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Determination Of Proximate Composition, Mineral And Heavy Metals In Sesame Seed (Sesamum Indicum)

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Abstract
Sesame seeds and its oil are highly nutritious and healthy due to its content in essential amino acids, protein, crude fat, carbohydrate and it is also a good source of various minerals. Therefore, it is essential to human health. The aim of this study is to determine the proximate composition (crude protein, ash, fat, moisture content, carbohydrate and crude fiber, energy value), mineral (calcium, iron, sodium, magnesium and copper) and heavy metals (As, Ba, Cr and Pb) of sesame seed and the oil physiochemical parameters. Extraction method was used for the extraction of oil from the sesame seeds. Different analytical technique was employed such as using Soxhlet extractor, Anthrone method, Kjedahl method, gravimetric method and inductively coupled plasma (ICP). The concentration of the mineral varies with iron being the highest with value of (8.03 mg/L), calcium (2.50 mg/L), sodium (2.39 mg/L), zinc (1.63 mg/L), potassium (1.07 mg/L), magnesium (0.36 mg/L), and copper showed the lowest concentration value of (0.02 mg/L). The results shown falls within the allowed daily requirement for iron, calcium, sodium, zinc, potassium, magnesium, and copper per day 18 mg/L, 1200 mg/L, 1500 mg/L, 11 mg/L, 800 mg/L, 300 mg/L, 10 mg/L respectively. The result revealed that sesame seeds and its oil can be used as an alternative supplement of protein and minerals in the body. In conclusion, the consumption of sesame seeds and its oil would help to prevent nutritional deficiencies in the future.

Keywords: *sesame seeds, proximate analysis, mineral composition, inductively coupled plasma, Physiochemical parameter.*

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I. Introduction

Sesame (*Sesamum indicum L*) is a tropical herbaceous annual plant that grows up to 1-2 m tall belongs to the family Pedaliaceae and they used in various food preparations, raw or roasted [1]; [2]. Sesame is planted in so many countries in the world such as China, Ethiopia, Burma, and they are the major producers of about 60% of the world production [2]; [3]. Sesame is an annual plant that is locally known as Ridi in Hausa and Yamati in Yoruba language in Nigeria. The plant seeds have different colors such as black, white, yellow, brown, and gray and it depends on the variety and strain of *S indicum*. Black and white sesame seeds are the most available in all parts of the world [4]. Sesame plant seed contains: oil, carbohydrates, proteins, and ash, which are essential in human nutrition [5]; [6]. Due to the high proteins content, sesame seeds can be used to make soup, bread, porridge, etc. and soap fat and synergist for insecticides in pharmaceuticals [7]. Sesame seed has very high oil contents among many other seeds in the world and it is a vegetable oil used for cooking soup in Nigeria, [8]; [9]. Because of the high content of protein, sesame seeds are used with bread, porridge, soup, confectionary, and in pharmaceuticals as a soap fat [4], [12]. The major composition of the sesame seed oil components are moisture, protein, fiber, fat, ash, and carbohydrate [6]. Sesame seeds are used in baking crackers, snacks, cakes, soup and stew, cookies and wafers [9]; [10], [11]. Sesame seed is a source of edible oil used as ingredient in different type of food products such as, cooking, bakery. Sesame seed in modern day nutrition is considered to solve the problem of micronutrient deficiencies [13]. Sesame seed oils have high antioxidant activity which reveal significant effect for reducing the blood pressure and useful for reducing chronic diseases [14]; [15]. The adjustment of diet may influence the present health, as well as determine whether an individual will develop some diseases such as cardiovascular disease, cancer, and diabetes later in life or not [16]; [17]. Sesame seed oil components exhibit some functions as anti-inflammatory substance to reduce blood lipid levels, estrogen activation levels, enhance bioavailability of ἀ-tocopherol, and increase antioxidant [18]. Essential heavy metals (Fe, Cu, Co, Cr, Zn, and Mn) are responsible for some metabolism in the human body while very low concentrations some essential heavy metals (Pb, Cd, Ni, and Hg) are toxic when in excess [19]. Analytical techniques that are used for metal ion quantification of are atomic absorption spectrometry (AAS), flame atomic absorption spectrometry (FAAS), cold vapor atomic absorption spectrometry (CVAAS), inductively coupled plasma mass spectrometry (ICP-MS), and inductively coupled plasma optical emission spectrometry (ICP-OES) [20]. These instruments earlier mentioned are used to quantify the concentrations of toxic heavy metals (As, Ba, Cd, Cr, Hg, Mn, Pb, Th, and U) and trace elements (Ca, Cu, Fe, K, Mg, Mo, Na, Ni, P, Se, and Zn) in food samples [4]; [21]; [22]; [23]. The determination of microelement concentrations using modern techniques is necessary to evaluate the nutrition and safety on dietary exposure [24]. The aim of this study is to determine the proximate composition and quantify the some toxic heavy metals (As, Ba, Cr, Pb, Th, and U) and essential mineral elements (Ca, Cu, Fe, K, Mg, Na, and Zn) in the sesame seed. Heavy metals are essential in human body, and play important role in several biochemical processes but most importantly their adverse effects to the ecosystem and living organisms. Attention has been given to toxic metals due to their toxicity and mutagenic effects even at very low concentrations. Sesame seed is a multi-functional seed used as supplement in spices, insecticides, medicines, soap, green manure and ornaments [24]. Trace essential elements (Fe, Zn, Cu, Mg, and Mn) are micronutrients required in small amount to function in various metabolic and physiological processes in the body [25]. Zinc is essential trace element required to aid enzymes that support the-body immune system but becomes toxic when in excess because it interferes with the metabolism of other minerals like Cu and Fe in the body [26]. Copper act as enzyme in the body and iron plays important role in the effective functioning of hemoglobin and excess can destroy vital body tissues (kidneys, heart, and lungs) as its deficiency lead to anemia and infertility [27]; [28].

II. Experimental

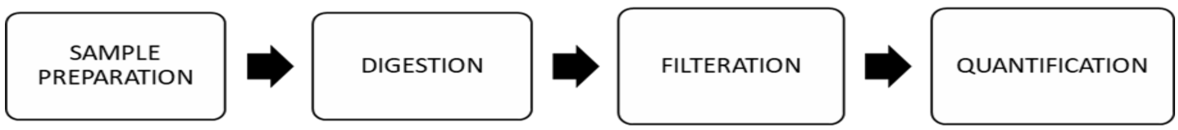
Study Area

The sesame seed was collected was purchased in a local market in Lagos State, Nigeria

Reagents and Chemicals

The reagents and chemicals used in this study are: hydrochloric acid, nitric acid sulphuric acid, hexane, tetrachloromethane, glacial acetic acid, chloroform, sodium thiosulphate, potassium iodide, Lantanum oxide, caustic soda (sodium hydroxide, potassium hydroxide) and they were purchased from Tunnex chemicals. All the reagents and chemicals in this study were all analytical grades and used as received without any further purification.

Experimental Procedure



Sampling and Sample Preparation

The Sesame seed (*Sesamum indicum L.*) sample was purchased from Ojo market, Lagos State, Nigeria. The sample was sieved to separate particles like sand, stones, soil before washing, and dried for 24 hours to remove moisture in the seed. It was crushed manually to a powder form using mortar and pestle and the homogenized crushed sample was sieved to a fine powder. The pulverized particle was packed in a polyethylene plastic bag and kept in a fridge until it is needed for extraction, digestion and proximate analysis.

Extraction of Oil

The extraction and separation technique used in this study was to recover the oil in the sesame seed sample was to remove the oil from the pulverized sesame seed sample using soxhlet extraction process [29]; [30]; [31]; [12].

Procedure

25g of the crushed fine powder of the sesame seed sample was weighed and transferred into a thimble (semi-permeable membrane) inside the soxhlet extractor containing 200 mL of hexane solvent for the extraction, Crushed sesame seed mixture in the soxhlet extractor was ~~put~~ placed inside a heating mantle and subjected to heating for 2 hrs. The extracted solid was removed from the apparatus by filtration to obtain the extracted lipids. The crude oil was obtained after the solvent extraction subjected to refluxing at 60 °C to remove the excess solvent from the extracted oil. The sesame oil was extracted in sets until adequate quantity of oil obtained for the analysis was obtained and stored in an air-tight bottle for further analysis or characterization [32].

Digestion

This is the dissolution of metals from the sesame seed oil sample using aqua regia (mixture of HNO_3 and HCl in ratio 2:1) Digestion involves contacting homogenized oil sample with concentrated acid mixtures to release all the metal constituents into solution before determining the elemental composition.

Procedure

Digestion was carried out on the pulverized sesame seed oil with a mixture of nitric acid and hydrochloric acid in ratio 2:1. A 0.4 g of the sesame seed oil was transferred into a digestion container with a 9 mL mixture of 69–72% HNO_3 and 70% HCl (2:1 v/v) and digested. The mixture solution was cool for 3 h at 120 °C. Lanthanum oxide catalyst was added and distilled water were added to dissolve the precipitate formed on cooling. The digested solution was filtered with 0.45 µm membrane filter poured into a 50 mL volumetric flask and diluted with deionized water and the digested solution was stored in a refrigerator. All the metals in the sample solution were quantified using inductively coupled plasma optical emission spectroscopy (ICP-OES).

Proximate Analysis of Sesame Seed

The nutritional values are usually listed on the packaging label of food and beverage products. The proximate compositions, moisture content, ash content, crude fat, crude fiber, and crude protein of the seed oil was determined by following standard methods [33]; [34].

Determination of Moisture Content

The sesame seed oil moisture content was determined according to AOAC [33]; [35]. A 0.5 g oil sample was dried in an oven to remove the moisture until constant weights was obtained. The percentage of moisture content of sesame seed oil is calculated is expressed using Eq. 1.

% Moisture = W2/W1 x 100 ………………………………………………………………… 1

W1 = weight of oil sample before heating, W2 = weight of sample after heating

Then, the sample was transferred into the muffle furnace and subjected to a temperature of 500 °C for 12 hours until white ash was formed. The sample was removed from the furnace and allowed to cool in a desiccator and weighed. The percentage of total ash content of sesame seeds was calculated using Eq. 2.

Ash (%) = Weight of Ash /Weight of sample x 100 ………………………………………… (2)

Determination of crude protein

Crude protein was determined in sesame seed using kjeldahl method. 2 g of sample was weighed and placed in digestion flask. 2 g of kjeldahl catalyst and 200 mL H_2SO_4 were added into the digestion flask and subjected to boiling until the solution becomes clear and allow it to cool. 60 mL H_2O was added with 6 drops mixed indicator was added and heated until all N_2 was distilled. The solution was titrated with NaOH and calculated in Equation 3.

Protein (%) = (A-B) x N x 14.007 x 6.250) / W …………………………………………………. (3)

Where: A = Volume (mL) of 0.2 N HCl used sample titration

B = Volume (ml) of 0.2 N HCl used in blank titration, N = Normality of HCl, W = Weigh (g) of sample, 14.007 = Atomic weigh of nitrogen, 6.25 = the protein- nitrogen conversation factor. [33].

Determination of Fiber Content

2.0 g of the sesame seed sample was weighed in a beaker; 200 mL of sulphuric acid was added to the boiling mixture and subjected to heating for about 30 mins and filtered. The residue was washed three times with hot water; add 100 mL of 2% NaOH into the boiling mixture and heated for 30 minutes, and filter. The filtrate was carefully washed three times with hot water until it was free from the acid. The sample was dried under suction and transferred to an oven at 105 °C overnight, and finally weighed. The residue was burn to ash in a muffle furnace at 550 °C for 3 hours until a light grey ash colour was formed, then weighed to until a constant weight was obtained, and the total crude fiber percent was calculated by the Equation 4.

Crude fiber (%) = W1 − W2/ W3 ………………………………………………………………… (4)

Where: W1 = weight of the sample before ignition, W2 = weight of the sample after ignition, and W3 = original sample weight. [33].

Extraction of fat content

Crude lipid content was extracted using Soxhlet apparatus described by AOAC (Association of Official Analytical Chemists 2005 [33]. A 2.0 g of sesame sample was weighed (W2) and placed inside a Soxhlet extraction apparatus; 250 mL of ether solvent was added and subjected to heating at 85 °C until the solvent was evaporated completely. The bottle containing the sample was cooled in desiccators and reweighed (W3), then, the fat content was calculated by Equation 5.

Fat (%) = W2 − W1/W3 x 100 ………………………………………………………………………. (5)
Where: W1 = the weight of empty bottle, W2 = the weight of bottle and oil, W3 = the weight of sample. [33].

Determination of carbohydrate

The percentage of carbohydrates in sesame seed was calculated by using the following formula with the same amount of seed sample Equation 6 [33].

Carbohydrate (%) = 100 − (% Moisture content + % Crude protein + % Fat + % Crude fiber + % Ash) ……………………………………………………………………………………………….. (6)

Determination of Energy Calorie

The energy calorie of sesame seed was determined using the oxygen bomb calorimeter method by Abbas et al. [30]. 0.5 g of the sesame seed sample was placed in a metallic decomposition vial attached to a cotton thread to enter the center of the ignition wire using a loop and the screw cap was tightened. With the decomposition process resulted in the burning of the sample in the vial was recorded by a computer software revealed the calories per gram of the sample. The energy value (EV) was calculated based on the protein content, oil content, and carbohydrate content expressed in kilocalories per 100 g of dried powder. The calculation utilized the following equation from the research by Equation 7 [36].

EV (Kcal/100g) = (2.62 × Protein Content) + (4.2 × Carbohydrate Content) + (8.37 × Oil Content). 7

Physical and Chemical Analysis of Sesame Seed Oil

Physical and chemical properties of the sesame seed oil were carried out to determine the iodine value (IV), peroxide value (PV), acid value (AV), saponification value (SV), free fatty acid (FFA) and specific gravity (SG) by the standard AOACS methods.

Iodine Value

The iodine value (IV) was the measure of the degree of unsaturation in fats and oil. The IV was determined using these methods [37]; [34]. 0.4 g of the oil sample was weighed into a conical flask was dissolved in 20 ml of carbon tetra chloride. After keeping the oil mixture in the dark cupboard for the set time, 20 mL of 10% KI solution and 125 mL of water were added to the mixture. 0.1 M sodium-thiosulphate ($Na_2S_2O_3$) solution was titrated with the mixture until the yellow colour almost disappears. Few drops of 1% starch indicator was added to the mixture and subject it to continuous vigorous stirring with addition of sodium thiosulphate solution drop-wise until the blue-black coloration disappear. The blank test was carried out with same procedure. The iodine value (IV)-expression is given in Equation 8:

IV = 12.69 c (V1-V2) m ………………………………………………………………………… (8)
V1 = volume of $Na_2S_2O_3$ used for the blank, V2 = volume of $Na_2S_2O_3$ used for determination,
m = Mass of the oil sample

Specific Gravity

The specific gravity (SG) of the sesame seed oil was determined using specific gravity bottle standard method. The SG is expressed in Equation 9 [34].

Specific gravity of oil sample = (W3 – W1) / (W2–W1) ……………………………………..... (9)
Where, W1 = Weight of empty specific gravity bottle, W2 = Weight of water + specific gravity bottle, W3 = Weight of test sample + specific gravity bottle.

Peroxide Value

Standard method was used to determine peroxide value [38]. 1.0 g of potassium iodide (KI) and 20 mL of solvent mixture (glacial acetic acid/chloroform, 2:1 by volume) was added to 1.0 g of the oil sample and the mixture was boiled for one minute. The hot solution was poured into a flask containing 20 mL of 5 % potassium iodide. Add few drops of starch solution to the mixture and titrated with 0.025 N sodium thiosulphate and the peroxide value was determined as expressed in Equation 10.

PV= SN103 / W ……………………………………………………………………………….. (10)
Where: S = mL of $Na_2S_2O_3$, N = Normality of $Na_2S_2O_3$, W = Weight of oil sample (g).
Where: C = concentration of $Na_2S_2O_3$ used

Acid Value

Standard method was used to determine acid value sesame seed oil [38]. 25 mL of diethyl ether and 25 mL of ethanol was mixed in a 250 mL beaker. The mixture was added to 10.0 g sesame oil in a 250 mL conical flask and adds few drops of phenolphthalein indicator solution to the mixture. The mixture was titrated with 0.1

M KOH to the end point with consistent stirring until a dark pink colour was observed. The acid value is expressed in Equation 11

Acid value = (V × N × 56.1) / W ………………..…………………………………………….. (11)

Where, V = volume of potassium hydroxide used, N = normality of
Potassium hydroxide, W = weight in g of the sample

Free fatty acid as oleic acid, per cent by weight = (28.2 × V × N) / W ……………………….. (12)

% FFA × 1.99 = Acid value.

Saponification Value (SV)

Standard method was used to determine saponification value (SV) [38]. 2.0 g oil sample was weighed in a conical flask and dissolved with 5 mL of chloroform; then, add 25 mL of 0.5 M alcoholic KOH. The mixture was refluxed for 30 minutes and the mixture was transferred into a conical flask, add few drops of phenolphthalein indicator. Titrated the mixture with 0.5 M HCl until the pink colour disappeared, indicating the end point. The saponification value was calculated as expressed in Equation 13:

Saponification value = (a − b) × M × 56.1/W × 100 …………………………………………… (13)

Where a = sample titre value, b = blank titre value, M = molarity of the HCl, and 56.1 = molecular weight of KOH. Ester value (EV) was evaluated as saponification value–acid value.

Mineral and Heavy Metal Analysis

The sesame seed sample digested in a microwave digester and the digested sample solution was injected to an Inductively Coupled Plasma–Optical Emission Spectrophotometer (Variance Liberty II) to analyze and determine the heavy metal concentrations. Running the samples in triplicate will help to determine the reproducibility of the instrument [39].

III. Results And Discussion

Proximate Composition Analysis

Proximate composition of sesame seed determinates the major components of food substance such as carbohydrate, fat, energy, moisture, protein, fiber, and ash, [6]. The proximate composition results of the sesame seed sample is presented in Figures 1 and 2. The composition of the sesame seed are 3.7 % moisture content, 2.76 % crude fibre, 0.43 % crude ash, 10.55 % crude protein, 31.3 % carbohydrate, 45.9 % crude fat and 580 calorie energy.

Carbohydrate

The result of carbohydrate content of the sesame seed presented in Figure 1 was estimated to be 31.3% and it is a diet that serves as a good source of carbohydrate daily required intake. The results reported in this study is higher than that of some previous studies reported (25.0 %) by (Shah et al., 2013)[40]; (23.4 %) by Nzikou et al., [41]) and it is a diet that can serve as a good source of daily required carbohydrate intake.

Crude Fat Content

Sesame seed crude fat content result is presented in Figure 1. The result of the oil is composed of linoleic oil revealed that the fat content represents the major component in the sample was estimated to be 45.9 % which falls within the range of those reported in previous studies [42]; [40]; [41]. Sesame seed oil has a high degree of polyunsaturation and it is a functional food that can regulate fasting blood sugar when diabetic patients were treated with the oil [43].

Energy Value Analysis

The result of sesame seed energy value analysis is presented in Figure 1. The result of the energy obtained from this study was estimated to be 580 calories which indicate that the sesame seed is an energy rich food that is suitable for human consumption. The sesame seed calorific value in a human body indicates the quantity of energy generated metabolism is expressed in kilojoules per 100 g [44]. The demand for sesame seed as food is increasing several consumers are now aware about the importance of energy intake and seek for more higher. [45]. The main reason for the high energy value of sesame seed is its proximate composition that reveals the presence of high amount of proteins, carbohydrate, and fats in the sesame seed [44].

% Moisture Content

The sesame seed % moisture content result is presented in Figure 1. The moisture content result obtained from this study was estimated to be 3.70 % low at which indicate a good quality sample and if the moisture content is below 6% as reported by Sheahan & Barrett, [46]. Low moisture content can result in low rate of oil rancidity with long life span of the sample [47]. From the result of this study, the moisture content was higher than the one reported in some previous studies, 3.15 – 3.52 % by Beshaw et al., [24], 0.22 – 3. 5 % by Nweke et al., [10], and lower than the results reported: 7.37 % by Samuel & Genevieve, [11], 4.16% - 4.62% by Ünal & Yalçın, [48], 5.43 – 5.81 %, by Seid & Mehari, [49] and 6.21 % by Ebere et al., [50]. Sesame seed sample moisture content < 6 % indicates a good seed during harvesting [46]. Lower moisture content of sesame seed is beneficial with respect to its quality and shelf life of the sample [51]. The sesame seed with low moisture content is an index of high yields, stability, shelf life, quality and indication of dry matter in the food [52]; [10].

Crude Protein

The result crude protein is presented in Figure 2. The sesame seeds economic value depends on its oil content instead of its protein content [48]; [53]. The crude protein content result in this study was 10.55 % which can be classified as high protein content. The sesame seed crude protein content can be classified as low range from 3.25 – 7.26 % while the classified high protein ranges from 7.26 – 11.27 % [10]. Ranganayaki et al., [54] reported that high protein content can be used to supplement low protein flours for cereal that it used for feeding infant. Sesame seed is an excellent source of plant proteins, which is in high demand in human and animal nutrition [11].

Ash Content

The ash content result is presented in Figure 2 was estimated to be 0.43 % is an indication of inorganic matter present in a food sample [52]; [55]. Loss of ash content is caused by soaking of sesame seeds in water [51]. The ash content indicates the presence of mineral element deposits in the food substance [56].

Crude Fibre Content

The sesame seed result of the crude fibre content is presented in Figure 2 was estimated to be 2.76 % was lower than some of the previously reported results [42] and higher than some previously reported result [1- the cholesterol level in the body to maintain the human health [6]; [57]; [49]. Studies have shown that dietary fibre improves glucose tolerance and can be used to treat diabetes with potential to promote health [7]; [58]. The crude fibre importance in human nutrition cannot be over emphasized. High fibre content prevents constipation, diverticulosis, and remove toxic materials from the body. Fibre has high water holding capacity to make stooling easy and bulky [56]; [59]).

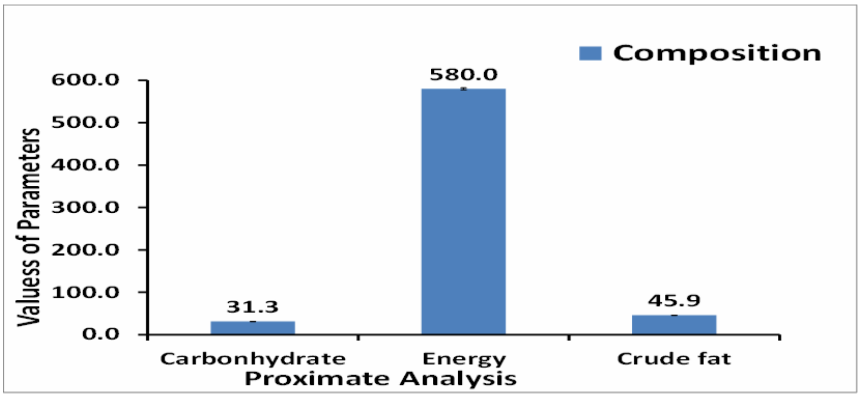


Figure 1: proximate analysis of sesame seeds (n = 2)

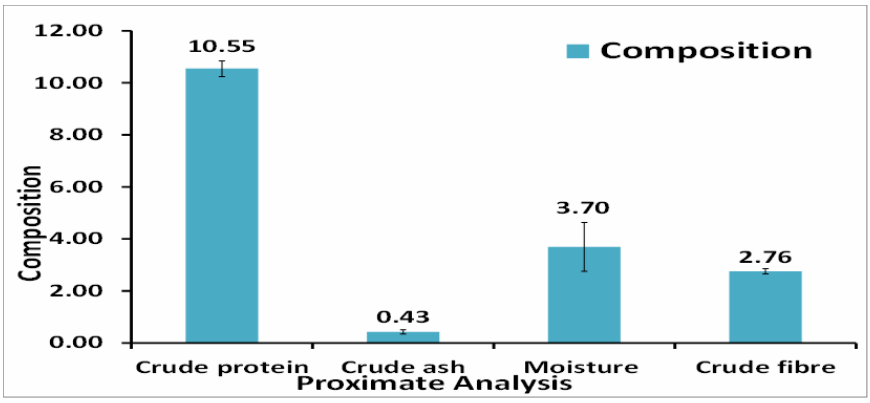


Figure 2: Proximate analysis of sesame seeds (n = 2)

Physicochemical Analysis

Physicochemical parameters used to measure the physical and chemical properties of seed oil content such as colour, specific gravity, acid value, peroxide value, saponification value, free fatty acid (FFA), and iodine value. The sesame seed oil economic value of depends on the quality of the oil content rather than its protein content. The sesame seed oil physicochemical parameters are presented in Table 1. The oil had a clear yellow colour with specific gravity of the oil of 0.9 obtained value was very close to the reference range 0.913 – 0.929 presented in Table 1. The SG value indicates good quality oil and it is higher than 0.88 reported by Betiku et al., [61]. The iodine value is a measure of the total number of double bonds present in fats and oils food sample [60]. The iodine value (IV) of 114.3 obtained was high and falls between the ranges of 104 – 120 which indicate the presence of unsaturated fatty acid. The degree of unsaturation in the fatty acids of triacyglycerol is determined by IV which is used to calculate the amount of double bonds present in an oil sample and the ability of oil to undergo oxidation. 2.70 % free fatty acid (FFA) was obtained from this study and the value was very close to the reference value of 3% which revealed stable oil. The sesame seed oil peroxide value 4.7 was obtained was used to determine the stability of the oil. The sesame seed fresh oil PV value was less than 10 meq/kg and the values ranging between 20 – 40 meq/kg indicates the ability of the oil to become rancid due to oxidation by oxygen during storage or processing of the oil to produce a rancid taste [62]. The peroxide value result obtained was within the range of 1.5 – 24, as reported by Codex standard [63]; Dim et al., [64]. The Saponification value of the oil was 197.8 (mg KOH/g oil) which was above the reference value 186 – 195 (mg KOH/g oil). The acid value was 5.3 % as an indication of the amount of fatty acid present in the seed oil. The iodine value obtained was 114.3 for the sesame oil which showed that it is rich in unsaturated fatty acids [65]. It possesses high oxidative stability and however, the economic value of sesame seed depends on its oil content rather than its protein content. The physicochemical results obtained from the sesame seed oil analysis are all in agreement with the literature Codex Alimentarius Commission [63]; Dim et al., [64].

Table 1: Physicochemical Properties of Extracted Sesame Seed Oil (n = 3)

Physicochemical Properties	Sesame Seed Oil	Codex Standard
Colour	Yellow	Yellow
Specific Gravity (SG) (at 27 °C)	0.9	0.913 – 0.929
Acid Value (AV) (mg KOH/g oil)	5.3	6.0 %
Peroxide Value (PV) (meq O_2/kg oil)	4.7	1.5 –24
Saponification Value (SV) (mg KOH/g oil)	197.8	186 – 195
Free Fatty Acid (as Oleic acid %)	2.7	3.0 %
Iodine Value (IV) (g of I_2 100/g of oil)	114.3	104 –120

Mineral Elements and Heavy Metal Analysis

It is consist of mineral elements (essential trace elements) and toxic heavy metals present in sesame seed.

Essential Trace Metals

This study presents the results of minerals or essential trace element of the sesame seed in Figure 3. The results of trace essential elements obtained in this study are: Cu (0.02 mg/L), Zn (1.63 mg/L), Ca (2.50 mg/L), Fe (8.03 mg/L), K (1.07 mg/L), Mg (0.36 mg/L) and Na (2.39 mg/L). Iron had the highest concentration 8.03 mg/L while copper the lowest concentration (0.02 mg/L). The essential trace minerals in the sesame seed are required in small amounts for the proper functioning and essential nutritional requirement to regulate water retention required activating and maintaining different body metabolic processes. The functions of the trace essential elements such as: K, Na, Ca, Mg, Cu, Fe, and Zn distributed in the sesame seed are important in the human body. Essential nutrient such as Potassium in the human body plays important role is the biosynthesis of proteins and amino acids [15]; [66]. Calcium and Magnesium helps to regulate enzyme activity land the acid-alkaline balance in the body [15]; [66]. Sodium is an essential trace mineral element which regulates the blood volume, blood pressure, osmotic equilibrium, etc. [24]. Calcium is essential for the growth of bones and teeth required for proper nerve functioning, contraction and relaxation of muscles, and health of immune system [68]. Calcium is responsible for healthy bone as well as regulating blood pressure enzyme activity, and the development of strong teeth [69]. Calcium and Magnesium plays important role in photosynthesis process in plants and of acid-alkaline balance in the body [15]; [66]. Magnesium is an essential element responsible for normal growth, sexual maturation, healthy immune system, and wound healing. Magnesium is present in the bones and it is responsible for the synthesis of protein, muscle contraction, and nerve transmission. Potassium is an essential element for muscle contraction, fluid and electrolyte balance, heart function, nerve transition, and nerve transmission. Iron is essential for energy metabolism and hemoglobin formation [70]. Fe in the human body act as a catalyst and in the absence of enzymatic catalyst most biochemical reactions are so slow and would not occur under mild conditions of temperature and pressure that is compatible with life [71]. Sesame seeds contain Fe which are consumed without any health problem. Copper is responsible for normal biological activities and it is therefore important consume a certain quantity of copper to maintain the human health [71]. Zinc is responsible for the proper functioning of the immune system in the human body and it facilitates carbohydrate catabolism, cells growth, cells division, and healing of wound [71]. Essential trace elements (Fe, Cu, and Zn) are components of proteins, enzymes and redox system for the human body system. Deficiency or excessive consumption of these metals (Fe, Cu, and Zn) in human body system which can lead to different disorders or diseases [4]. Pregnant and breast feeding women are required to consume 11 and 12 mg/day Cu, respectively and the Cu is used for different biochemical processes [72]. At higher concentrations, essential heavy metals are toxic and would affect soft tissues particularly blood and kidneys.

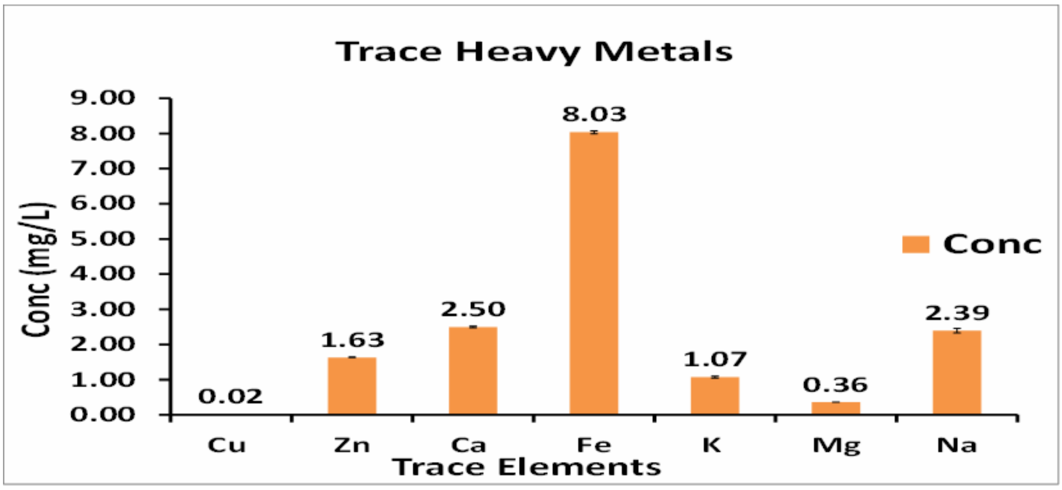


Figure 3: trace heavy metals in sesame seeds (n = 3)

Heavy Metals

Heavy metals enter and contaminate the human body through food chain and the presence of heavy metals in sesame seed oil can cause oxidative deterioration and adverse effects on the shelf life. The heavy metal uptake through food chain is related to the heavy metals concentration and the amount consumed of in sesame seed [73]. The mineral profile (mg/100 g) of sesame seed is divided into essential or trace and non-essential or toxic heavy metals presented in Figures 3 and 4.

Non-Essential Toxic Heavy Metals

In this present study, the sesame seed non-essential toxic heavy metals are presented in Figure 4. The results of non-essential heavy metals are As (0.03 mg/L), Ba (0.01 mg/L), Cr (0.01 mg/L), Pb (0.03 mg/L). The results of toxic heavy metal in sesame seed identified are As, Ba, Cr, and Pb as contaminants by the world organizations, which are required for natural biological function, but can also lead to toxicity [74]. The identified and determined concentrations of the four non-essential toxic heavy metals average concentration are in this order: Pb > As > Cr > Ba. The concentration result of arsenic (0.03 mg/L) was higher than permissible limit of 0.01 mg/L of WHO standard. Chronic arsenic contamination due to long time exposure can cause skin pigmentation, skin cancer, and hyperkeratosis [75]. Exposure of children to arsenic contamination has been reported to cause health issues such as cancer and lung disease much later in life [75]. However, studies have shown that too much consumption of arsenic in food may seriously cause liver cancer. Barium average concentration obtained in this study was 0.01 mg/L which falls within permissible limit of 0.7 mg/L of WHO standard. The sesame seed concentration of chromium falls within the permissible limit (0.05 mg/L) of WHO standard. Chromium improves the sensitivity of insulin and enhance metabolism. Deficiency of chromium in the human body include: loss of weight, reduced response to glucose in the blood with increase in the risk of diabetes coupled with many other body factors [76]. Chromium detected in the evaluated sesame seed had an average concentration of 0.01 mg/L which falls within the minimal proposed permissible limit level 0.01 mg/L of WHO standard [77]. The health issues of lead (Pb) affects the respiratory, renal, nervous, cardiovascular, hematopoietic, immune, endocrine, hepatic, and reproductive systems in man [78]. The accumulation of Pb in bones and teeth can cause neurological and developmental effects [76]; [78]. The contamination of foods with Pb may be from environmental pollution, absorption of metal emanating from the equipment, or metal tin cans used for packaging. The lead poisoning usually target some organs such as blood, bones, kidneys, brain, and the thyroid glands [79]. It has been reported that the exposure lead can ~~to~~ cause brain damage, severe anemia, reproductive problems, permanent neurological disorders, diminished intelligence and several other diseases [79]; [80]. All the toxic heavy metals in the sesame seed falls with the permissible limit of WHO standard [77].

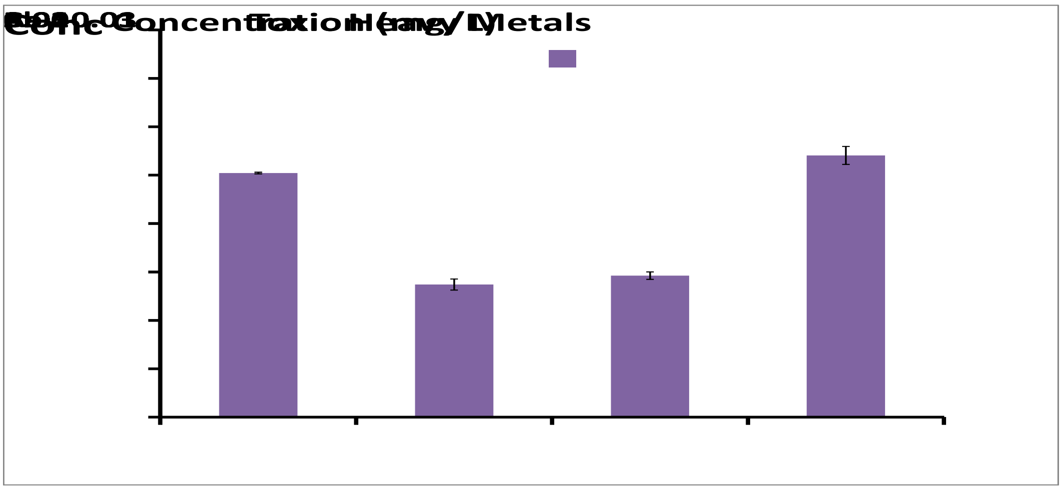


Figure 4: toxic heavy metals in sesame seeds (n = 3)

IV. Conclusion

The investigation of the proximate compositions, essential trace elements (K, Na, Ca, Mg, Cu, Fe, and Zn) and toxic heavy metals (As, Ba, Cr, and Pb) in sesame seed was conducted using ICP-OES. The results of the proximate composition and essential elemental components revealed the presence of some useful elements in the human body. The determination of proximate composition and metals in sesame seed sample was successfully conducted using analytical methods. The concentrations of all the essential metal results were found to be lower than the permissible limit recommended by FAO/WHO. The mineral composition of calcium and iron helps to maintain an optimal bone development, zinc is responsible for the metabolism and structural stability of nucleic acid while magnesium regulate blood glucose level and the production of energy and protein which keep the heart beat steadily. It can then be mentioned that sesame seeds (*sesamum indicum*) could be used as protein and mineral matter supplement to balance human nutrition. Sesame seeds (*sesamum indicum*) could prevent nutritional deficiency in the future. Heavy metal plays vital functions in the human body when it is below tolerable limits.

References

[1] Alegbejo, M. D., Iwo, G. A., Abo, M. E., & Idowu, A. A. (2003). Sesame: A Potential Industrial And Export Oilseed Crop In Nigeria. Journal Of Sustainable Agriculture, 23(1), 59-76.

[2] Babajide, P. A., & Oyeleke, O. R. (2014). Evaluation Of Sesame (Sesamum Indicum) For Optimum Nitrogen Requirement Under Usual Farmers' Practice Of Basal Organic Manuring In The Savanna Ecoregion Of Nigeria. Evaluation, 4(17).

[3] Ogbonna, P. E., & Ukaan, S. L. (2013). Chemical Composition And Oil Quality Of Seeds Of Sesame Accessions Grown In The Nsukka Plains Of South Eastern Nigeria. Afr J Agric Res, 8(9), 797-803.

[4] Hu, J., & Zhou, L. (2019). Assessment Of Microelements In Six Varieties Of Sesame Seeds Using Icp-Ms. In Iop Conference Series: Earth And Environmental Science (Vol. 330, No. 4, P. 042063). Iop Publishing.

[5] Elleuch, M., Besbes, S., Roiseux, O., Blecker, C., & Attia, H. (2007). Quality Characteristics Of Sesame Seeds And By-Products. Food Chemistry, 103(2), 641-650.

[6] Aja, P. M., Offor, C. E., & Orji, O. U. (2015). Proximate And A Nutrient Compositions Of Parkia Biglobosa Fruits In Abakaliki, Ebonyi State, Nigeria. International Journal. Current Microbiology Applied Sciences, 4(2), 394-398.

[7] Bamigboye, A. Y., Okafor, A. C., & Adepoju, O. T. (2010). Proximate And Mineral Composition Of Whole And Dehulled Nigerian Sesame Seed. African Journal Of Food Science And Technology, 1(3), 71-5.

[8] Hansen. (2011). Sesame Profile. Agricultural Marketing Resource Centre.

[9] Bedigian, D. (2006). Assessment Of Sesame And Its Wild Relatives In Africa: In Ghazanfar, S.A. And Beentje, H.J (Eds). Taxonomy And Ecology Of African Plants, Their Conservation And Sustainable Use. Royal Botanic Gardens 3:481-491. [15

[10] Nweke, F. N., Ubi, B. E., & Kunert, K. J. (2011). Determination Of Proximate Composition And Amino Acid Profile Of Nigerian Sesame (Sesamum Indicum L.) Cultivars. Nigerian Journal Of Biotechnology, 23.

[11] Samuel, N. C., & Genevieve, A. C. (2017). Proximate Analysis And Phytochemical Properties Of Sesame (Sesamum Indicum L.) Seeds Grown And Consumed In Abakaliki, Ebonyi State, Nigeria. International Journal Of Health And Medicine, 2(4), 1-4.

[12] Kyari, M.Z. (2008). Extraction And Characterization Of Seed Oils. Int. J. Agrophys., 22, 139–142. [Google Scholar]

[13] Aglave, H. R. (2018). Physiochemical Characteristics Of Sesame Seeds. J Med Plants Stud, 6(1), 64-66.

[14] Rangkadilok, N., Pholphana, N., Mahidol, C., Wongyai, W., Saengsooksree, K., Nookabkaew, S., & Satayavivad, J. (2010). Variation Of Sesamin, Sesamolin And Tocopherols In Sesame (Sesamum Indicum L.) Seeds And Oil Products In Thailand. Food Chemistry, 122(3), 724-730.

[15] Hassan, M. A. (2013). Studies On Egyptian Sesame Seeds (Sesamum Indicum L) And Its Products. 2. Effect Of Roasting Conditions On Peroxide Value, Free Acidity, Iodine Value And Antioxidant Activity Of Sesame Seeds (Sesamum Indicum L.).

[16] World Health Organization (2003) Diet, Nutrition And The Prevention Of Chronic Diseases. Who Technical Report Series 916, Geneva.

[17] Aande, T. M., Agbidye, I. G., & Adah, C. A. (2020). Formulation, Proximate Analysis And Sensory Evaluation Of Mumu From Pearl Millet, Irish Potato And Sesame Seed Blend. Agricultural Sciences, 11(3), 235-246.

[18] Abu-Almaaly, R. A. (2019). Estimate The Contamination By Some Heavy Metals In Sesame Seeds And Rashi Product That Available In Local Markets. Plant Archives (09725210), 19(2).
[19] Engwa, G. A., Ferdinand, P. U., Nwalo, F. N., & Unachukwu, M. N. (2019). Mechanism And Health Effects Of Heavy Metal Toxicity In Humans. Poisoning In The Modern World-New Tricks For An Old Dog, 10, 70-90.
[20] Khan, S. R., Sharma, B., Chawla, P. A., & Bhatia, R. (2022). Inductively Coupled Plasma Optical Emission Spectrometry (Icp-Oes): A Powerful Analytical Technique For Elemental Analysis. Food Analytical Methods, 1-23.
[21] Filipiak-Szok, A., Kurzawa, M., & Szłyk, E. (2015). Determination Of Toxic Metals By Icp-Ms In Asiatic And European Medicinal Plants And Dietary Supplements. Journal Of Trace Elements In Medicine And Biology, 30, 54-58.
[22] . Bakircioglu, D., Topraksever, N., & Kurtulus, Y. B. (2014). Determination Of Zinc In Edible Oils By Flow Injection Faas After Extraction Induced By Emulsion Breaking Procedure. Food Chemistry, 151, 219-224.
[23] Fallah, A. A., Saei-Dehkordi, S. S., Nematollahi, A., & Jafari, T. (2011). Comparative Study Of Heavy Metal And Trace Element Accumulation In Edible Tissues Of Farmed And Wild Rainbow Trout (Oncorhynchus Mykiss) Using Icp-Oes Technique. Microchemical Journal, 98(2), 275-279.
[24] Beshaw, T., Demssie, K., Tefera, M., & Guadie, A. (2022). Determination Of Proximate Composition, Selected Essential And Heavy Metals In Sesame Seeds (Sesamum Indicum L.) From The Ethiopian Markets And Assessment Of The Associated Health Risks. Toxicology Reports, 9, 1806-1812.
[25] Uzoekwe, N. M., Ukhun, M. E., & Ejidike, P. P. (2021). Proximate Analysis, Vitamins, Moisture Content And Mineral Elements Determination In Leaves Of Solanum Erianthum And Glyphaea Brevis. Journal Of Chemical Society Of Nigeria, 46(1).
[26] Malede, M., Tefera, M., & Mehari, B. (2020). Trace Metals In The Leaves Of Selected Plants Used To Treat Hepatitis In Dembia, Ethiopia. Journal Of Herbs, Spices & Medicinal Plants, 26(1), 101-112.
[27] Gaetke, L. M., & Chow, C. K. (2003). Copper Toxicity, Oxidative Stress, And Antioxidant Nutrients. Toxicology, 189(1-2), 147-163.
[28] Abbaspour, N., Hurrell, R., & Kelishadi, R. (2014). Review On Iron And Its Importance For Human Health. Journal Of Research In Medical Sciences: The Official Journal Of Isfahan University Of Medical Sciences, 19(2), 164.
[29] Canarium, C. O. O. F. (2015). Applied Research Journal.
[30] Abbas, A., Mahmoud, A., Hamza, Y., & Salim, Y. (2020). Extraction And Physicochemical Characterization Of Seed Oil From Terminalia Mantaly Seed. Int J Res Innov Appl Sci, 60, 64.
[31] Adebayo, S. E., Orhevba, B. A., Adeoye, P. A., Musa, J. J., & Fase, O. J. (2012). Solvent Extraction And Characterization Of Oil From African Star Apple (Chysophyllumalbidum).
[32] Das, M., Das, S. K., & Suthar, S. H. (2002). Composition Of Seed And Characteristics Of Oil From Karingda [Citrullus Lanatus (Thumb) Mansf]. International Journal Of Food Science & Technology, 37(8).
[33] Aoac (2005) Official Methods Of Analysis Of The Association Of Analytical Chemistry International, 18 (Edn). Gaithersburg, Md Usa Official Method 2005.08.
[34] Aoac (1990).Official Methods Of Analysis, Of The Analytical Chemist, (15 Editions). Association Of Official Analytical Chemist Arlington Va, Pp 1058 – 1059.
[35] Abdelmageed, M., Ali, M., Mahmoud, H.A., Aldoma, M., & My, H. (2020). Proximate Composition Of Sudanese Sesamum Indicum L. (White And Brown) Sesame Seeds. 574–577. Https://Doi.Org/10.32474/Aoics.2020.04.000195
[36] Bouzid, H. A., Bijla, L., Ibourki, M., Oubannin, S., Elgadi, S., Koubachi, J., & Gharby, S. (2023). Ziziphus Lotus (L.) Lam. Almonds Nutritional Potential: Evidence From Proximate Composition, Mineral, Antioxidant Activity, And Lipid Profiling Reveals A Great Potential For Valorization. Biomass Conversion And Biorefinery, 1-15.
[37] Thomas, A. Fats And Fatty Oils. In Ullmann's Encyclopedia Of Industrial Chemistry; Wiley: Weinheim, Germany, 2002. [Google Scholar]
[38] Aoac. Official Methods Of Analysis Of The Association Of Official Analytical Chemistry, 14th Ed.; Aoac: Washington, Dc, Usa, 2000. [Google Scholar]
[39] Mohajer, A., Baghani, A. N., Sadighara, P., Ghanati, K., & Nazmara, S. (2020). Determination And Health Risk Assessment Of Heavy Metals In Imported Rice Bran Oil In Iran. Journal Of Food Composition And Analysis, 86, 103384.
[40] Shah, M. A., Manaf, A., Hussain, M., Farooq, S., & Zafar-Ul-Hye, M. (2013). Sulphur Fertilization Improves The Sesame Productivity And Economic Returns Under Rainfed Conditions. Int. J. Agric. Biol, 15(6), 1301-1306.
[41] Nzikou, J. M., Mvoula-Tsiéri, M., Ndangui, C. B., Pambou-Tobi, N. P. G., Kimbonguila,, A., Loumouamou, B., Silou, T. & Desobry, S. (2018) Characterization Of Seeds And Oil Of Sesame (Sesamum Indicum L.) And The Kinetics Of Degradation Of The Oil During Heating. Research Journal Of Applied Sciences, Engineering And Technology, 2(3), 227-232.
[42] Anilakumar, K. R., Pal, A., Khanum, F., & Bawa, A. S. (2010). Nutritional, Medicinal And Industrial Uses Of Sesame (Sesamum Indicum L.) Seeds-An Overview. Agriculturae Conspectus Scientificus, 75(4), 159-168.
[43] Aslam F, Iqbal S, Nasir M, & Anjum Aa (2019). White Sesame Seed Oil Mitigates Blood Glucose Level Reduces Oxidative Stress And Improves Biomarkers Of Hepatic And Renal Function In Participants With Type 2 Diabetes Mellitus White Sesame Seed Oil Mitigates Blood Glucose Level Reduces Oxidative St. J Am Coll Nutr. 38:235–46. Doi: 10.1080/0731572420181500183
[44] Prada, M., Saraiva, M., Sério, A., Coelho, S., Godinho, C. A., & Garrido, M. V. (2021). The Impact Of Sugar-Related Claims On Perceived Healthfulness, Caloric Value And Expected Taste Of Food Products. Food Quality And Preference, 94, 104331.
[45] Irshad, Z., Aamir, M., Akram, N., Asghar, A., Saeed, F., Ahmed, A... & Teferi Asres, D. (2023). Nutritional Profiling And Sensory Attributes Of Sesame Seed-Enriched Bars. International Journal Of Food Properties, 26(2), 2978-2994.
[46] Sheahan, M., & Barrett, C. B. (2014). Understanding The Agricultural Input Landscape In Sub-Saharan Africa. Recent Plot, Household, And Community-Level Evidence.
[47] Ademola, O. A., & Abioye, O. R. (2017). Proximate Composition, Mineral Content And Mineral Safety Index Of Lablab Purpureus Seed Flour. Int J Sci. Health Res, 2(4), 44-50.
[48] Ünal, M. K., & Yalçın, H. (2008). Proximate Composition Of Turkish Sesame Seeds And Characterization Of Their Oils. Grasas Y Aceites, 59(1), 23-26.
[49] Seid, F., & Mehari, B. (2022). Elemental And Proximate Compositions Of Sesame Seeds And The Underlying Soil From Tsegede, Ethiopia. International Journal Of Analytical Chemistry, 2022.
[50] Ebere, C. E., Chukwuemeka, S. I., & Chinedu, E. I. (2019). Proximate And Mineral Composition Of Sesamum Indicum L. Seed. Medicinal & Analytical Chemistry International Journal, 3(4), 152. Https://Doi.Org/10.23880/Macij-16000152
[51] Singharaj, S., & Onsaard, E. (2015). Production And Characteristic Of Sesame Proteins. Journal Of Food Science And Agricultural Technology (Jfat), 1, 188-192
[52] Adebowale, A. A., Sanni, S. A., & Falore, O. A. (2011). Varietal Differences In The Physical Properties And Proximate Composition Of Elite Sesame Seeds.

[53] Bahkali, A. H., Hussain, M. A., & Basahy, A. Y. (1998). Protein And Oil Composition Of Sesame Seeds (Sesamum Indicum, L.) Grown In The Gizan Area Of Saudi Arabia. International Journal Of Food Sciences And Nutrition, 49(6), 409-414.
[54] Ranganayaki, S., Vidhya, R., & Jaganmohan, R. (2012). Isolation And Proximate Determination Of Protein Using Defatted Sesame Seed Oil Cake. International Journal Of Nutrition And Metabolism, 4(10), 141-145.
[55] Sotelo, R., Sofowora,A., Index, E.E.I.J. (2007). Medicinal Plant And Traditional Medicine In African: Spectrum Book Ltd, Nigeria, 25 Pp.
[56] Alozie, Y., Udo, A., & Orisa, C. (2017). Proximate, Anti-Nutrient And Vitamin Composition Of Full-Fat And Defatted Seed Flour Of Telfairia Occidentalis. Turkish Journal Of Agriculture-Food Science And Technology, 5(11), 1256-1260.
[57] Bello, M. O., Falade, O. S., Adewusi, S. R. A., & Olawore, N. O. (2008). Studies On The Chemical Compositions And Anti-Nutrients Of Some Lesser Known Nigeria Fruits. African Journal Of Biotechnology, 7(21).
[58] A Larrauri, J., Goñi, I., Martín Carrón, N., Rupérez, P., & Saura Calixto, F. (1996). Measurement Of Health Promoting Properties In Fruit Dietary Fibres: Antioxidant Capacity, Fermentability And Glucose Retardation Index. Journal Of The Science Of Food And Agriculture, 71(4), 515-519.
[59] Jansen, G. R. (1980). A Consideration Of Allowable Fibre Levels In Weaning Foods. Food And Nutrition Bulletin, 2(4), 1-10.
[60] Gharby, S., Harhar, H., Matthäus, B., Bouzoubaa, Z., & Charrouf, Z. (2016). The Chemical Parameters And Oxidative Resistance To Heat Treatment Of Refined And Extra Virgin Moroccan Picholine Olive Oil. Journal Of Taibah University For Science, 10(1), 100-106.
[61] Betiku, E., Adepoju, T. F., Omole, A. K., & Aluko, S. E. (2012). Statistical Approach To The Optimization Of Oil Extraction From Beniseed (Sesamum Indicum) Oilseeds. Journal Of Food Science And Engineering, 2(6), 351.
[62] Akubugwo Ie, & Ugbogwu Ae (2007). Physicochemical Studies On Oils From Five Selected Nigerian Plant Seeds. Pak. J. Nutr. 6(1):75-78
[63] Codex Alimentarius, (2001). Named Vegetable Oils 8, Codex Standard 210.
[64] Dim, P. E., Adebayo, S., & Musa, J. (2013). Extraction And Characterization Of Oil From Sesame Seed. Research Journal Of Pharmaceutical, Biological And Chemical Sciences, 4(2), 752-757.
[65] Alimentarius, C. (1999). Codex Standard For Named Vegetable Oils. Codex Stan, 210, 1-13.
[66] Lee, S. W., Jeung, M. K., Park, M. H., Lee, S. Y., & Lee, J. (2010). Effects Of Roasting Conditions Of Sesame Seeds On The Oxidative Stability Of Pressed Oil During Thermal Oxidation. Food Chemistry, 118(3), 681-685.
[67] Fallon, S. & M.G. Enig, (2001). Nourishing Traditions. The Cookbook That Challenges Politically Correct Nutrition And The Diet Dictocrats. Revised American 2 Ed., Pp: 40-45.
[68] Raskh, S. (2020). The Importance And Role Of Calcium On The Growth And Development Of Children And Its Complications. International Journal For Research In Applied Sciences And Biotechnology (Ijrasb), 7(6), 162-167.
[69] Liu, J., Huang, F., & He, H. W. (2013). Melatonin Effects On Hard Tissues: Bone And Tooth. International Journal Of Molecular Sciences, 14(5), 10063-10074.
[70] Vogt, A. C. S., Arsiwala, T., Mohsen, M., Vogel, M., Manolova, V., & Bachmann, M. F. (2021). On Iron Metabolism And Its Regulation. International Journal Of Molecular Sciences, 22(9), 4591.
[71] Gebrekidan, A., & Desta, A. A. (2019). Assessment On The Levels Of Selected Essential And Non-Essential Metals In Sesame Seeds (Sesamum Indicum L.) Collected From Sheraro Town, Northwest Tigray, Ethiopia. Bulletin Of The Chemical Society Of Ethiopia, 33(2), 191-202.
[72] Xiang, G., Wen, S., Jiang, X., Liu, X., & He, L. (2011). Determination Of Trace Copper (Ii) In Food Samples By Flame Atomic Absorption Spectrometry After Cloud Point Extraction.
[73] Kheirati Rounizi, S., Akrami Mohajeri, F., Moshtaghi Broujeni, H., Pourramezani, F., Jambarsang, S., Kiani, H., & Khalili Sadrabad, E. (2021). The Chemical Composition And Heavy Metal Content Of Sesame Oil Produced By Different Methods: A Risk Assessment Study. Food Science & Nutrition, 9(6), 2886-2893.
[74] Rai, P. K., Lee, S. S., Zhang, M., Tsang, Y. F., & Kim, K. H. (2019). Heavy Metals In Food Crops: Health Risks, Fate, Mechanisms, And Management. Environment International, 125, 365-385.
[75] Medina-Pizzali, M., Damián-Bastidas, N., & Vargas-Reyes, M. (2019). Arsenic In Baby Foods: Health Effects And Dietary Exposure. Quality Assurance And Safety Of Crops & Foods, 11(4), 369-380.
[76] Mbunga, B. K., Gjengedal, E. L., Bangelesa, F., Langfjord, M. M., Bosonkie, M. M., Strand, T. A & Engebretsen, I. M. (2022). Heavy Metals In Children's Blood From The Rural Region Of Popokabaka, Democratic Republic Of Congo: A Cross-Sectional Study And Spatial Analysis. Scientific Reports, 12(1), 18576.
[77] Who. (2011). Guidelines For Drinking-Water Quality - 4th Ed. World Health Organization.
[78] Okechukwu & Omokpariola, (2024). Pollution Indices And Health Risk Assessment Of Heavy Metal Levels In Oryza Sativa (Rice) Consumed In Southeastern, Nigeria. Chemical Research And Technology, 1(1), 8-15.
[79] Nkansah, M. A., & Amoako, C. O. (2010). Heavy Metal Content Of Some Common Spices Available In Markets In The Kumasi Metropolis Of Ghana. American Journal Of Scientific And Industrial Research, 1(2), 158-163.