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Heavy Metal and Anti-Nutrient Profile of *Solanum melongena* and *Solanum gilo*: Implications for Animal Health and Skin Quality

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ABSTRACT :

This study assessed the heavy metal and anti-nutrient composition of Solanum melongena and Solanum gilo and their implications for animal health and skin quality, and leather production. This study comparatively evaluated the anti-nutritional factors and heavy-metal concentrations of two commonly consumed garden-egg varieties, Solanum melongena (sweet) and Solanum gilo (bitter), obtained from Zaria metropolis, Kaduna State, Nigeria. Fresh fruit samples were collected, authenticated, and analysed using standard laboratory procedures. Anti-nutrient analysis showed higher tannin (4.11 mg/g), glycoside (6.48 mg/g), oxalate (5.67 mg/g), and phytate (4.46 mg/g) levels in S. melongena, while saponin content was markedly higher in S. gilo (11.50 mg/g). Heavy-metal analysis revealed lead (1.80 and 1.35 mg/kg) and cadmium (0.125 and 0.080 mg/kg) levels in S. melongena and S. gilo, respectively, exceeding FAO/WHO limits, whereas copper and arsenic were within permissible ranges. The study concludes that although both varieties are nutritionally valuable, elevated lead and cadmium levels pose potential public health risks. The findings suggest that S. melongena and S. gilo have potential as feed and industrial resources, but require careful monitoring and processing to minimise harmful effects and optimise their safe use in agriculture and leather industries.

Key Words: *Solanum spp*, Heavy metals, Anti-Nutrients, Animal feed, Leather production

INTRODUCTION

The plant genus Solanum has approximately 1,000 species worldwide, and Solanum species (eggplants) are members of the Solanaceae family. About 25 species, including domesticated ones, are found in Nigeria; their leaves, fruits, or both are consumed as vegetables or utilised in traditional medicine (Bonsu *et al.,* 2008). In Nigeria, people refer to them as "garden eggs" and go by the names gauta in Hausa, afufa or anara in Igbo, or igba in Yoruba. According to Rushton, all eggplants are members of the scientific order Polemoniaries and family Solanaceae, also known as the nightshade (Laudeman *et al.,* 2008). According to historical data presented by certain writers, the cultivation of eggplant started in India but was first widely grown in China (Akin-Osanaiye *et al.,* 2004). According to studies, eggplant is one of the top ten food sources in the world for health (Caguiat and Hautea, 2014). Due to its widespread use, eggplant is referred to as the king of vegetables in India, South Africa, Malaysia, and Singapore (Bhaskar and Ramesh, 2015).

Solanum melongena and *Solanum gilo* are widely cultivated and consumed in Nigeria, serving as both food and potential livestock feed. Their use in animal nutrition, however, requires careful evaluation of safety parameters such as heavy metal residues and anti-nutrient content, which can influence animal health, productivity, and product quality (Adeleye, 2002). Heavy metals like lead, cadmium, and chromium, when present in feeds, can accumulate in animal tissues, affecting hide and skin quality and posing risks to leather processing (Khan, 2008). Similarly, anti-nutrients such as tannins, phytates, and oxalates can interfere with nutrient absorption, impacting growth and overall animal performance (Soetan & Oyewole, 2009).

Antinutritional factors are primarily associated with compounds or substances of natural or synthetic origin, which interfere with the absorption of nutrients, and act to reduce nutrient intake, digestion, and utilisation, and may produce other adverse effects. Beyond food and feed, phytochemicals and mineral elements in garden eggs may have implications for hide and leather quality. Tannins, for example, are known for their protein-binding properties, which can enhance collagen stability and improve leather tanning efficiency (Kundu, 2019). Understanding the balance between beneficial phytochemicals and potentially harmful heavy metals or anti-nutrients is therefore essential for determining the suitability of *S. melongena* and *S. gilo* in animal feed and leather production.

Antinutrients can reduce the bioavailability of important nutrients or pose health concerns when consumed in excessive amounts. On the other hand, *Heavy-metal contamination* has become an increasing concern in vegetables cultivated in urban and peri-urban areas. Given such concerns, a comparative assessment of the anti-nutritional factors and heavy-metal levels of *S. melongena* and *S. gilo* within Zaria metropolis is essential. This study aims to assess the heavy metal and anti-nutrient profile of *Solanum melongena* and *Solanum gilo* grown in Zaria metropolis and to evaluate their implications for animal feed safety, quality hide and skin, and the leather industry.

MATERIALS AND METHODS

Sample Collection and Preparation

Fresh samples of Solanum melongena and Solanum gilo were bought within Zaria metropolis, and taken to the Department of Botany, Ahmadu Bello University (ABU) Zaria, for identification and were properly labelled thereafter. They were washed with distilled water to remove all unwanted particles. The fruits were diced and air-dried. The air-dried samples were pulverised using an electric grinder. The powders were stored in air-tight container in refrigerator for heavy metals and antinutrients analyses.

ANTI-NUTRIENTS DETERMINATION

Tannin, oxalate and phytate were determined by the methods described by Kingsley, (2019).

Determination of tannin (Folin-Denis spectrophotometric method)

A measured weight of each sample (1.0 g) was dispersed in 10 mL distilled water and agitated. This was allowed to stand for 30 mins at room temperature while continuously stirring every 5 mins. At the end of 30 mins, it was centrifuged and the extract obtained. 2.5 mL of the extract was dispersed into a 50 mL volumetric flask.

Similarly, 2.5 mL of standard tannic acid was dispersed into a separate 50ml flask. A 1.0 mL Folin-Denis reagent was measured into each flask followed by the addition of 2.5 mL of saturated Na_2CO_3 solution. The mixture was diluted and made up to the 50 mL mark of the flask and was incubated for 90 mins at room temperature. The absorbance was measured at 250 nm in a UV spectrophotometer; readings were taken with the blank sample at zero. The tannin content was given as follows;

% Tannin = An/As x C x 100/w x VF/VA

An= absorbance of the test sample

As = absorbance of standard solution

C = concentration of standard solution

W = weight of sample used

VF = total volume of extract

VA = volume of extract analyzed

Oxalate Determination

This determination involved three major steps: digestion, oxalate precipitation, and

permanganate titration.

Digestion

2 g of the sample was suspended in 190 mL of distilled water in a 250 mL volumetric flask. 10 mL of 6M HCl was added and the suspension digested at 100 °C for 1 hour. The solution was cooled, and then made up to 250 mL mark before filtration.

Oxalate Precipitation

Duplicate Portions of the filtrate were measured into breakers and four drops of methyl red indicator added. Then NH_4OH solution was added (drop wise) until the test solution changed from pink to faint yellow colour (pH 4.0-4.5). Each portion was then heated to 90°C, cooled and then filtered to remove the precipitate containing ferrous ion. The filtrate was again heated to 90 °C and 10ml of 5% $CaCl_2$ solution was added while being stirred constantly. The solution was then heated and left overnight at 25 °C, it was then centrifuged at 2000rpm for 5minutes. The supernatant was decanted and the precipitate completely dissolved in 20ml of 25% (v/v) H_2SO_4 solution.

Permanganate Titration

At this point, the total filtrate resulting from the digestion of 2 g of sample was made up to a volume of 300 mL. Aliquots of 125 mL of the filtrate was heated until near boiling and then titrated against 0.02M standardized $KMnO_4$ solution to a faint pink color which persisted for 30 seconds. The calcium

oxalate content was calculated using the formula formula;

$$Oxalate\ content = \frac{(V_{me}) \times (D_f)}{M_e \times M_f}(\frac{mg}{100g})$$

Where T is the titre of KMnO4 (mL),
Vme is the volume-mass equivalent
Df is the Dilution factor= Vt/A Where Vt is the total volume of filtrate (300 mL) and A is the aliquot used i.e. 125 mL,
Me is the molar equivalent of KMnO4 in oxalate and
Mf is the mass of sample used.

Phytate Determination

5 mL of the sample was mixed, cured for 5 hrs and filtered. Aliquots of 2500 mL of the filtrate in a conical flask was added to 5.00 mL of 0.30% ammonium thiocynate, the mixture was titrated with standard iron (III) chloride solution to a persistent brownish-yellow coloration that persisted for 4 mins. The amount of phytates was calculated with the equation below;

$$Phytic\ acid = \frac{Titre\ value \times 0.0019 \times 1.9 \times 100}{2}$$

Saponins Determination

20 g of each sample was placed in conical flask and 100ml of 20% aqueous ethanol was added. The mixture was heated on water bath at 55o C for 4 hours with continuous stirring. It was filtered and the residue reextracted with another 200 ml of 20% ethanol. The combined extract was reduced to 40 ml over water bath at about 90o C. The concentrate was transferred into a 250 ml separation funnel and 20 ml of diethyl ether added and vigorously shaken. The aqueous layer was recovered while the ether layer was discarded. The aqueous layer was purified and 60 ml of n-butanol was added. The n-butanol extract washed twice with 10 ml of 5 % aqueous NaCl. The remaining solution was evaporated and dried in the oven to a constant weight (Obadoni and Ochuko, 2002). The saponin content was calculated using the formula below: % Yield = Weight of saponin / Weight of sample ×100.

Glycosides Determination

In this test, the samples were mixed with 10 mL freshly prepared Baljet's reagent (95 mL of 1% picric acid + 5 mL of 10% NaOH). The mixture was allowed to stand for 1 hour. This is followed by dilution with 20 mL distilled water and the absorbance was measured at 495 nm using UV spectrophotometer. The percentage yield of glycosides was calculated as follows: Weight of sample (g): Absorbance of sample/Absorbance of standard x Concentration of standard (Abdullahi *et al.,* 2020).

DETERMINATION OF HEAVY METALS

1 gm of eggplant powder from each sample was weighted by four-level sensitive scale, mixed with 10 ml of nitric acid (which was measured by using a sterilized pipette) into a 100 ml sterilized beaker and incubated for 24 hours at 25ºC. Then, Samples were concentrated to 5 ml at 120ºC by using magnetic Stirrer equipment. The samples were cooled at 25ºC for 15 minutes. Further, 5 ml nitric acid was added and heated at 120ºC by using magnetic Stirrer equipment until the samples became 5 ml. Then, samples were cooled at 25ºC for about 15 minutes.

After that, 3 ml hydrogen peroxide (which was measured by using a sterilized pipette) was added to the samples and concentrated at 120ºC to 5 ml and cooled at 25ºC for 15 minutes. The samples volume completed to 100 ml by distilled water filtered by filter paper and kept at 100ml volumetric flask. Atomic Absorption Spectrometry (AAS) for estimating the amounts of trace elements (Lindenmayer *et al.,* 2023).

AAS technique was used to estimate the heavy metals concentration in eggplant samples. AAS is an advanced technique for evaluating the numbers of existed chemical components in natural products (fruits and vegetables) through the evaluation of absorbing light that passed through the chemical components. The procedure was carried out by observing the color spectrum that evolved when such material was stimulated by light. Standard operating parameters were set before the operation. The hollow cathode lamps for Pb, Cd, Cu, and As were used as a radiation source. The concentrations of samples were measured according to the Beer-Lambert law and it was assessed employed a calibration curve which was acquired by utilizing the standard for recognized concentrations for generating this curve, a specific wavelength was preferred and the detector was used for measuring only the energy transmitted at that wavelength. If the concentration of the target atom in the sample increased, the absorption was also increased proportionally (Ajasa *et al.,* 2004). A series of samples that contain recognized concentrations of selected compounds was analyzed, and

the corresponding absorbance was recorded. The measured absorption at each concentration was then plotted so that a straight line could then be drawn between the resulting points. From this line, the concentrations of the substances under investigation were extrapolated from the substances' absorbance.

RESULTS AND DISCUSSIONS

Table 1: Anti-Nutrient Composition

Metabolite	*Solanum molengena (%)*	*Solanum gilo (%)*
Tannin	4.11	3.66
Saponin	5.20	11.50
Glycoside	6.48	5.83
Oxalate	5.67	5.33
Phytate	4.46	4.20

Table 2: Heavy Metal Concentrations in the Garden Egg Samples

Metal	*Solanum melongena* (mg/kg)	*Solanum gilo* (mg/kg)	WHO/FAO Limit (mg/kg)
Lead (Pb)	1.80	1.35	0.30
Cadmium (Cd)	0.13	0.08	0.02
Copper (Cu)	1.63	1.30	2.30
Arsenic (As)	0.10	0.07	0.10

Table 1 above shows the levels of antinutrients determined. Anti-nutritional factors are primarily associated with compounds or substances of natural or synthetic origin, which interfere with the absorption of nutrients, and act to reduce nutrient intake, digestion, and utilization and may produce other adverse effects. Antinutrients are frequently related to plant-based, raw or vegan diets and are naturally synthesized in plants (Bikila, 2022).

All the antinutrients determined are higher in the *S. melongena,* except Saponin, which is higher in *S. gilo.* The highest amount of antinutrient is 11.5% of saponin in *S. gilo.* Saponins are a class of compounds with a steroid or triterpenoid backbone (aglycone) linked to one or more sugar chains (Sparg *et al.,* 2004). Saponin acts as an antinutrient by binding to dietary minerals like zinc, iron, and calcium, reducing their absorption (Oakenfull & Topping, 1987). It interacts with bile acids, affecting lipid digestion and absorption (Sidhu & Oakenfull, 1986), as well as inhibiting digestive enzymes like trypsin and chymotrypsin (Liener, 1994). These can disrupt cell membranes and have antimicrobial properties, potentially influencing skin health indirectly by affecting overall animal health. High levels may cause irritation or toxicity, impacting hide quality (Cheeke, 2000).

Glycosides consist of a glycone (sugar moiety) linked to an aglycone (non-sugar moiety) through a glycosidic bond (Dewick, 2009). Glycosides act as antinutrients by inhibiting digestive enzymes, such as cyanogenic glycosides, interfering with nutrient metabolism (Gilani & Atta-ur-Rahman, 2005). Some glycosides can be toxic to animals, affecting health and potentially skin quality. Their impact on hide and leather is less direct, often related to overall animal health (Okwu, 2004).

Tannins are polyphenolic compounds with a complex structure. They're generally classified into two main types, which are the hydrolyzable tannins, the sters of gallic acid (gallotannins) or ellagic acid (ellagitannins) with a sugar core, and the condensed tannins (proanthocyanidins), which are flavonoid units linked through C-C bonds. The structure varies depending on the type of tannin (Khanbabaee & van Ree, 2001). Tannins as antinutrients bind to proteins, reducing protein digestibility and utilisation. They chelate minerals like iron, zinc, and calcium, reducing their absorption. Tannins inhibit digestive enzymes such as trypsin and amylase and interact with vitamins and other nutrients, thereby affecting their bioavailability (Kumar & Singh, 1984; Gillo, 2002; Scalbert, 1991; Huang, 2009). At moderate levels, tannins can bind to collagen, enhancing its stability and resistance to microbial degradation, which improves hide quality and benefits leather tanning (Kundu, 2019). However, excessive tannins

can reduce protein digestibility, potentially affecting animal growth and skin thickness (Soetan & Oyewole, 2009).

Oxalate is a chemical compound that can form soluble and insoluble salts in water. This substance is present in a wide range of foods, with plant products being the main sources of dietary oxalates (Hönow & Hesse, 2002). Oxalate can form soluble and insoluble salts in water. When binding with sodium, potassium, and ammonium ions, it forms soluble oxalates, whereas with calcium, iron, and magnesium, it precipitates, forming insoluble compounds and making these minerals unavailable for absorption. This potentially affecting mineral balance and skin health. Free oxalates are delivered to the kidney and can be excreted, increasing urinary oxalate levels, or can chelate with calcium ions there, forming calcium oxalate crystals, which can cause serious health issues like kidney stones, also known as nephrolithiasis or urolithiasis (Petroski & Minich, 2020). Its direct impact on hide and leather quality is minimal, but overall animal health could be influenced (Rahman, 2013)

Phytate is one of the prime antinutrient factors in the plant-based diet because monogastric animals and human digestive systems are incapable of metabolizing phytate. Phytates or phytic acids occur naturally in the plant kingdom. Phytate is generally known as myo-inositol-1,2,3,4,5,6-hexakis dihydrogen phosphate, which is present in foods at various levels ranging from 0.1 to 6.0% (Gupta *et al.,* 2015). Because plant-based foods contain more amount of phytic acids than animal-based foods, the vegetarian diets culture in developing countries contribute to high ingestion levels. According to a previous report, phytic acid hinders the activity of enzymes, which are necessary for protein degradation in the small intestine and stomach. Generally, phytic acids affect the bioavailability of minerals. Phytic acid is generally a negatively-charged structure, which generally binds with positively charged metal ions such as zinc, iron, magnesium and calcium to make complexes and reduce the bioavailability of these ions through lower absorption rates. Mainly due to this chelating property, phytic acid is considered as a most effective anti-nutrient in foods, and a cause of mineral ions deficiencies in animal and human nutrition (Bikila, 2022), and could therefore negatively impact hide quality.

Table 2 shows the levels of heavy metals in *S. melongena* and *S. gilo.* Heavy metal toxicity has proven to be a major threat and there are several health risks associated with it. The toxic effects of these metals, even though they do not have any biological role, remain present in some or the other form harmful for the human body and its proper functioning. They sometimes act as a pseudo element of the body while at certain times they may even interfere with metabolic processes. The levels of lead in *S. melongena* and *S. gilo* is 1.80mg/kg and 1.35mg/kg respectively. Both are higher than that of the WHO/FAO limits. Similarly, the levels of cadmium in *S. melongena* and *S. gilo* is 0.13mg/kg and 0.08mg/kg respectively. These are higher than those of the WHO/FAO limits. However, the levels of cupper and arsenic fall within the range accepted by WHO/FAO.

Lead is a highly toxic metal whose widespread use has caused extensive environmental contamination and health problems in many parts of the world. Lead is a bright silvery metal, slightly bluish in a dry atmosphere. It begins to tarnish on contact with air, thereby forming a complex mixture of compounds, depending on the given conditions. The sources of lead exposure include mainly industrial processes, food and smoking, drinking water and domestic sources. Human activities in Zaria metropolis, such as mining, manufacturing and fossil fuel burning, have resulted in the accumulation of lead and its compounds in the environment, including air, water and soil. Lead does not play any useful biological functions in the body. (Monisha *et al.,* 2014).

Lead poisoning can also occur from drinking water. The pipes that carry the water may be made of lead and its compounds, which can contaminate the water. According to the Environmental Protection Agency (EPA), lead is considered a carcinogen. Lead has major effects on different parts of the body. Lead distribution in the body initially depends on the blood flow into various tissues, and almost 95% of lead is deposited in the form of insoluble phosphate in skeletal bones. Lead accumulation in animal tissues can result from contaminated feed. It can weaken skin structure, reduce hide strength, and affect leather quality by interfering with collagen cross-linking (Adeyeye, 2002; Ogundipe, 2015). Lead residues in leather can pose health risks to workers and consumers.

Cadmium is a metal of the 20th century. It is a byproduct of zinc production. Soils and rocks, including coal and mineral fertilisers, contain some amount of cadmium. Cadmium has many applications, *e.g.* in batteries, pigments, plastics and metal coatings and is widely used in electroplating. Cadmium and its compounds are classified as Group 1 carcinogens for humans by the International Agency for Research on Cancer (Henson & Chedrese, 2004). Cadmium is released into the environment through natural human activities such as mining, smelting, tobacco smoking, incineration of municipal waste, and the manufacture of fertilisers.

Cadmium is highly toxic to the kidney and it accumulates in the proximal tubular cells in higher concentrations. Cadmium can cause bone mineralisation either through bone damage or by renal dysfunction. Studies on humans and animals have revealed that osteoporosis (skeletal damage) is a critical effect of cadmium exposure, along with disturbances in calcium metabolism, formation of renal stones and hypercalciuria. Inhaling higher levels of cadmium can cause severe damage to the lungs. If cadmium is ingested in higher amounts, it can lead to stomach irritation and result in vomiting and diarrhoea. On very long exposure time at lower concentrations, it can become deposited in the kidney and finally lead to kidney disease, fragile bones and lung damage (Bernard, 2008). Cadmium and its compounds are highly water-soluble compared to other metals. Their bioavailability is very high, and hence, it tends to bioaccumulate. Long-term exposure to cadmium can result in morphopathological changes in

the kidneys. Cadmium interacts with essential nutrients, through which it causes its toxicity effects. Experimental analysis in animals has shown that 50% of cadmium gets absorbed in the lungs and less in the gastrointestinal tract. Cadmium is toxic to animals and can accumulate in skin and other tissues, potentially leading to skin lesions and reduced hide quality. In leather, cadmium residues can cause environmental and health issues (Khan, 2008).

CONCLUSION

This study revealed that Solanum melongena and Solanum gilo contain varying levels of heavy metals and anti-nutrients. The present investigation showed that eggplant could accumulate a higher level of heavy metals including Pb, and Cd, that were higher than the reported safe limits of FAO and WHO. While some of these compounds, like tannins, may offer benefits for hide quality and leather tanning by stabilizing collagen, excessive levels of heavy metals and anti-nutrients pose risks to animal health, feed safety, and leather quality. Heavy metals can accumulate in animal tissues, weakening skin structure and introducing toxicity concerns in leather processing, while anti-nutrients can impair nutrient absorption and overall animal performance.

Therefore, for *S. melongena* and *S. gilo* to be safely utilized in animal feed and leather production, proper processing and monitoring are essential to reduce harmful components while retaining beneficial phytochemicals. These findings highlight the need for further research into safe inclusion levels and detoxification methods to optimise their use in agriculture and industry.

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