10^{-7}$	$<6078\times10^{-7}$	$<6078\times10^{-7}$

The undesired minerals concentrations in cereal grains samples were generally low (table 3.2). Beryllium concentrations were almost zero in all samples. Barium, strontium, chromium aluminum and tin concentrations may all be considered at the safe level standards. All the samples may be regarded as being free of cadmium, lead arsenic and antimony.

Table (3.3) Crops plants contents of macro minerals

Mineral	Food types					
	Roselle	Adasia	Termes	Date	Lubia	Kabkabi
Na	220.9	35.9228	28.19	<.1421	22.23	108.0
K	22,112	17,414	6931	9628	12,343	10,275
Mg	3245	1302	1370	728.7	1351	1437
Ca	16436	1004	1966.241	1041	689.14	1152
P	1606	3639	2909	777.6	2864	2466

Garden crops samples which are frequently used by Sudanese people showed high concentrations of potassium, calcium, magnesium and phosphorus (table 3.3).

Sodium concentrations were found to be fairly low in all the samples ranging from (<0.01421 ppm) in Gondaila date to (220.9 ppm) in Roselle. Low sodium concentrations in crops are generally expected because sodium ions are very soluble in water and plants rarely adsorb higher sodium ions from soils. The five studied garden crops may also be considered as very good sources of K, Mg, Ca, and P. this results (table 3.3) agree with these reganted by Rahma Ismaeil Adam, et al. (2016).

Table (3.4) Crops plants contents of undesired minerals

Mineral	Food types					
	Roselle	**Adasia**	**Termes**	**Date**	**Lubia**	**Kabkabi**
Be	0.0200	$<3\times10^{-5}$	0.0100	$<3\times10^{-5}$	0.0100	0.0100
Sr	74.35	7.169	7.851	2.537	7.111	11.98
Ba	30.34	0.7499	7.131	0.3895	0.9688	1.270
Cr	2.067	0.0100	3.416	0.320	$<583\times10^{-4}$	0.0300
Cd	0.0499	198×10^{-7}	198×10^{-7}	198×10^{-7}	198×10^{-7}	198×10^{-7}
Al	223.7	$<333\times10^{-7}$	26.34	11.32	<.002547	$<333\times10^{-7}$
Sn	0.2796	0.9498	2.497	0.6193	1.019	0.9098
Pb	$<4727\times10^{-7}$	$<4727\times10^{-7}$	.3296	0.0400	$<4727\times10^{-7}$	$<4727\times10^{-7}$
As	$<2547\times10^{-7}$	$<2547\times10^{-7}$	$<2547\times10^{-7}$	$<2547\times10^{-7}$	$<2547\times10^{-7}$	$<2547\times10^{-7}$
Sb	<.006078	0.1000	0.0899	0.0899	.1298	0.0500

The undesired minerals concentrations were generally low in garden crops (table 3.4) the elements are normally classified as highly toxic or carcinogenic showed almost negligible concentrations. These are lead, arsenic, antimony, cadmium, tin, beryllium as well as aluminum and chromium in some samples. Strontium, aluminum and barium showed relatively high concentrations in Roselle in addition strontium was found in all samples.

Table (3.5) Macro minerals contents of wild plants (in ppm)

Minerals	Food type			
	Tabldy	**Aradeeb**	**Gudaim**	**Doum**
Na	122.3	76.33	69.59	151.3
K	16.081	11,434	9410	27.648
Mg	1370	1208	1225	1260
Ca	2629	1767	5412	851.4
P	638.5	902.3	1103	1111

The wild crops samples showed relatively high sodium concentrations when compared to cereal grains and garden crops samples. Tabaldy, Aradaib, Gudaim and Doum showed generally high potassium content. The four types of crops were rich in calcium, followed by magnesium and phosphorus (Table 3.5) thus; they may be described as good source of K, Ca, Mg and P.

Table (3.6) Undesired minerals contents of wild crops (in ppm)

Minerals	Food type			
	Tabldy	**Aradeeb**	**Gudaim**	**Doum**
Be	0.0500	0.0100	0.0100	0.0299
Sr	53.17	24.44	20.47	12.09
Ba	15.16	26.25	13.39	1.937
Cr	0.6993	0.2097	0.2999	0.5290
Cd	<.000198	<.000198	0.0100	<.000198
Al	781.6	55.95	36.93	423.1
Sn	0.4496	0.3296	0.2100	0.6089
Pb	0.2298	<.004727	<.004727	<.004727
As	0.1199	<.002547	<.002547	0.0998
Sb	<.006078	0.000	<.006078	.898

In wild crops (Table 3.6) Beryllium, Chromium, Cadmium, Tin, Lead Arsenic and Antimony as undesired minerals showed very low concentrations. Aluminum concentrations were relatively high in all the analyzed samples. Strontium and Barium showed significantly risky concentrations since the cation (Sr^{2+}) and (Ba^{2+}) are established to be of high toxicity.

Conclusion

As a conclusion, the results obtained by this study indicated, that, all the analyzed samples of food types that, consumed by Sudanese in daily consumption or frequent use, were rich in the essential macronutrients Sodium, Potassium, Magnesium, Calcium and Phosphorus. Sudanese who depends on these crops, as main types of diets, may not need any minerals supplementation additives to their food. On the other hand concentrations of the undesired minerals as hazardous, toxic or carcinogenic agents, were found to be generally low. All the studied samples of food types may be described, as safe and almost free from any undesirable inorganic contaminants.

Recommendations

- ❖ Further studies may be needed, to widen the survey in this field or to analyze more other types of foods which were not included in this study.
- ❖ Samples from other Sudanese states and areas may need to be analyzed.
- ❖ Aluminum risk may also need more investigations.

References

Abdel Moneim E. Sulieman, et al; (2012) *Comparative* Study on Five Sudanese Date (Phoenix dactylifera L.) Fruit Cultivars, *Food and Nutrition Sciences*, **3**, *1245-1251*

Ali H. Abdelrahman, (1998), Trends in Sudanese Cereal Production, Consumption, and Trade, *Center for Agricultural and Rural Development, Iowa State University*.

Anupama M., et al; (2016), Role of Strontium Biological Systems, *European Journal of Pharmaceutical and Medical Research*, **3(**12**)**, 177-184 ,

Bhattacharya P, Samal AC, Majumdar J, Santra SC. (2010). Arsenic contamination in rice, wheat, pulses, and vegetables: a study in an arsenic affected area of West Bengal, India. *Water Air Soil Pollut* ; **213**:3–13.

Burger J. Dixon C, Boring CS, Gochfeld M. (2003), Effect of deep-frying fish on risk from mercury. *J Toxicol Environ Health* **66**(9):817–28.

D´ıaz OP. et al; (2004), Contribution of water, bread, and vegetables (raw and cooked) to dietary intake of inorganic arsenic in a rural village of Northern Chile. *J Agri Food Chem* **52**:177 3–9.

Falco G; et al; (2004), Dietary intake of hexachlorobenzene in Catalonia, Spain. *Sci. Total Environ*; **322**:63–70.

Fact Sheet, (2016), Foods High in Potassium, *The Ohio State University Wexner Medical Center.*

Fact sheet, (2011), Magnesium, *National institute of health, office of dietary* supplements.

Farid ATM, et al; (2003), A study of arsenic Contamination irrigation water and its carried-over effect on vegetables, *Proceedings of the International Symposium on Fate of Arsenic in the Environment;* 113–21.

G.O. Mohammed Elhassan and S.M. Yagi, (2010), Nutritional Composition of Grewia Species (Grewia tenax (Forsk.) Fiori,G. flavescens Juss and G. Villosa Willd) Fruits , *Advance Journal of Food Science and Technology* **2**(3); 159-162.

Greger, JL. (1993), Aluminum metabolism, *Annual Review of Nutrition*, **13**(1), 43-63

Issoufou Amadou , Mahamadou E. Gounga and Guo-Wei Le, (2013) , Millets: Nutritional composition, some health benefits and processing ,*Emir. J. Food Agric*. **25** (7): 501-50.

James J Elser,(2012), Phosphorus: a limiting nutrient for humanity, *Current opinion in biotechnology;* **3** ; 833-838.

Jon Yaneff, (2017), Phosphorus: Deficiency Symptoms, Health Benefits, Daily Recommendations & Best Food Sources; *www.doctorshealthpress.com*

K. O. Soetan, C. O. Olaiya and O. E. Oyewole ,(2010), The importance of mineral elements for humans, domestic animals and plants, *African Journal of Food Science*, **4** (5) 200-222.

Kamil Fijorek, et al; (2014), Serum Potassium, Sodium and Calcium Levels in Healthy Individual Literature Review and data analysis , *Folia Medica Cracoviessia* , **1**, 53–70.

Karine Landry, (2014), Human Health Effects of Dietary Aluminum, *Interdisciplinary Journal of Health Sciences*, **4** (1); 39-44

Kirti Shekhawat, Sreemoyee Chatterjee, and Bhumika Joshi, (2015), Chromium Toxicity and its Health Hazards, *International Journal of Advanced Research*, **3**; 7; 167-172.

Lars Järup, (2003), Hazards of heavy metal contamination, *British Medical Bulletin*

Liobet JM, Falco G, Casas C, Teixido A, Domingo JL. (2003). Concentrations of arsenic, cadmium, mercury, and lead in common foods and estimated daily intake by children, adolescents, adults, and seniors of Catalonia, Spain. *J Agric Food Chem* **51**:838–42.

Manju Mahurpawar, (2015), Effects Of Heavy Metals on Human Health, *International Journal of Research*; page: 1-7.

Magdi A. Osman, (2004), Chemical and Nutrient Analysis of Baobab (Adansonia digitata) , *Plant Foods for Human Nutrition* **59**: 29–33.

Martı-Cid R, Bocio A, Llobet JM, Domingo JL. (2007), Intake of chemical Contaminants through fish and seafood consumption by children of Catalonia, Spain: health risks. *Food Chem Toxicol* **45**:1968–74.

Michael S. Stone, Lisa Martyn and Connie M. Weaver, (2016), Potassium Intake, Bioavailability, Hypertension, and Glucose Control, *Nutrients*, **8 (7)**; 1-13.

Monisha Jaishankar, Tenzin Tseten , Naresh Anbalagan, Blessy B.Mathew, Krishnamurthy N.Beeregowda,(2014), Toxicity, mechanism and health effects of some heavy metals, *Interdiscip Toxicol* Vol. **7**(2); 60–72.

Mona S Calvo , Christel J Lamberg-Allardt, (2015); Phosphorus; *Advances in Nutrition, An International Review Journal* , **6** (6); 860-862

Munteanu Constantin, Iliuţã Alexandru, 2011, The role of sodium in the body *Balneo Research Journal*, **2** (1); 70-74.

Noha A. Mohammed, Isam A. Mohamed Ahmed and Elfadil E. Babiker, (2011) ,Nutritional Evaluation of Sorghum Flour (*Sorghum bicolor L. Moench)* During Processing of Injera, *World Academy of Science, Engineering and Technology* **51;** 03-22 .

P. Hajeb, J. J. Sloth, Sh. Shakibazadeh, N. A. Mahyudin, and L. Afsah-Hejri , (2014) ,Toxic Elements in Food: Occurrence, Binding, and Reduction Approaches, *Comprehensive Reviews in Food Science and Food Safety* ,**13,** 457-472.

Fact sheet Panel on Dietary Reference Intakes for Electrolytes and Water; (2005) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes; Food and Nutrition Board; Institute of Medicine. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate; The National Academies Press: Washington, DC,USA.

Paul Howe and Peter Watts, (2005), Tin and Inorganic Tin Compounds, *United Nations Environment Programme, the International Labour Organization, and the World Health Organization Geneva*

Piste Pravina , Didwagh Sayaji and Mokashi Avinash , (2012), Review Article Calcium and its Role in Human Body, *International Journal of Research in Pharmaceutical and Biomedical Sciences* ISSN: **4** (2); 659- 668.

Qais Faryadi , (2012), A Critical Review The Magnificent Effect of Magnesium to Human Health, *International Journal of Applied Science and Technology* , **3**(2**)**;118-126.

Rahma Ismaeil Adam, Omer Adam M Gibla, Esraa Omer Adam Mohammed , (2016), Physicochemical analysis of some natural sudanese juices (Roselle, Adansonia digitata and Tamairndus indica) , *International Journal of Multidisciplinary Research and Development Online* , (**3)**; 6; 94-96 .

Rasmussen RS, Morrissey MT, (2007), Effects of canning on total mercury, protein, lipid, and moisture content in troll-caught albacore tuna (Thunnusalalunga). *Food Chem* ,**101**(3); 1130–1135.

Robert A.Goyer and Thomas W. Clarkson, (1996), Toxic Effects of Metals, *The McGraw-Hill Companies Retrieved from*.

Ross G. Cooper, Adrian P. Harrison, (2009), The exposure to and health effects of antimony, Denmark *Indian Journal of Occupational and Environmental Medicine* **13** (1); 3-10.

Rude, R.K. (1998), Magnesium Deficiency: A Cause of Heterogeneous disease in Humans. *J Bone Miner Res*.**13**, pp. 749.

Sabine Martin and Wendy Griswold,(2009), Human Health Effects of Heavy Metals , *Environmental Science and Technology Briefs for Citizens , Center for Hazardous Substance Research* , 15 ; 1-6

Sadiq, I. S., Duruminiya, N. I., Balogun, J. B., kwada, D. and Izuagie, T, (2016), Nutritional and Anti-nutritional Value of Tamarind Fruit (Tamarindus indica), *International Journal of Applied Research and Technology*, **5**, 3, 50 – 56.

Safiya Altuhami Ballal Taha, Abd Elazeem Ahmed Mohamed Nour and Abd Elmoneim Osman Elkhalifa,(2016), The value of tamarind (Tamarindus indica L.) pulp and its potential use in vinegar production, *Nova Journal of Medical and Biological Sciences* **5**(3):1-8 .

Shimelis Admassu,al Mulugeta Teamir, and Dawit Alemu, (2009), Chemical Composition OF Local and Improved Finger Millet [Eleusine Corocana (L.) Gaertin] Verities Grown in Ethiopia, *Ethiop J Health Sci*. **19**, 1.

Stiven Foster and Harlal Choudhury, (2005), Toxicological Review of Barium and compounds . *U.S. Environmental Protection Agency Washington, DC* (CAS No. 7440-39-3)

Taylor C. Wallace , Robert Murray and Kathleen M. Zelman ,(2016), The Nutritional Value and Health Benefits of Chickpeas and Hummus, *Nutrients* , **8**, 766.

Tizazu H and SA Emire,(2010), Chemical Composition, Physicochemical And Functional Properties of Lupin (Lupinus albus) Seeds Grown in Ethiopia, *African Journal of Food Agriculture Nutrition and Development* ,**10** :8 ;3029-3046

Vander A., Sherman J., Luciano D. (2001), Human physiology, The Mechanisms of Body Function. 8th edition, *McGraw-Hill, Boston*.

Vormann, J. (2003). Magnesium: Nutrition and Metabolism. *Molecular aspect of Medicine*, **23**, 27.

World Health Organization (WHO) (1990), Environmental health criteria 107: barium. *Sponsored by United Nations, Environment Programme, International Labour Organisation, and World Health Organization. Geneva, Switzerland*

Williamt. Cefalu, Frank B. HU, (2004), Role of Chromium in Human Health and in Diabetes, Diabetes *Care*, 27 (11); 2741-2751**.**

www.apjcn.nhri.org.tw / Food data chart – sodium

www.apjcn.nhri.org.tw Food data chart, phosphorus

www.iofbonehealth.org *International Osteoporosis Foundation 2017*