

Production and quality evaluation of green and black herbal tea from *Solanum aethiopicum* (Garden egg leaf) and *Lasianthera africana* (Editan leaf)

PHILIPPA Chinyere OJIMELUKWE

philippaco60@gmail.com

Michael Okpara University of Agriculture <https://orcid.org/0000-0002-0263-0597>

VICTORIA MGBEAHURIKE

Michael Okpara University of Agriculture

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Production and quality evaluation of green and black herbal tea from *Solanum aethiopicum* (Garden egg leaf) and *Lasianthera africana* (Editan leaf)

Victoria Mgbeahurike (mgbeahuruikevictoria2019@gmail.com)

and Philippa C Ojimelukwe (philippaco60@gmail.com)

Department of Food Science and technology

Michael Okpara University of Agriculture, Umudike, Abia State Nigeria

This study was conducted to investigate the quality of green and black herbal teas produced from *Solanum aethiopicum* (garden egg) and *Lasianthera africana* (editang) using *Moringa oleifera* as a control. The plant leaves were steamed to produce green tea and fermented to produce black tea. Their chemical composition, microbial safety and sensory properties were evaluated. A 2×3 factorial experiment arranged in a completely randomized design (CRD) was employed, and data were analyzed using analysis of variance (ANOVA) at $p \leq 0.05$. The results revealed significant ($p < 0.05$) differences in the nutrient, phytochemical, and sensory qualities of the teas. Editang Green Tea had the highest protein (26.82%) and energy value (335.09 kcal/100 g), while Editang Black Tea contained the highest carbohydrate (58.86%). Moringa Green Tea had the highest ash content (10.01%), suggesting high mineral density. Vitamin analysis showed that Garden Egg Black Tea was particularly rich in Vitamins A (850.02 µg/100 g), E (6.57 mg/100 g), and K (1.03 mg/100 g), whereas Editang Black Tea had the highest Vitamin D (0.07 µg/100 g). Phytochemical profiling indicated that Garden Egg Black Tea contained the highest flavonoids, tannins, and saponins, while Moringa Green Tea had the highest alkaloid content. Microbial counts (1.0×10^4 – 2.3×10^4 CFU/g) were within acceptable limits, though *Staphylococcus aureus* and *Bacillus* spp. were identified, highlighting the need for improved hygienic practices. Sensory evaluation showed that although Lipton (commercial control) remained the most acceptable, Garden Egg Green Tea and Moringa Black Tea were comparable in taste, aroma, and general acceptability, while Editang-based teas scored lower. The findings demonstrate that *S. aethiopicum* and *L. africana* teas possess comparable nutritional, phytochemical, and sensory properties to commercial tea. With optimization of processing conditions and improved quality control, these indigenous teas could serve as competitive, health-promoting alternatives to commercial teas, thereby supporting dietary diversification and the utilization of indigenous food resources.

Key words; *Solanum aethiopicum*, *Lasianthera africana*, *Moringa oleifera*, green tea, black tea, nutrients, bioactive compounds

Introduction

Herbal tea can be prepared from different plant materials using hot or cold water to extract the biologically active constituents (Poswal *et al.*, 2019). Plant parts, such as flowers, roots, barks, and seeds may be used to produce herbal teas. Herbal teas may differ in taste, colour or aroma, depending on the nature of the plant material and the blends used for the infusion. It takes only

a few minutes to prepare herbal infusion (Malongane *et al.*, 2020) and it is served immediately (Sehgal, 2022). Generally, herbal teas have low calories and can be used to prevent or manage a number of systemic and chronic disease conditions because of their antioxidant properties (Prajapati *et al.*, 2022). They are rich in polyphenols and flavonoids (Shao *et al.*, 2019). Herbal teas are helpful for the management of inflammation, atherosclerosis and type 2 diabetes (Jurendic and Šćetar, 2021). They scavenge free radicals because of their phytochemical content and are healthy beverage that does not contain caffeine (Ramphinwa *et al.*, 2023). The present research investigated local plant leaves with medicinal value for their potentials as herbal teas.

MATERIALS AND METHODS

Source of raw materials

Fresh *Solanum aethiopicum*, *Lasianthera africana* and *Moringa oleifera* were obtained from a local market in Umuahia, Abia State, Nigeria. The leaves were identified at the Department of Plant Science and Biotechnology, Michael Okpara University of Agriculture, Umudike, Abia State.

Sample preparation

Sample preparation was by the method of Maduforo *et al.* (2022). Three hundred grams (300 g) of each sample (*Solanum aethiopicum*, *Lasianthera africana* and *Moringa oleifera*.) were cleaned, washed and divided into two. One half (150 g) was used to produce green tea; while the other half was used to produce black tea. *Moringa oleifera* leaf was used as the control.

Production of green tea from the leaves of *Moringa oleifera*, *Solanum aethiopicum* and *Lasianthera africana*.

The flowchart for production of green tea from leaves is presented in Fig.1. Fresh leaves of *Solanum aethiopicum*, *Lasianthera africana* and *Moringa oleifera*, weighing 150 g each were washed using pipe borne water. An electric steamer (John Lewis model) was filled to the maximum level with cold water. The timer was set for 60 min and the steamer was switched on to raise the water to a temperature of 60°C using an inserted thermometer. The washed leaves were placed in the plastic container of the steamer and steamed for 3 min. After steaming, the leaves were allowed to cool to room temperature for 30 min prior to rolling, using a manual plate mill (Corona) to disrupt the leaf cells and increase their surface area. The rolled leaves were spread on trays and dried immediately in a hot air oven for 6 h at 50°C till the product became crispy. The dried products were coarsely milled using a manual plate (Corona Mill), sieved using a USA standard testing sieve No. 30, packed in air tight containers and stored at room temperature.

Processing of black tea from the leaves of *Solanum aethiopicum*, *Lasianthera africana* and *Moringa oleifera*.

The flowchart for production of black tea from *Solanum aethiopicum*, *Lasianthera africana* and *Moringa oleifera*, leaves is presented in Fig.2. One hundred and fifty (150) gram portion of each leaf was washed with tap water and allowed to drain. The drained leaves were thinly spread on jute bags and withered under the shade for 3 h. The leaves were allowed to lose about 60% of their moisture (to make them pliable) by weighing them at intervals of 30 min. The withered leaves were rolled using a manual corona plate mill. After rolling, the leaves were thinly spread on trays and left at room temperature for 3 h for fermentation to take place. The darkened fermented leaves were dried in a hot air oven at 50°C for 4 h, cooled and coarsely

milled using a manual corona plate mill in order to obtain a coarse product, which was sieved using a USA standard testing sieve No. 30 and packaged in an air tight container.

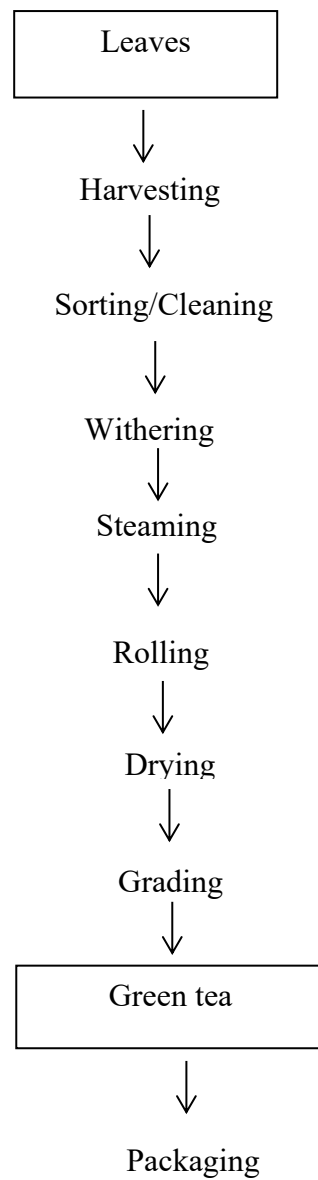


Figure 1: Production of green tea
Source: Maduoforo *et al.* (2022) with slight modifications

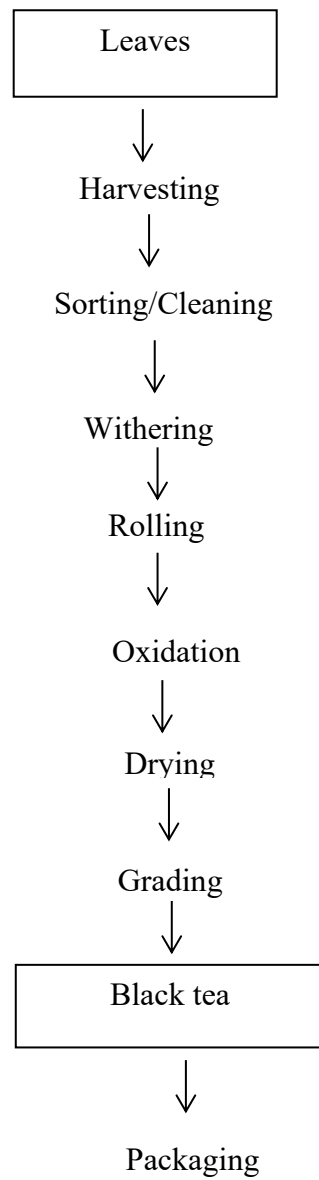


Figure 2: Production of black tea

Source: Maduoforo *et al.* (2022) with slight modifications

Determination of proximate composition and energy value

The moisture, protein, fat, fibre, ash and carbohydrate contents were determined using the method described by AOAC (2019).

Phytochemical analysis

The flavonoid, tannin, saponin and alkaloid contents were determined according to the method of AOAC (2019).

The Vitamin A, D, E and K content were determined according to the method of AOAC (2019).

Determination of Vitamin A (Retinol)

One (1) gram, of each sample was weighed and macerated with 20 ml of n-hexane in a test tube for 10 minutes. Then 3 ml of the upper hexane extract was transferred into a dry test tube in duplicates and evaporated to dryness. Following this, 0.2ml of Acetic anhydride chloroform reagent was added and 2 ml of 50% Trichloroacetic acid (TCA) in chloroform was also added. The absorbance was taken at 15 seconds and 30 seconds intervals at 620 nm.

Determination of Vitamin D

Vitamin D content was determined by mixing the carr-price reagent (20% m/v of Antimony trichloride in chloroform with 40% pure Acetylchloride) freshly prepared and free from alcohol. Nine (9) ml of the Carr-price reagent was added to 1ml sample extracted with chloroform and the extinction was measured at 500 nm against the reagent blank and the concentration was extrapolated from a standard curve or graph using the vitamin D standard.

Determination of Vitamin E (Tocopherol)

One gram (1g) of the original sample was weighed, macerated with 20 ml of n- hexane in a test tube for 10 minutes and centrifuged for 10 minutes. The solution was filtered, 3 ml of the filtrate was transferred into a dry test tube in duplicates and evaporated to dryness in a boiling water bath. Following this, 2ml of 0.5N alcoholic Potassium hydroxide was added and boiled

for 30 minutes in a water bath. Then 3 ml of n-hexane was added and was shaken vigorously. The n-hexane was transferred into another set of test tubes and evaporated to dryness. A volume, 2ml, of ethanol was added to the residue. Another volume, 1ml of 0.2% Ferric chloride in ethanol was added. Then 1ml of 0.5% $\alpha^1 \alpha^1$ -dipyridyl in ethanol was added followed by the addition of 1ml of ethanol to make it up to 5 ml. The solution was mixed and absorbance taken at 520 nm against the blank.

3.5.4 Determination of Vitamin K

The solution in which the concentration of vitamin K was being determined was placed in a flask and the sodium pentacyanoamineferroate reagent was added. The solution was stirred and then allowed to stand for 15 minutes to allow maximum colour development. When the blue colour had developed, the absorption of the solution was measured with a spectrophotometer at 650 nm. The standard vitamin K solution was prepared by dissolving 5 milligrams of crystalline vitamin K in water and diluting it to 100 ml. This solution was stable for 4 to 6 hours. The absorption of the solution was read on a spectrophotometer at 650nm, against a reagent blank

MICROBIAL ASSAY

Five different types of culture media were prepared according to the manufacturer's instructions and used: Nutrient Agar (NA), MacConkey agar (MA), Salmonella- Shigella agar (SSA), Potato Dextrose agar (PDA) and Baird-Parker agar (BPA). Plating was done in duplicates, the inoculated Agar media were incubated at 37°C for 24-48 h while Potato Dextrose Agar (PDA), plates were incubated at 25°C for 48-72 h. After incubation, colonies that developed on the plates were counted to obtain total viable count. Pure cultures of the isolates were obtained by repeated sub-culturing on fresh agar plates for further studies and

identification. For bacterial colony purification, the streak techniques on the Nutrient agar was employed, while the fungal isolates were transplanted to new set of PDA agar by picking.

EXPERIMENTAL DESIGN

Two by three factorial experimental design was used in carrying out the research work. Completely randomized design (CRD) was used for treatments in carrying out the sensory analysis.

STATISTICAL ANALYSIS

Data obtained from the experiment were subjected to Analysis of Variance (ANOVA) to determine the significance of treatments. The statistical analyses were carried out using R Statistical Software (version 4.5.1; R Core Team, 2024). Where significant differences were detected ($p \leq 0.05$), treatment means were separated using the Tukey's Honest Significant Difference (HSD) test. Results were expressed as mean values $\pm$ standard error (SE), and data were represented graphically with error bars to indicate the variability within replicates.

RESULTS AND DISCUSSION

Proximate Composition of the Tea Samples

Table 1 presents the proximate composition on of the six tea samples studied. The moisture content (mc) ranged from 5.19% (Editang Black Tea) to 7.64% (Moringa Green Tea). The significant difference ($p < 0.05$) indicates variation in water activity and storage stability among samples. Moringa Green Tea had the highest moisture, suggesting it may have lower storage stability due to susceptibility to microbial growth, while Editang Black Tea had the lowest mc, indicating better shelf-life.

Protein content varied significantly ($p < 0.05$) from 11.22% (Moringa Green Tea) to 26.82% (Editang Green Tea), making it the best potential dietary protein source among the samples. Variation in protein could be due to differences in plant species, processing, and nutrient retention during drying (Ajayi *et al.* 2020).

Fat content ranged between 3.72% (Moringa Black Tea) to 6.26% (Garden Egg Black Tea). Garden Egg Black Tea had the highest fat, which could contribute to flavor and energy density, while Moringa Black Tea had the lowest fat, indicating a leaner profile.

Fibre content varied significantly from 8.69% (Garden Egg Green Tea) to the highest value ($p < 0.05$) 10.39% (Editang Green Tea). Fibre, is beneficial for digestive health and prevention of constipation. Garden Egg Green Tea had the least fibre. High fibre content in teas aids in lowering cholesterol and maintaining gut health (FAO, 2016).

Ash content, which reflects total mineral composition, ranged from 6.31% (Moringa Black Tea) to 10.01% (Moringa Green Tea) indicating richer mineral availability in the green tea. These findings corroborate studies by Duru *et al.* (2019), who linked high ash content in herbal teas to significant micronutrient contributions.

Carbohydrate content ranged between 43.54% (Garden Egg Black Tea) and 58.86% (Editang Black Tea). Editang Black Tea contributes more energy to the diet. This is consistent with the report of Ijarotimi and Keshinro (2012) that carbohydrate-rich herbal teas can serve as supplementary energy beverages.

Energy values ranged significantly from 316.46 kcal/100g (Moringa Green Tea) to 335.09 kcal/100g (Editang Green Tea). Editang Green Tea is more energy-dense, making it a better option for individuals requiring higher calorie intake, while Moringa Green Tea may be preferable for those seeking weight control.

Proximate analysis revealed significant variations among the tea samples in terms of moisture, protein, fat, fibre, ash, carbohydrate, and energy values. Editang Green Tea stood out as the most protein- and energy-rich, while Editang Black Tea excelled in carbohydrate content. Moringa Green Tea had the highest ash content, suggesting higher mineral density. Thus, the various teas had different nutritional potentials that underscores their suitability for diverse dietary needs. Processing methods (green vs. black tea preparation) significantly influenced proximate composition of the teas (Ojo *et al.*, 2021).

Table 1: Proximate composition of the teas

Sample	MC	CP	Fat	CF	Ash	CHO	EV
Editang Black Tea	5.19±0.01 ^f	12.69±0.02 ^e	3.96±0.01 ^e	10.21±0.01 ^b	9.10±0.02 ^b	58.86±0.01 ^a	321.82±0.01 ^e
Editang Green Tea	5.49±0.01 ^e	26.82±0.02 ^a	5.61±0.01 ^b	10.39±0.01 ^a	7.36±0.01 ^e	44.34±0.02 ^e	335.09±0.13 ^a
Garden egg Black Tea	6.81±0.01 ^c	25.29±0.01 ^b	6.26±0.03 ^a	9.59±0.01 ^d	8.51±0.01 ^c	43.54±0.03 ^f	331.69±0.05 ^b
Garden egg Green Tea	7.09±0.02 ^b	18.61±0.01 ^d	4.51±0.01 ^d	8.69±0.01 ^f	7.87±0.02 ^d	53.24±0.01 ^d	327.99±0.13 ^d
Moringa Black Tea	6.21±0.01 ^d	19.49±0.01 ^c	3.72±0.02 ^f	9.79±0.01 ^c	6.31±0.01 ^f	54.49±0.02 ^c	329.34±0.05 ^c
Moringa Green Tea	7.64±0.01 ^a	11.22±0.02 ^f	4.74±0.01 ^c	9.16±0.01 ^e	10.01±0.01 ^a	57.24±0.02 ^b	316.46±0.13 ^f

Values are means ± standard deviation of replicate determination ^{a-d}. Means having different superscript within the same column are significantly different (p<0.05); MC = Moisture Content; CP = Crude Protein; CF = Crude Fibre; CHO = Carbohydrate; EV = Energy Value.

Vitamin Composition of the Tea Samples

The results presented in Table 2 show significant ($p < 0.05$) differences in the concentrations of vitamins A, D, E, and K across the different tea samples.

Vitamin A content ranged from 602.04 $\mu\text{g}/100\text{ g}$ in Moringa Green Tea to 850.02 $\mu\text{g}/100\text{ g}$ in Garden Egg Black Tea, which was significantly ($p < 0.05$) higher than all other samples. This indicates that Garden Egg teas, particularly the black version, is a richer sources of Vitamin A, which plays a vital role in vision and immune function (Olson *et al.*, 2020). Black tea processing often leads to concentration of bioactive compounds compared to green tea (Yashin *et al.*, 2011).

For Vitamin D, the levels ranged from 0.03 $\mu\text{g}/100\text{ g}$ in both Garden Egg Black Tea and Moringa Black Tea to 0.07 $\mu\text{g}/100\text{ g}$ in Editang Black Tea. Editang Black Tea was significantly ($p < 0.05$) higher in Vitamin D content than the other teas, while the Garden Egg Black Tea and Moringa Black Tea had the least. Although the overall concentration of Vitamin D was low across all samples, it was present in measurable amounts despite its limited availability from dietary sources.

Vitamin E, concentrations ranged from 3.54 mg/100 g in Moringa Green Tea to 6.57 mg/100 g in Garden Egg Black Tea which was significantly ($p < 0.05$) the highest source. Moringa Green Tea had the lowest value. The higher levels of Vitamin E in Garden Egg Black Tea could be attributed to the abundant presence of tocopherols in Solanum species (Odetola *et al.*, 2012). Vitamin E, is a powerful antioxidant, which combats oxidative stress and prevents lipid peroxidation (Traber & Atkinson, 2007).

For Vitamin K, the concentration varied between 0.49 mg/100 g in Moringa Black Tea and 1.03 mg/100 g in both Editang Black Tea and Garden Egg Black Tea. Editang Black Tea and Garden Egg Black Tea recorded the highest and were significantly ($p < 0.05$) different from the other teas, whereas Moringa Black Tea had the least. Vitamin K is required for blood clotting and bone health. Its higher concentration in black tea varieties confirms earlier findings that fermentation can enhance the bioavailability of some fat-soluble vitamins (Manach *et al.*, 2004).

Garden Egg Black Tea is the richest in vitamins A, E, and K, while Editang Black Tea recorded the highest Vitamin D content.

Table 2: Vitamin Composition of the Tea Samples

Sample	A	D	E	K
Editang Black Tea	620.32±0.03 ^e	0.07±0.01 ^a	3.89±0.01 ^e	1.03±0.01 ^a
Editang Green Tea	840.32±0.03 ^b	0.05±0.01 ^{bc}	6.04±0.02 ^b	0.82±0.02 ^c
Garden egg Black Tea	850.02±0.03 ^a	0.03±0.01 ^d	6.57±0.02 ^a	1.03±0.01 ^a
Garden egg Green Tea	780.07±0.02 ^c	0.04±0.01 ^{cd}	5.19±0.01 ^c	0.65±0.01 ^d
Moringa Black Tea	690.22±0.03 ^d	0.03±0.01 ^d	4.59±0.01 ^d	0.49±0.01 ^e
Moringa Green Tea	602.04±0.01 ^f	0.06±0.01 ^{ab}	3.54±0.01 ^f	0.87±0.01 ^b

Values are means ± standard deviation of replicate determination ^{a-d}. Means having different superscript within the same column are significantly different ($p < 0.05$)

3. Result of the Phytochemical Composition of Tea Samples

The phytochemical composition of six different tea samples are shown in Figure 3.

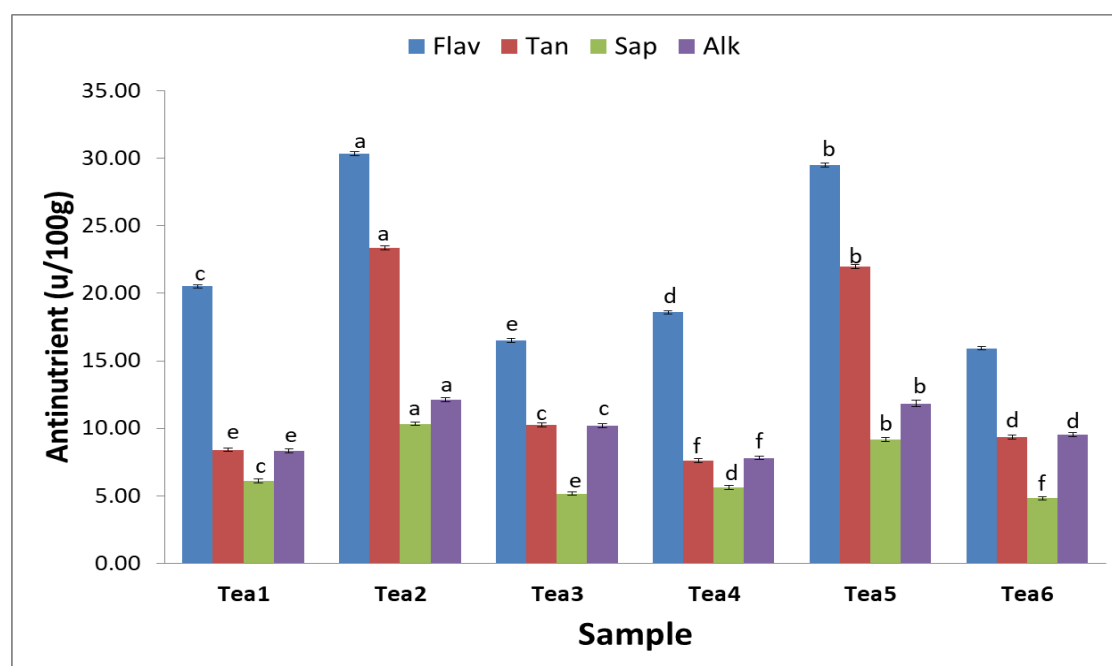
Flavonoid content was highest ($p < 0.05$) in Garden Egg Black Tea (3.32 ± 0.03 u/100g), followed by Editang Green Tea (2.52 ± 0.02 u/100g), and lowest in Moringa Green Tea (1.52 ± 0.03 u/100g).

The significantly higher flavonoid concentration in Garden Egg Black Tea ($p < 0.05$) suggests a fermentation-enhanced oxidation of phenolics. Flavonoids are polyphenols with notable antioxidant, anti-inflammatory, and vasodilatory properties. They promote overall health by scavenging free radicals and reducing oxidative stress (Panche *et al.*, 2016).

Garden Egg Black Tea had the highest tannin concentration (0.84 ± 0.03 u/100g) ($p < 0.05$) and Moringa Black Tea the lowest (0.41 ± 0.01 u/100g) ($p, 0.05$). Interestingly, Moringa Green Tea had a relatively high tannin content (0.77 ± 0.02 u/100g), nearly comparable to the black tea variants, highlighting that green tea processing can preserve tannins more effectively in some species. Tannins are astringent compounds that can form complexes with proteins and minerals, potentially inhibiting their bioavailability when present in high concentrations (Chung *et al.*, 1998). However, moderate tannin intake is beneficial due to its antioxidant and antimicrobial effects.

Saponin concentration ranged from 0.11 ± 0.01 u/100g in Editang Black Tea to 0.44 ± 0.02 u/100g in Garden Egg Black Tea. Garden Egg Green Tea also had a high saponin content (0.33 ± 0.04 u/100g), significantly higher than Moringa and Editang samples ($p < 0.05$). Green teas contained more saponins than black teas. Saponins are naturally occurring glycosides with foam-forming properties and possess cholesterol-lowering, immunomodulatory, and anticancer potentials (Shi *et al.*, 2004).

Moringa Green Tea exhibited the highest alkaloid content (0.89 ± 0.01 u/100g), while Moringa Black Tea had the lowest (0.41 ± 0.01 u/100g) (at least 50% reduction). Alkaloids are nitrogen-containing compounds with pharmacological effects, including stimulation of the central nervous system, antimicrobial activity, and analgesic properties (Cushnie *et al.*, 2014). The high alkaloid level in Moringa Green Tea suggest potential therapeutic application.



Tea1 - Garden egg Green Tea, Tea2 - Garden egg Black Tea, Tea3 - Moringa Green Tea, Tea4 - Moringa Black Tea, Tea5 - Editang Green Tea and Tea6 - Editang Black Tea. Values in the same column with different superscripts are significantly different ($p < 0.05$)

Figure 1: Phytochemical Composition of Tea Samples

Microbial Analysis of the Tea Samples

The microbial count on the isolated organisms from the different tea samples are presented in Table 3. The results showed varying levels of microbial growth across the samples, with counts ranging from 1.0×10^4 cfu/ml in Moringa Black Tea to 2.3×10^4 cfu/ml in Garden Egg Black Tea. The predominant organisms isolated were *Staphylococcus aureus* and *Bacillus* spp.

The microbial load of the tea samples ranged between 1.0×10^4 and 2.3×10^4 cfu/ml, indicating that all samples supported some degree of microbial growth after 24 hours of incubation. Moringa Black Tea recorded the lowest microbial count (1.0×10^4 cfu/ml), while Garden Egg Black Tea exhibited the highest count (2.3×10^4 cfu/ml). Generally, microbial loads within this range are considered relatively moderate but may pose potential safety concerns depending on the nature of the isolated organisms (Ray & Bhunia, 2013).

Staphylococcus aureus was isolated in Garden Egg Green Tea, Moringa Green Tea, Moringa Black Tea, and Editang Black Tea, in moderate growth levels. The presence of *S. aureus* is of concern, as it is a known pathogen capable of producing enterotoxins that cause foodborne illnesses (Kadariya *et al.*, 2014). Its presence in tea samples may be attributed to contamination during handling, packaging, or post-processing exposure to unhygienic conditions.

On the other hand, *Bacillus* spp. was isolated in Garden Egg Black Tea and Editang Green Tea. *Bacillus* species are spore-forming organisms commonly associated with soil, plant materials, and processing environments. While many *Bacillus* strains are harmless, some, such as *Bacillus cereus*, can produce toxins that lead to food poisoning (Logan & De Vos, 2009). Their presence in the

samples may reflect contamination from raw materials or inadequate drying and storage conditions.

The relatively lower microbial count observed in Moringa Black Tea could suggest that its phytochemical constituents possess antimicrobial properties, as several studies have reported that moringa extracts contain bioactive compounds with inhibitory effects against bacteria (Leone *et al.*, 2015). Conversely, the higher microbial counts in Garden Egg and Editang teas may reflect either higher susceptibility to contamination or less effective antimicrobial protection.

There is need for strict hygienic practices during processing, packaging, and storage of herbal teas to promote food safety. Ensuring proper drying, packaging under hygienic conditions, and incorporating antimicrobial treatment steps (such as pasteurization or irradiation) would enhance the microbial safety and shelf life of locally developed teas.

Table 3: Microbial count of tea samples

Sample	Count	Isolated organisms
Garden egg Green Tea	1.4×10^4	<i>S. aureus</i> isolated after 24 hours of incubation
Garden egg Black Tea	2.3×10^4	<i>Bacillus spp</i> isolated after 24 hours of incubation.
Moringa Green Tea	2.2×10^4	<i>S. aureus</i> isolated after 24h of incubation
Moringa Black Tea	1.0×10^4	Moderate growth of <i>S. aureus</i> isolated after 24h of incubation.
Editang Green Tea	1.9×10^4	Moderate growth of <i>Bacillus spp.</i> isolated after 24h of incubation.
Editang Black Tea	1.5×10^4	Moderate growth of <i>S. aureus</i> isolated after 24h of incubation

Tea1 - Garden egg Green Tea, Tea2 - Garden egg Black Tea, Tea3 - Moringa Green Tea, Tea4 - Moringa Black Tea, Tea5 - Editang Green Tea and Tea6 - Editang Black Tea

Sensory Properties of Tea Samples

Sensory evaluation revealed that appearance (APP) scores ranged from 4.30 in Editang Green Tea to 7.95 in Lipton. Lipton (7.95), Garden Egg Black Tea (7.40), and Garden Egg Green Tea (7.00) were rated high and did not differ significantly ($p>0.05$), suggesting that panelists considered them visually appealing. Conversely, Editang Green Tea had the lowest rating. Consumers often judge quality by visual properties such as colour intensity and brightness (Kong *et al.*, 2018).

Taste, scores varied from 3.55 (Editang Green Tea) to 7.45 (Lipton). Lipton and Garden Egg Green Tea recorded the highest scores, both within the “like moderately to like very much” Editang Green Tea is somehow bitter. This finding is consistent with the report of Owusu *et al.* (2019), who observed that plant-based teas rich in phytochemicals may develop strong, sometimes unfavorable taste notes.

For aroma, Lipton (7.55 ± 0.94^a) received the highest score, followed closely by Garden Egg Black Tea (6.95 ± 1.79^{ab}). The Editang teas recorded the lowest scores, particularly Editang Green Tea (4.85 ± 1.79^d). Differences in aroma perception among samples are likely attributable to variations in volatile compounds and processing techniques (Xie *et al.*, 2020).

The mouthfeel scores revealed that Lipton (7.25 ± 0.97^a) was significantly preferred ($p<0.05$), followed by Moringa Green Tea (6.35 ± 1.63^{ab}) and Garden Egg Green Tea (6.25 ± 1.91^{ab}). Editang Green Tea (3.20 ± 2.19^c) scored the lowest, suggesting that its astringency or texture may have been unfavorable. According to Adepoju and Omotayo (2014), high tannin levels in herbal beverages can produce a drying and rough mouthfeel, which often reduces consumer acceptance.

Regarding general acceptability Lipton (8.10 ± 0.91^a) was the most accepted, while Editang Green Tea (4.05 ± 2.35^d) was the least. Garden Egg Green Tea (7.20 ± 1.06^{ab}) and Moringa Black Tea

(7.10±1.65^{ab}) recorded relatively high acceptance, comparable to Lipton, indicating promising potential for consumer adoption.

The findings suggest that although Lipton remains the benchmark for sensory preference, locally developed teas such as Garden Egg Green Tea and Moringa Black Tea show competitive sensory quality in terms of taste, aroma, and general acceptability. This observation is in line with the report of Yang *et al.* (2021), who emphasized that consumer adoption of novel herbal teas is strongly dependent on optimizing sensory qualities.

Table 4. Sensory scores of different teas

SAMPLE	APP	TASTE	AROMA	MOUTHFEEL	GEN. ACC
Lipton	7.95±0.83 ^a	7.45±1.00 ^a	7.55±0.94 ^a	7.25±0.97 ^a	8.10±0.91 ^a
Moringa Green Tea	5.70±2.13 ^b	5.60±1.90 ^b	5.00±2.42 ^d	6.35±1.63 ^{ab}	5.80±2.02 ^c
Moringa Black Tea	7.05±1.57 ^a	5.70±2.59 ^b	5.55±1.43 ^{cd}	5.50±2.21 ^b	7.10±1.65 ^{ab}
Editang Green Tea	4.30±2.45 ^c	3.55±2.23 ^c	4.85±1.79 ^d	3.20±2.19 ^c	4.05±2.35 ^d
Editang Black Tea	6.95±1.67 ^a	5.85±1.53 ^b	5.85±1.76 ^{bcd}	5.95±1.54 ^b	6.55±1.79 ^{bc}
Garden egg Green Tea	7.00±1.12 ^a	7.10±1.68 ^a	6.25±1.71 ^{bc}	6.25±1.91 ^{ab}	7.20±1.06 ^{ab}
Garden egg Black Tea	7.40±1.76 ^a	6.35±1.81 ^{ab}	6.95±1.79 ^{ab}	6.15±1.69 ^{ab}	6.60±1.93 ^{bc}

Values are means ± standard deviation of replicate determination ^{a-d}. Means having different superscript within the same column are significantly different (p<0.05)

Figure 2 shows the microbial load of the tea samples ranging from 1.0×10^4 CFU/g in Moringa Black Tea to 2.3×10^4 CFU/g in Garden Egg Black Tea. The highest microbial count observed in Garden Egg Black Tea (2.3×10^4 CFU/g) suggests this tea provides a favorable environment for microbial growth compared to others. Moringa Black Tea recorded the lowest microbial count (1.0×10^4 CFU/g), indicating better resistance to microbial proliferation, which could be linked to the inherent antimicrobial properties and bioactive compounds generated during fermentation (Leone *et al.*, 2015).

The predominant organisms isolated were *S. aureus* and *Bacillus* spp. The presence of *S. aureus* is a potential foodborne pathogen capable of producing heat-stable enterotoxins that cause food poisoning (Kadariya *et al.*, 2014). However, the observed counts remained within the acceptable microbiological limits for herbal teas as recommended by the International Commission on Microbiological Specifications for Foods (ICMSF, 2005), which sets the permissible limit at $\leq 10^5$ CFU/g for total viable counts in dried foods. This implies that while contamination exists, the levels are not immediately hazardous to consumers if proper preparation (e.g., boiling water steeping) is applied.

Green teas in general showed slightly lower microbial proliferation compared to black teas, (with the exception of Moringa Green Tea). Green tea polyphenols, particularly catechins, possess strong antibacterial activity against gram-positive bacteria including *S. aureus* (Farhan, 2022). The oxidation process involved in black tea production, will reduce the concentration of antimicrobial compounds and lead to higher microbial load (Unachukwu *et al.*, 2010).

The results demonstrate that while all tea formulations analyzed are microbiologically safe for consumption, the presence of potentially pathogenic microorganisms like *S. aureus* highlights the

importance of strict adherence to Good Manufacturing Practices (GMP) during tea production, packaging, and storage.

Correlation Analysis of Nutritional and Phytochemical Parameters

The correlation mapping of nutrients and phytochemicals in the samples is shown in Figure 2.

There were positive high correlations between Vitamin A and vitamin E ($r=0.98$); vitamin and crude protein ($r=0.95$); vitamin E and crude protein ($r=0.95$); vitamin E and energy ($r=0.95$); vitamin E and flavonoids ($r=0.90$); crude protein and energy ($r=0.96$).

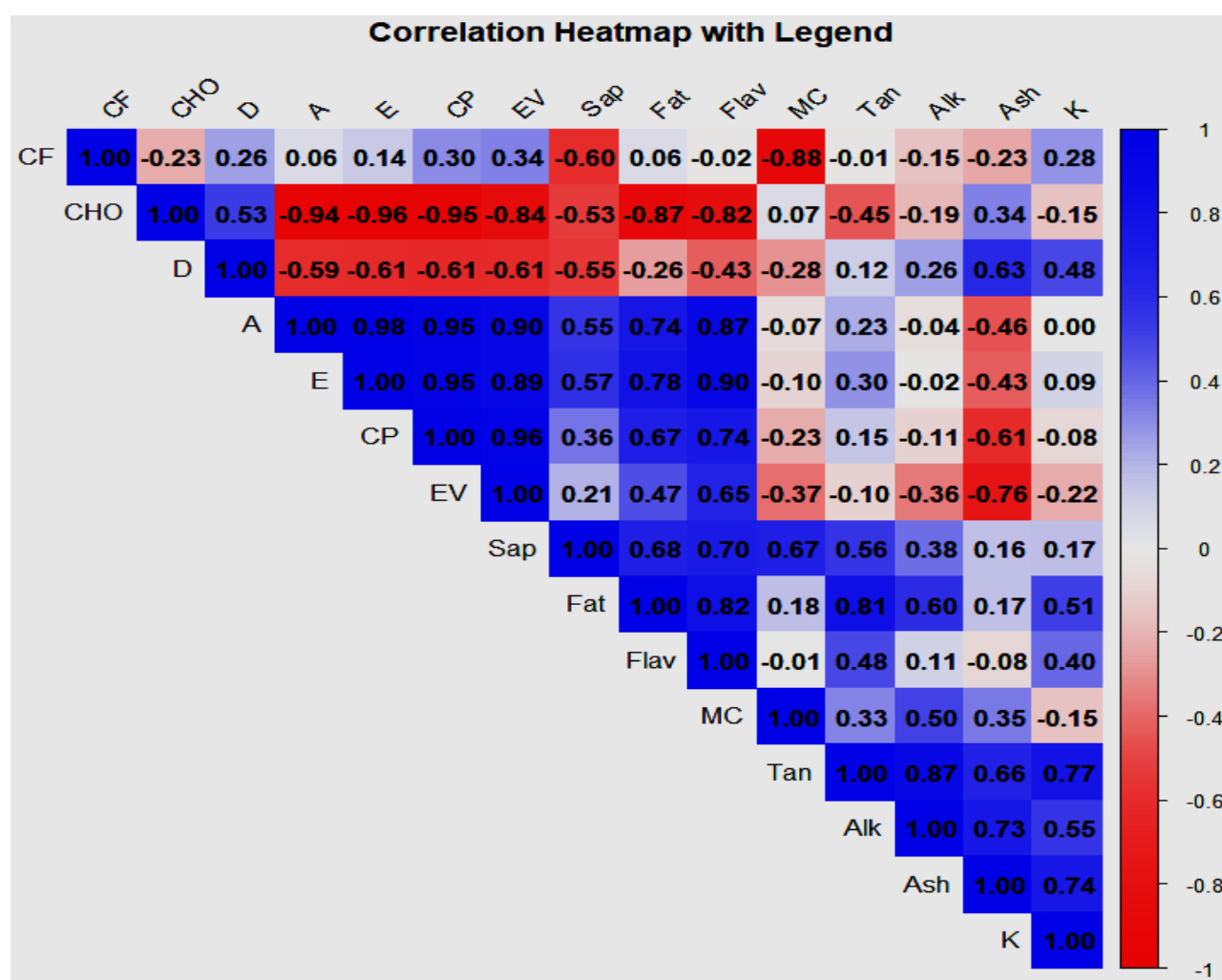


Figure 4.2: Correlation Analysis of Nutritional and Phytochemical Parameters

Conclusion

The study evaluated the nutritional, phytochemical, microbial, and sensory properties of six locally developed tea samples—Editang Black Tea, Editang Green Tea, Garden Egg Black Tea, Garden Egg Green Tea, Moringa Black Tea, and Moringa Green Tea—and compared them with a commercial control (Lipton).

Although Editan teas were found to be nutrient dense, they had the poorest sensory properties. This suggests that editan leaves could be developed in other ways while Garden egg leaf and Moringa leaves should be considered for further potentials in commercial tea product development.

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