



## Studies on Nutritional Profile and Mineral Bioavailability of some Solanum Species Consumed as Fruits in Ekiti State, Nigeria<sup>#</sup>

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### ABSTRACT

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African eggplants are highly valued constituents of the Nigerian food. However, their nutritional potentials have not been fully tapped due to inadequate information on their nutritional and anti-nutritional qualities. This present study investigated the proximate, minerals, anti-nutrient contents as well as the estimation of mineral ratios and Mineral Safety Index of four selected edible solanum species namely, *Solanum anguivi*, *S. gilo*, *S. menalogenia* and *S. aethiopicum*. The proximate contents (%) ranged from 4.19-5.46 (moisture content), 1.71-2.49 (crude fat), 4.57-5.45 (crude ash), 3.76-4.93 (crude protein), 5.20-6.30 (crude fiber) and 77.14-78.58 (carbohydrate). The solanum species were good sources of energy with total metabolizable energy of 1.458MJ-1.484MJ. The four solanum species contained high K, Ca, Mg, low Fe, Mn, Zn and Cu, while amount of Cd, Ni and Pb were very low. The mineral ratios of K/Na, Ca/Mg, Ca/K, Zn/Cu and [K/(Ca+Mg)] were below the minimum good ratios levels of 1.0, 4.17, 4.0, 8.0 and 2.2 respectively which are good for man. The anti-nutrient contents revealed low phytate, oxalate and cyanide levels. The calculated Phytate/Zn, Phytate/Ca and Oxalate/Ca were lower than the threshold levels and would support absorption and bioavailability of Zn and Ca in the samples while that of Phytate/Fe was above the critical value and this indicates unavailability of iron in these eggplant fruits. The mineral differences observed showed that *S. menalogenia* and *S. aethiopicum* had greater minerals while the Mineral Safety Index results revealed that the body could not be overloaded with any of the minerals investigated. The eggplants are rich in fiber, ash, carbohydrate and minerals with moderate protein. The low level of the anti-nutrient is good and poses no deleterious effect when consumed. The eggplants have nutritional health benefits; hence, their consumption should be encouraged to address food insecurity in Nigeria

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## Introduction

Public awareness on the importance of consumption of nutritionally rich food is increasing daily and this led to the increased demand for knowledge on the nutritional profile of fruits and vegetables (Kina et al., 2021; Akgül et al., 2022; Krupodorova et al., 2022). Fruits and vegetables play an important role in human nutrition. They contribute an indispensable constituent of human diet in Africa generally and West Africa in particular (Ezen – Steven et al., 2013). Fruits and vegetables are important sources of vitamins, minerals, fibers and health benefiting phytochemicals. They contain less carbohydrates and protein but are rich in oil, carotene, ascorbic acid, riboflavin, folic acid and macro and micro elements depending on the fruit or vegetable consumed (Fasuyi, 2016). Fruits help in prevention and elucidation of several micronutrient deficiencies in mankind most especially in less developed countries of the world (Oyeyemi et al.,

2015). It has become a general norm that a diet rich in fruits, vegetables, grains and pulses reduces the risk of various diseases (Urugaiaya and Leighton, 2000).

Several studies have reported that vegetarians are less prone to diseases, enjoy longevity, stay healthier and have stronger immunity (Morgra and Rathi, 2013). Several authors have documented the chemical and nutritional health relevance of various fruits and vegetables (Adeleke and Abiodun, 2010; Oyeyemi et al., 2015; Sevindik et al., 2017; Awotodun and Ogunbanwo, 2019; Uysal et al., 2021; Unal et al., 2022). Reports have shown that numerous fruits and vegetables both cultivated and uncultivated (wild) have been utilized by different people at different time in different part of Africa mainly as supplement to conventional foods (Dounon et al., 2012; Addis et al., 2013; Oyeyemi and Tedela, 2014).

Despite an increasing focus on the health benefits of fruits and vegetables, their consumption is below the recommended intake among adults in Nigeria. This may lead to malnutrition, deficiency of minerals, vitamins and Iron in daily diet. Despite the facts that fruits and vegetables play vital roles in man's health by providing the body with needed nutrients and energy, a large percentage of these fruits and vegetables are not fully exploited or are completely neglected. This could lead to local food scarcity especially during seasonal food shortage period and increase the level of malnutrition in rural areas. Hence, there is the need for continuous search for plant foods that could meet the nutritional requirements of man especially the poor rural communities. The research work was therefore carried out to assess the proximate, mineral and anti-nutrient compositions as well as provide information on mineral bioavailability of some edible *Solanum* species fruits.

*Solanum* is a large and widely spread genus of flowering plants that belongs to the family Solanaceae. It has at least 1500 species and not less than 100 indigenous species in Africa. About 25 species have been reported in Nigeria (Gbile and Adesina, 1988) and these include those domesticated with their leaves, fruits or both eaten as vegetables or used in traditional medicine (Edijala et al., 2005). Some of the *Solanum* species consumed but not well utilized in Nigeria include *S. gilo*, *S. aethiopicum*, *S. melongena* and *S. anguivi*.

*Solanum anguivi* Lam. popularly called Africa eggplant or forest bitter berry, is an important but rare medicinal herb found throughout non-arid part of Africa. It grows mostly in the wild, but sometimes as a semi-cultivated vegetable. The domesticated species are consumed as leafy and/or fruit vegetables that are rich in essential minerals and vitamins (Dentol and Nwangburuka, 2011). In South Western part of Nigeria where it is called 'igba yinrin' the fruits of *S. anguivi* is eaten as vegetable because it is believed that it has therapeutic effect in managing hypertension and diabetes (Oyeyemi et al., 2015). The roots can be employed in the treatment of coughs, catarrh, nasal ulcers, asthma, tooth ache, cardiac disorder, nervous disorder and fever (Johnson et al., 2010).

*Solanum melongena* L. is an economic flowering vegetable that belongs to the nightshade family. It is an annual to short-lived perennial plant often much branched, with stems that can become more or less woody. The fruits vary greatly in size and shape and colour. The fruit is edible and widely used because of its many nutritional benefits. The fruit is helpful in preventing and treatment of several diseased conditions as it is effective in the reduction of blood cholesterol levels (Ossamulu et al., 2014b). Other medicinal applications include the use of the roots and fruits as carminative and sedatives, and to treat coelic problems (Ibiam and Nwigwe, 2013). The leaf juice is used to treat uterine complaints and alcoholic extract of leaves as a sedative as well as treating tetanus after abortion (Doganlar et al., 2002).

*S. gilo* L. popularly called scarlet eggplant or bitter brinjal was once treated as a distinct species but now known as a cultivar group of *S. aethiopicum* (Anaso, 1991). The eggplant is commonly found throughout Africa from southern Senegal to Nigeria. The fruits are round at the top and bottoms are flattened out and have grooved

portions (Chinedu et al., 2011). It had been traditionally valued due to its medicinal properties for a very long time (Lalhmingsanga et al., 2018). It is eaten fresh or pureed into juice like a tomato. Fruits possess analgesic, anti-inflammatory, anti-asthmatic and anti-glaucoma properties (Odetola et al., 2004).

*Solanum aethiopicum* L. is commonly called African eggplant or Scarlet eggplant which is widely cultivated in Nigeria and across African continent (Doganlar et al., 2002). The eggplant is a deciduous shrub to perennial or annual herbs that grows up to 200 cm tall, often much branched, branches and leaves with or without prickles and stellate hairs. It is grown as a commercial crop for domestic consumption and also for export (Daunay et al., 2001). The immature fruits of *S. aethiopicum* are used as vegetables in stews and sometimes eaten raw. The leaves and shoots are as cooked as vegetables. It is a delicacy food in the Eastern part of Nigeria where Igbo people traditionally welcome visitors by offering the fruits. The leaves are eaten as leafy vegetables and are actually more nutritious than the fruit. Fruits of bitter cultivars are used as medicine in many African countries. Medicinal applications include the use of the roots and fruits as a carminative and sedative, to treat coelic problems and high blood pressure (Bukanya and Carasco, 1999), leaf juice is used as a sedative to treat uterine complaints, anti-emetic and to treat tetanus after abortion (Ibiam and Nwigwe, 2013).

## Materials and Methods

### Collection and preparation of plant samples

Fresh green fruits of *S. anguivi*, *S. gilo*, *S. melongena* and *S. aethiopicum* were purchased from Oja Oba in Ado Ekiti, Ekiti State. The fruits were identified and authenticated at the Herbarium of the Department of Plant Science and Biotechnology, Faculty of Science, Ekiti State University. The fruits were thoroughly washed with distilled water, cut into slices and air dried for three weeks. The fruits were pulverized using optimal mixer grinder (2053). The powdered samples were stored in air tight plastic containers. All analyses were done in triplicate and results are presented as mean  $\pm$  standard deviation of triplicate determinations.

### Proximate analysis

Proximate composition (moisture content, crude protein, crude fat, ash and crude fiber) were determined using the standard procedure as described by the Association of Official Analytical Chemists (AOAC, 2005). Moisture content was determined by heating 2.0 g of the powdered sample to a constant weight in a crucible placed inside oven at temperature of 105 °C. The dry matter was used in the determination of the other parameters. The crude protein content was calculated by multiplying the total organic nitrogen by 6.25 (AOAC, 2005). Crude fat was obtained by exhaustively extracting 5.0 g of the powdered sample in a Soxhlet apparatus using petroleum boiling range 40-60 °C as the extract. Ash content was determined by incineration of 10.0 g sample placed in a muffle furnace maintained at 550 °C for 5 h. Crude fiber was obtained by digesting 2.0 g of sample with H<sub>2</sub>SO<sub>4</sub> and NaOH and incinerating the residue in a muffle furnace maintained at 550 °C for 5 h. Carbohydrate content

was determined according to Onwuka (2005) calculation equation i.e Available Carbohydrates = (% moisture+ % ash + % protein + % fiber+ crude fiber%). Each analysis was carried out in triplicate.

#### **Determination of the mineral compositions**

The mineral contents Potassium, Calcium, Phosphorus, Sodium, Iron and Magnesium were determined by Atomic Absorption Spectrophotometry after dry ashing of the plant samples. Quantitatively, the sample was transferred into a conical flask and dissolved in 10 mL of 3% ferric chloride and the mixture was heated on a hot plate. The solution was then filtered into a 100 mL flask and made to the mark with distilled water (AOAC, 2005).

#### **Determination of Energy**

Energy was calculated using Atwater factor method as described by Osborne and Voogt (1978). The estimated energy value in the samples in Kilojoule (Kcal/100g) was determined by adding the multiply values for crude fat, crude protein and carbohydrate using the factor (9Kcal, 4Kcal and 4Kcal) respectively. The energy value in Kilojoule was determined by adding the multiply values for crude fat, crude protein and carbohydrate using the factor (37Kcal, 17Kcal and 17Kcal) respectively.

#### **Other calculations**

Mineral ratios (Ca/P, Na/K, Ca/Mg and the millequivalent ratio of  $[K/(Ca + Mg)]$ ) as well as the Mineral Safety Index (MSI) of Na, Mg, P, Ca, Fe and Zn were calculated (Hathcock, 1985).

#### **Determination of some Anti-nutrient substances**

The Oxalate content was determined using High Pressure Liquid Chromatograph (HPLC) methods described by Wilson et al. (1980) while Phytate and Cyanide composition were determined according to methods described by Wheeler and Ferrel (1971) and AOAC (2010) respectively.

#### **Determination of molar ratio of Phytate/Mineral**

The molar ratio of phytate and minerals was determined by dividing the weight of phytate and minerals with its atomic weight (Phytate: 660g/mol.; Oxalate: 88.019g/mol.; Fe: 55.85g/mol.; Zn: 65.38g/mol.; Ca: 40.08g/mol.). The molar ratio between phytate and mineral was obtained after dividing the mole of phytate with the mole of mineral. The [phytate]:[Zn], [phytate]: [Ca], [phytate][Ca]/[Zn], [phytate]:[Fe] and [Oxalate]:[Ca] molar ratios were calculated as previously described by Wyatt and Trang-Tejas (1994); IZINCG (2004).

#### **Determination of molar ratio of Oxalate/Minerals**

The molar ratio of oxalate and minerals was determined by dividing the weight of oxalate and minerals with its atomic weight. The molar ratio between oxalate and mineral was then obtained after dividing the mole of oxalate with the mole of mineral.

#### **Mineral bioavailability**

Molar ratios of anti-nutrient/mineral were used to predict the mineral bioavailability (Morris and Ellis, 1989). The suggested critical values used to predict the

bioavailability were Phytate: Calcium < 0.5, Phytate: Iron > 1, Phytate: Zn > 15, Oxalate: Calcium > 1 and Phytate: Calcium/Zinc > 0.5 (Morris and Ellis, 1989; Hallberg et al., 1989).

#### **Statistical data analysis**

Descriptive statistics (mean, standard deviation and coefficient of variation) were determined (Chase, 1976) and all data were subjected to Chi-square ( $\chi^2$ ) test to determine significant differences among the results obtained (Oloyo, 2001).

#### **Results and discussion**

Nutrients are the substances found in food which drive biological activity and are essential for the human body (Pehlivan et al., 2021; Mohammed et al., 2022). The nutritional benefits that can be derived from any food material can be measured by the proximate estimation of the food. Table 1 depicts the proximate estimation of the four selected solanum species in Ekiti State. The result showed that the moisture content ranged from 4.19% in *S. aethiopicum* to 5.46% in *S. anguivi*. The proximate composition of the four studied Solanum species revealed that they contained low moisture content. The results obtained in this present study were low compared to the previous reports of Chinedu et al. (2011) for *S. aethiopicum* (88.73%) and sweet *S. macrocarpon* (96.61%). The moisture content is a parameter that can be used to predict the stability and susceptibility of materials to microbial attack. High moisture content could lead to high microbial decomposition while low moisture could promote longevity and storage stability. However, low moisture content observed in the four edible Solanum species could prevent microbial spoilage hence allow a long shelf life for the eggplants. The values of the crude fat reported in this work were low and compared favourably with the values of 1.97% and 2.32% for *Synsepalum dulcificum* (Schumach & Thorn Daniell) leaves and fruits respectively (Awotedu and Ogunbanwo, 2019). Albeit, the values of our findings were lower than the values (7.30-8.90%) for raw and processed *Solanum incanum* (Auta et al., 2011).

The crude fat content ranged from 1.71% to 2.49%, ash from 4.57 to 5.45%, crude fiber ranged from 5.20 to 6.30%, crude protein ranged from 3.76 to 4.93% and carbohydrate ranged from 77.14 to 78.58%. The result also revealed that there was no significant difference among all the proximate parameters at  $\chi^2_{tab.0.05}$ . The low crude fat contents in the garden egg fruits are in accordance with the general submission that vegetables are low lipids containing foods (Linta, 1992). The result is advantageous and the fruits can therefore be recommended as part of weight reducing diets. The results of crude fiber in our finding revealed that the four solanum species have moderate concentration of crude fiber and the contents were higher than 1.02% reported for *Cucumis sativum* fruit (Agatemor et al., 2018). Dietary fiber in food can be employed in the treatment of gastro intestinal problems such as constipation by overcoming the hypotonic (Yohanna, 2013) and diarrhea. The eggplant fruits are good source of fiber which supports the local assertion that garden egg fruits are fibrous fruits that help in proper digestion and control of bowel movement.

Table 1. Proximate Composition of four edible Solanum species in Ekiti State, Nigeria

| Parameter     | Samples |       |       |       | Mean  | S.D  | CV%   | Min (x) | Max (x) | $\chi^2_{cal.0.05}$ | Remark |
|---------------|---------|-------|-------|-------|-------|------|-------|---------|---------|---------------------|--------|
|               | SA      | SM    | SG    | ST    |       |      |       |         |         |                     |        |
| Moisture      | 5.46    | 4.86  | 5.09  | 4.19  | 4.90  | 0.53 | 10.81 | 4.19    | 5.46    | 0.1746              | NS     |
| Crude Fat     | 1.83    | 2.42  | 1.71  | 2.49  | 2.11  | 0.39 | 18.48 | 1.71    | 2.49    | 0.2267              | NS     |
| Crude Fiber   | 5.20    | 6.08  | 6.01  | 6.30  | 5.89  | 0.48 | 8.15  | 5.20    | 6.30    | 0.1179              | NS     |
| Crude Protein | 4.29    | 4.93  | 3.85  | 3.76  | 4.21  | 0.53 | 12.62 | 3.76    | 4.93    | 0.2035              | NS     |
| Ash           | 4.64    | 4.57  | 5.17  | 5.45  | 4.96  | 0.42 | 8.47  | 4.57    | 5.45    | 0.1086              | NS     |
| Carbohydrate  | 78.58   | 77.14 | 78.17 | 77.36 | 77.81 | 0.68 | 0.87  | 77.14   | 78.58   | 0.0176              | NS     |

SA: *S. anguivi*, SM: *S. melanogena*; SG: *S. gilo*; ST: *S. aethiopicum*; Chi-square ( $\chi^2$ ) at  $p=0.05$ ,  $v=n-1=3$  critical value = 7.81, NS= results not significantly different, Standard deviation (SD), Coefficient of variation per cent (CV%)

Table 2. Proportion of contribution from Fat, Protein and Carbohydrate to total Energy

| Parameter        | <i>S. anguivi</i> | <i>S. melanogena</i> | <i>S. gilo</i>   | <i>S. aethiopicum</i> | Mean     | SD    | CV%   |
|------------------|-------------------|----------------------|------------------|-----------------------|----------|-------|-------|
| Total energy     |                   |                      |                  |                       |          |       |       |
| (E in kJ/100g)   | 1,475.86          | 1,484.73             | 1,458.72         | 1,471.17              | 1,472.62 | 10.84 | 0.74  |
| (E in kcal/100g) | 347.97            | 350.06               | 342.47           | 346.87                | 347.10   | 2.75  | 0.79  |
| PEF %            |                   |                      |                  |                       |          |       |       |
| (E in kJ/100g)   | (4.59)* 67.71**   | (6.03) 89.54         | (4.41) 64.38     | (6.26) 92.13          | 78.44    | 14.41 | 18.37 |
| (E in kcal/100g) | (4.73) 16.47      | (6.22) 21.78         | (4.49) 15.39     | (6.46) 22.41          | 19.01    | 3.59  | 18.88 |
| PEP %            |                   |                      |                  |                       |          |       |       |
| (E in kJ/100g)   | (4.90) 72.29      | (5.64) 83.81         | (4.49) 65.45     | (4.35) 63.92          | 71.36    | 9.05  | 12.68 |
| (E in kcal/100g) | (4.93) 17.16      | (5.63) 19.72         | (4.50) 15.40     | (4.35) 15.04          | 16.83    | 2.14  | 12.72 |
| PEC %            |                   |                      |                  |                       |          |       |       |
| (E in kJ/100g)   | (90.51) 1,335.86  | (88.32) 1,311.38     | (91.10) 1,328.89 | (89.39) 1,315.12      | 1,322.81 | 11.50 | 0.87  |
| (E in kcal/100g) | (90.33) 314.32    | (88.14) 308.56       | (91.30) 312.68   | (89.21) 309.44        | 311.25   | 2.71  | 0.87  |
| UEDP %           |                   |                      |                  |                       |          |       |       |
| (E in kJ/100g)   | 43.37             | 50.29                | 39.27            | 38.35                 | 42.82    | 5.44  | 12.70 |
| (E in kcal/100g) | 10.30             | 11.83                | 9.24             | 9.02                  | 10.10    | 1.28  | 12.67 |

\*values in bracket indicate the % proportion while \*\* values indicate the proportion contribution from fat, protein and carbohydrate to total energy, Standard deviation (SD), Coefficient of variation per cent (CV%), PEF = proportion of total energy due to fat, PEP = proportion of total energy due to protein, PEC = proportion of total energy due to carbohydrate, UEDP = utilization of 60% of PEP %.

The solanum fruits contained reasonable level of crude protein when compared with some leafy vegetables consumed in Nigeria. The crude protein contents were higher than 1.82%, 2.62% and 2.86% reported for *Talinum triangulare*(Jacq.), *Ocimum gratissimum*(Linn.) and *Murraya koenigii* (L.) respectively (Idoko et al., 2014). However, the values compared favourably with crude protein contents in *Myriathus arboreus* (P.Beauv.) (4.20%) and *Spargonophorus spargonophora* (Linn.) (3.56%) reported by Oyeyemi et al. (2014). Proteins are essential nutrients for human body. Protein helps to supplies adequate amounts of amino acids for immune functions, maintaining strong muscle and repair of body tissues (Pugalethi et al., 2004). Deficiency of protein can lead to decreased immunity, digestive problems, growth retardation in children, lower mental alertness and many other health issues. The carbohydrate contents in the studied solanum species were high. The values were relatively higher than the values reported by Ladi et al. (2016) for some leafy vegetables native to Igala Kingdom, Kogi State, Nigeria. The eggplants meet carbohydrate content of 60-75% as recommended by CODEX CAC/ GL (1991). Hence, the eggplants fruits are carbohydrate rich food.

The proportion percentage contribution from crude fat, crude protein and carbohydrate to total energy content in the four *Solanum* species is represented in Table 2. Highest

total energy (1,484.73kJ/100g) was obtained in *S. melanogena* while the least value was obtained in *S. gilo* (1,458.73kJ/100g) with low CV% of 0.74. PEF% (kJ/100g) ranged from 92.13 to 64.38, PEP% (kJ/100g) ranged from 63.92 to 83.81, PEC% value ranged from 1,311.38 to 1,335.86 while UEDP% in kJ/100g ranged from 38.25 to 50.29. The results revealed that the solanum species are energy rich fruits.

The result of the mineral composition (mg/kg) revealed Na (59.40 - 74.45), K (85.55 - 125.30), Ca (25.60 - 37.12), Mg (36.58 - 44.11), Fe (0.85 - 1.31), Mn (0.418 - 0.624), Zn (1.70 - 2.10), Cu (0.324 - 0.414) while Cd, Ni and Pb were present in low concentrations. However, Pb was not found in *S. aethiopicum* (Fig. 1-3). Na, K, Ca and Mg (major essential minerals) are minerals of major significant and are adequately present in all the garden egg fruits investigated. Fe, Mn, Zn and Cu, (trace minerals) were present in low quantities while toxic/ non-essential minerals (Pb, Ni and Cd) were found in very low quantities that are below permissible toxic level. These major and minor minerals play significant roles in human diet. Potassium (K) is commonly found in a variety of unrefined foods, especially fruits and vegetables. It is necessary for the normal functioning of all cells (WHO, 2003). It regulates the heartbeat and ensures proper functioning of the muscle and nerves. Human needs calcium to build and maintain strong bones. It equally helps in blood clot,

muscles contract and regulates the heart's rhythm (Pravina et al., 2013). Magnesium (Mg) is an electrolyte that affects heart health, muscle function and strengthen bone and protect bone against osteoporosis (Castiglioni et al., 2013). Iron (Fe) plays significant role in hemoglobin boosting, reduces fatigue, improve muscle endurance and boost immunity. Zinc (Zn) supports a number of functions such as DNA synthesis, immune function metabolism and growth. Copper (Cu) plays an important role in maintaining collagen and elastin, which are major structural components of our body. It acts as a cofactor for several enzymes. Cu plays vital role in iron metabolism, connective tissue synthesis and neurotransmitter synthesis (Collin, 2014).

The calculated mineral ratios of the four garden eggs fruits as shown in Table 3 revealed that K/Na (1.44-1.68), Fe/Cu (2.62-3.16), Fe/Pb (60.71-108) and Ca/Pb (2107.1-1560.0) were above the minimum good ratio level of 0.5, 0.9, 4.4 and 84 while other calculated mineral ratios were below the good values. The ratios of the minerals are often considered as more important than the mineral levels. The selected mineral ratios revealed important balance between these elements as well as avail information on the possible factors that could arise due to disruption of their relationships. Such disruption may affect disease state, physiological and developmental factors, the effects of diet and drugs (Watt, 2010). The Na/K ratios in this study fall within the standard value of 0.6. Nieman et al. (1992) reported that in order to avoid hypertension, the ratio of Na/K in food material should be about 0.6. Similarly, FAO/WHO (2016) recommended Na/K ratio of less than 1 as favourable ratio to control high blood pressure. This implies that the results fall within a ratio that would probably not promote the development of high blood pressure when consumed by human being. Ca/Mg ratio helps in regulating blood sugar. The mineral ratios of Ca/Mg in this present study were low and advantageous. Magnesium deficiency and or a high Ca/Mg ratio result in the release of too much insulin which leads to a drop in blood sugar. Fe/Cu ratios were higher than recommended value (0.9). This high level is as a result of high level of Fe against low level of Cu. The mineral ratios of Na/Mg, Ca/K, Zn/Cu and milliequivalent ratio of [K]/(Ca + Mg) are

within the standard values in the samples. Similarly, Ca/Pb and Fe/Pb were relatively higher than the recommended levels. Very low level of Pb in the garden egg fruits is cheering since Pb is not biochemically useful to man (Olaleye et al., 2017). Lead toxicity increases blood enzyme levels and reduces protein synthesis (Yuan et al. 2015). It can also impose toxic effects in kidneys, nervous, cardiovascular and reproductive systems (Carocci et al. 2016). These relationships are most apparent in a hair mineral analysis.

The summary of the result of the anti-nutrient content and molar ratio of the Solanum species was given in Table 4. The result showed moderate phytate, oxalate and cyanide contents while calculated molar ratio for [Phy]/[Zn] ranged from 1.65 to 1.09, [Phy]/[Ca] had 0.04 to 0.083, [Phy]/[Fe] varied from 1.38 to 2.12 and [Phy]/[Ca]/[Zn] ranged from 0.57 to 0.90 and [Oxa]/[Ca] ranged from 0.422 to 0.516. Anti-nutrient factors affect the bioavailability of proteins, vitamins, minor minerals as well as major minerals in food and hence decrease its nutritive value (Eltayeb et al., 2007). The phytate contents in the eggplants investigated were lower than 66.4, 84.96 and 394.0mg/100g previously reported for Indian rice (Brand A) wheat flour and Oat cereal (Norhaiz and Nor Faizadatul Ain, 2009). Phytate has been reported to inhibit digestive enzymes like pepsin, trypsin and amylase (Kumar and Becker, 2010). However, phytic acid at low concentration has now been considered to possess biological activities like antioxidant, anti-carcinogenic and hypoglycemic activities (Ferguson et al., 2001). The oxalate contents compared favourably with the values (31.5mg/100g) reported for oxalate content in the leaves of *Synsepalum dulcificum* (Awotedu and Ogunbanwo, 2019). The oxalate intake should be less than 40-50mg per day as recommended by the American Dietetic Association (2005) for someone suffering from kidney stone problem. The oxalate contents in the four solanum were below the permissible level of 40-50mg/day. The cyanide contents in the solanum species were low and could not pose any health problem to the consumers when taken in moderate quantity. ACGIH (2001) reported that 80% of the absorbed cyanide is detoxified in the liver by the enzyme rhodanase and excreted from the urine.

Table 3. Calculated mineral ratios of the four edible Solanum species

| Mineral ratio | Standard | Sample |        |       |       | Mean   | SD     | CV%   | $\chi^2$ | Remark |
|---------------|----------|--------|--------|-------|-------|--------|--------|-------|----------|--------|
|               |          | SAG    | SME    | SGL   | SAE   |        |        |       |          |        |
| Na/K          | 0.6      | 0.62   | 0.59   | 0.69  | 0.65  | 0.64   | 0.04   | 6.25  | 0.0859   | NS     |
| K/Na          | 0.5      | 1.61   | 1.68   | 1.44  | 1.54  | 1.57   | 0.10   | 6.37  | 0.0201   | NS     |
| Ca/Mg         | 1.0      | 0.79   | 0.84   | 0.67  | 0.79  | 0.77   | 0.07   | 9.09  | 0.0251   | NS     |
| Na/Mg         | 4.17     | 1.85   | 1.69   | 1.62  | 1.60  | 1.69   | 0.11   | 6.50  | 0.0228   | NS     |
| Ca/K          | 4.0      | 0.26   | 0.29   | 0.29  | 0.32  | 0.29   | 0.02   | 6.89  | 0.0621   | NS     |
| [K]/(Ca+Mg)]  | 2.2      | 1.67   | 1.54   | 1.38  | 1.37  | 1.49   | 0.14   | 9.39  | 0.0412   | NS     |
| Zn/Cu         | 8.0      | 5.25   | 4.98   | 5.19  | 5.32  | 5.13   | 0.12   | 2.34  | 0.0149   | NS     |
| Fe/Cu         | 0.9      | 2.62   | 3.16   | 2.67  | 2.67  | 2.78   | 0.25   | 8.99  | 0.0698   | NS     |
| Ca/Pb         | 84       | 2107.1 | 2183.5 | 2560  | 0     | 1712.7 | 1158.8 | 67.66 | 639.41   | S      |
| Fe/Pb         | 4.4      | 60.71  | 77.06  | 108   | 0     | 61.44  | 45.41  | 67.39 | 39.26    | S      |
| Zn/Cd         | 500      | 94.4   | 98.09  | 161.5 | 132.1 | 121.5  | 31.59  | 26.0  | 24.65    | S      |

Chi-square ( $\chi^2$ ) at  $p=0.05$ ,  $v_{n-1=3}$  critical value = 7.81, S=results significantly different, NS=results not significantly different, Standard deviation (SD), Coefficient of variation per cent (CV%), SAG - *S. anguivi*, SME - *S. melanogena*, SGL - *S. gilo*, SAE - *S. aethiopicum*.

Table 4. Anti-nutrient Composition (mg/100g), Calculated [Phy]/[Zn], [Phy]/[Ca], [Phy/Fe] and [Ca][Phy]/[Zn] Molar ratios of four edible Solanum species in Ekiti State

| Parameter      | SAG   | SME   | SGL   | SAE   | Mean  | SD    | CV%   | Ideal value |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------------|
| Phytate        | 21.25 | 26.30 | 18.90 | 15.50 | 20.49 | 4.53  | 22.11 | -           |
| Oxalate        | 33.50 | 37.05 | 24.30 | 29.70 | 31.14 | 5.45  | 17.50 | -           |
| Hydrocyanide   | 8.55  | 10.68 | 6.62  | 5.18  | 7.78  | 2.38  | 30.59 | -           |
| Ca             | 29.50 | 37.12 | 25.60 | 32.01 | 31.06 | 4.82  | 15.52 | -           |
| Fe             | 0.85  | 1.31  | 1.08  | 0.93  | 1.04  | 0.20  | 19.23 | -           |
| Zn             | 1.70  | 2.06  | 2.10  | 1.85  | 1.93  | 0.18  | 9.33  | -           |
| [Phy]/[Zn]     | 1.23  | 1.26  | 0.89  | 0.83  | 1.05  | 0.22  | 20.95 | >15         |
| [Phy]/[Ca]     | 0.43  | 0.043 | 0.045 | 0.028 | 0.137 | 0.195 | 142.3 | <6          |
| [Phy][Ca]/[Zn] | 0.90  | 1.17  | 0.57  | 0.66  | 0.825 | 0.26  | 31.52 | >0.5        |
| [Phy]/[Fe]     | 2.11  | 1.70  | 1.50  | 1.41  | 1.68  | 0.31  | 18.45 | >1          |
| [Oxa][Ca]      | 0.516 | 0.454 | 0.422 | 0.422 | 0.454 | 0.044 | 9.69  | 1           |

Standard deviation (SD), Coefficient of variation per cent (CV%), SAG - *S. anguivi*, SME - *S. melanogena*, SGL - *S. gilo*, SAE - *S. aethiopicum*.

Table 5. Mineral differences (mg/100g) of four edible Solanum species in Ekiti State

| Parameter | <i>S. anguivi</i> /<br><i>S. melanogena</i> |        | <i>S. anguivi</i> /<br><i>S. gilo</i> |        | <i>S. anguivi</i> /<br><i>S. aethiopicum</i> |        | <i>S. melanogena</i> /<br><i>S. gilo</i> |        | <i>S. melanogena</i> /<br><i>S. aethiopicum</i> |        | <i>S. gilo</i> /<br><i>S. aethiopicum</i> |        |
|-----------|---|--------|---------------------------------------|--------|--|--------|--|--------|---|--------|---|--------|
|           | Diff.                                       | %diff. | Diff.                                 | %diff. | Diff.  | %diff. | Diff.                                    | %diff. | Diff.   | %diff. | Diff.                                     | %diff. |
| Na        | -5.05                                       | -7.27  | 10.0                                  | 14.41  | 5.20   | 7.49   | 15.05                                    | 20.22  | 10.25   | 13.76  | -4.8                                      | -8.08  |
| K         | -13.40                                      | -11.97 | 26.35                                 | 23.55  | 13.15  | 11.75  | 39.78                                    | 31.72  | 26.55   | 21.19  | -13.2                                     | -15.42 |
| Ca        | -7.62                                       | -28.83 | 3.90                                  | 13.22  | -2.51  | -8.50  | 11.52                                    | 31.03  | 5.11  | 13.76  | -6.41                                     | -25.04 |
| Mg        | -6.53                                       | -17.38 | 1.00                                  | 2.66   | -2.67  | -7.11  | 7.53                                     | 17.07  | 3.86  | 8.75   | -3.67                                     | -10.03 |
| Mn        | -0.57                                       | -113.8 | 0.08                                  | 16.56  | -0.21  | -4.19  | 0.21                                     | 33.65  | 0.01  | 1.60   | -0.104                                    | -24.88 |
| Fe        | -0.46                                       | -54.11 | -0.23                                 | -27.06 | -0.08  | -9.41  | 0.23                                     | 17.55  | 0.38  | 29.0   | 0.15                                      | 15.0   |
| Zn        | -0.36                                       | -21.18 | -0.40                                 | -23.53 | -0.15  | -8.82  | -0.04                                    | -1.94  | 0.21  | 10.19  | 0.26                                      | 11.91  |
| Cu        | -0.09                                       | -27.78 | -0.08                                 | -25.0  | -0.024                                       | -7.41  | 0.009                                    | 2.17   | 0.014   | 15.94  | 0.057                                     | 14.07  |

Table 6. Mineral Safety Index (MSI) of Na, Mg, Ca, Fe, Zn, Cu

| Sample | Na  |       |       | Mg |       |       | Ca |      |      | Fe  |       |      | Zn |      |       | Cu |       |       |
|--------|-----|-------|-------|----|-------|-------|----|------|------|-----|-------|------|----|------|-------|----|-------|-------|
|        | TV  | CV    | D     | TV | CV    | D     | TV | CV   | D    | TV  | CV    | D    | TV | CV   | D     | TV | CV    | D     |
| SAG    | 4.8 | 0.67  | 4.13  | 15 | 1.41  | 13.59 | 10 | 0.25 | 9.75 | 6.7 | 0.38  | 6.32 | 33 | 3.74 | 29.26 | 33 | 3.56  | 29.4  |
| SME    | 4.8 | 0.72  | 4.08  | 15 | 1.65  | 13.35 | 10 | 0.31 | 9.69 | 6.7 | 0.59  | 6.11 | 33 | 4.53 | 28.47 | 33 | 4.55  | 28.45 |
| SGL    | 4.8 | 0.57  | 4.23  | 15 | 1.37  | 13.63 | 10 | 0.21 | 9.79 | 6.7 | 0.48  | 6.22 | 33 | 4.62 | 28.38 | 33 | 4.46  | 28.54 |
| SAE    | 4.8 | 0.62  | 4.18  | 15 | 1.51  | 13.49 | 10 | 0.27 | 9.73 | 6.7 | 0.42  | 6.28 | 33 | 4.07 | 28.93 | 33 | 3.83  | 29.17 |
| Mean   | -   | 0.645 | 4.16  | 15 | 1.49  | 13.52 | -  | 0.26 | 9.74 | -   | 0.47  | 6.23 | -  | 4.24 | 28.76 | -  | 4.10  | 28.89 |
| SD     | -   | 0.065 | 0.064 | -  | 0.124 | 0.125 | -  | 0.04 | 0.04 | -   | 0.09  | 0.09 | -  | 0.41 | 0.41  | -  | 0.48  | 0.467 |
| CV%    | -   | 10.08 | 1.54  | -  | 8.34  | 0.92  | -  | 15.4 | 0.41 | -   | 19.27 | 1.46 | -  | 9.66 | 1.41  | -  | 11.91 | 1.67  |

CV = calculated value, TV = Table value (TV of MSI), D = difference, RAI = recommended adult intake, Standard deviation (SD), Coefficient of variation per cent (CV%), No standard for K, Mn and Pb; SAG - *S. anguivi*, SME - *S. melanogena*, SGL - *S. gilo*, SAE - *S. aethiopicum*.

Bioavailability is the proportion of the total amount of mineral element that is potentially absorbable in a metabolically active form (Simic et al., 2009). The absorption and bioavailability of Fe, Zn, and Ca in the human body can be predicted by calculating molar ratios of phytate to mineral (Luo et al., 2009). Mineral bioavailability can be affected by phytate content, which may in turn lead to mineral deficiencies. A phytate to Zn molar ratio (Phy: Zn) higher than 15 associated with low Zn bioavailability and Phy: Zn within the range of 5 to 15 and less than 5 is associated with moderate and high estimated bioavailability, with a Zn absorption corresponding to 15%, 30% and 50% respectively (Magallanes-Lopez et al., 2017). The result of Phy: Zn in this study was less than 15 which implies Zn bioavailability cannot be impaired by phytate level in the studied solanum fruits. Ca absorption can be impaired by a molar ratio of phytate to calcium (Phy: Ca) above 0.17 (Sardberg and Swanberg, 1997). The Phy: Ca molar ratio was below the

threshold of 0.17 for all the solanum species except *S. anguivi* (Table 4). This implies that the bioavailability of Ca is not affected by phytic acid in the fruits. The Phy: Ca molar ratios results in this present work were in tandem with the previous studies of Amos et al. (2020) in some commonly consumed staple cereal food in Zaria, Nigeria. High Ca content in food could cause negative effect of phytate on Zn absorption. A molar ratio of phytate calcium to zinc (Phy x Ca / Zn) has been suggested as a better predictor of Zn absorption (Ellis et al., 1987). In the report of Davis and Warrington (1986), it was noted that if the molar ratio of [Phy][Ca]/[Zn] is greater than 0.5mol/kg there would be interference with the availability of Zn. However, the results of [Phy][Ca]/[Zn] molar ratio in our research work were greater than ideal value of > 0.5 suggesting that Ca interference was more likely to affect Zn bioavailability. The Phy: Fe molar ratios reported in this study were greater than 0.4 which indicated poor iron bioavailability for all the Solanum species analyzed. The

bioavailability of Ca could be equally affected by the oxalate content in food. Oxalate bind to minerals such as Ca and Fe to form Calcium oxalate and Iron oxalate respectively preventing the body from absorbing beneficial nutrient in the digestive tract especially when taken in high concentration. High oxalate foods may increase the risk of kidney stones and other health related problems. The oxalate: Calcium molar ratios of the four *Solanum* were below the critical value of 1 suggesting that they would promote Ca availability in the eggplant fruits.

The result of the calculated mineral ratio differences of the garden eggs (Table 5) indicated that there were greater values of Ca, Mg, Mn, and Cu in *S. melanogena* and *S. aethiopicum* compared to *S. anguivi*. The results equally revealed that seven minerals (Na, K, Ca, Mg, Fe, Mn and Cu) had greater values (mineral difference) in *S. melanogena*. The mineral differences are in order of *S.*

*melanogena* > *S. anguivi* (8 minerals), *S. anguivi* > *S.gilo* (5minerals), *S. aethiopicum* > *S. anguivi* (7 minerals), *S. melanogena* > *S.gilo* (7 minerals). In summary, *S. melanogena* fruits were richer in both macro and micro nutrients followed by *S. aethiopicum* while *S. anguivi* has the least mineral element. Comparatively, *S. menalogena* and *S. aethiopicum* could be recommended as the best eggplant richer in mineral contents. Table 6 contained the mineral safety index of the garden egg samples. All the values were below the tabulated values. The Mineral Safety Index values in all the samples gave positive differences which mean that the minerals might not cause mineral overloading or become toxic to the consumers of these garden eggs. The very low level of Cu is desirable and could not impair the metabolism of Fe, Zn and Mn in the body when consumed.



Plate. 1. Pictures of the four *Solanum* species investigated

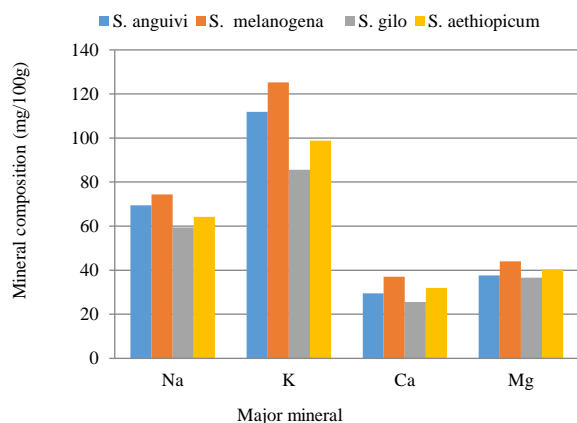


Figure 1 Major mineral composition (mg/100g) of four edible *Solanum* species

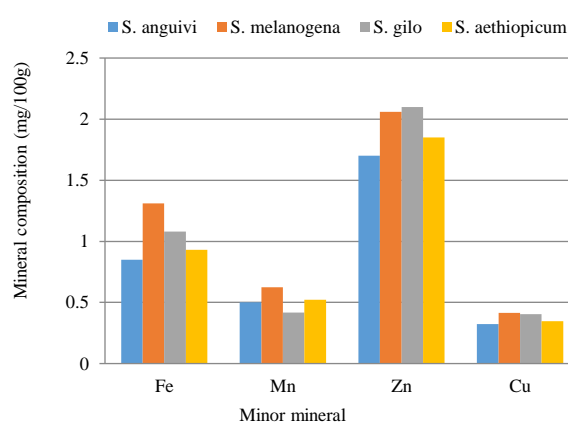


Figure 2. Minor mineral composition (mg/100g) of four edible *Solanum* species

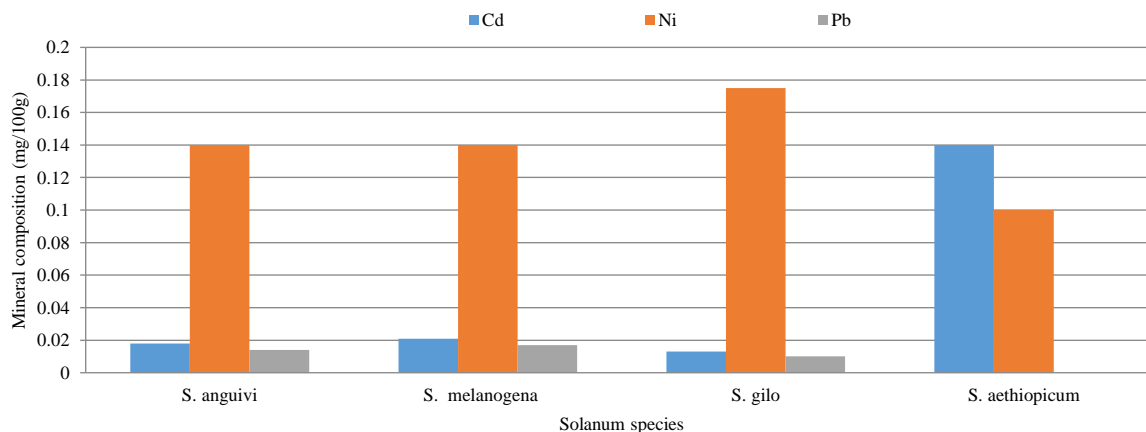


Figure 3 Non-essential mineral composition (mg/100g) of four edible *Solanum* species



## Conclusion

Studies on the nutritional and anti-nutritional profiles of the four edible eggplants have established the rich nutritional values and safety consumption of the *Solanum* species. The eggplants are rich sources of bioavailable Ca, Zn, crude fiber, ash and carbohydrate with moderate amount of crude protein. Their mineral ratios and anti-nutrient factors are below the permissible level which implies that their consumption would not cause ill health to man. The Mineral safety index of the fruits is good and cannot cause mineral loading in the body. The result has suggested that the eggplants are nutritionally rich and when consumed in sufficient amount would contribute to nutritional requirements and health management of man. Hence, their cultivation and consumption should be encouraged.

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