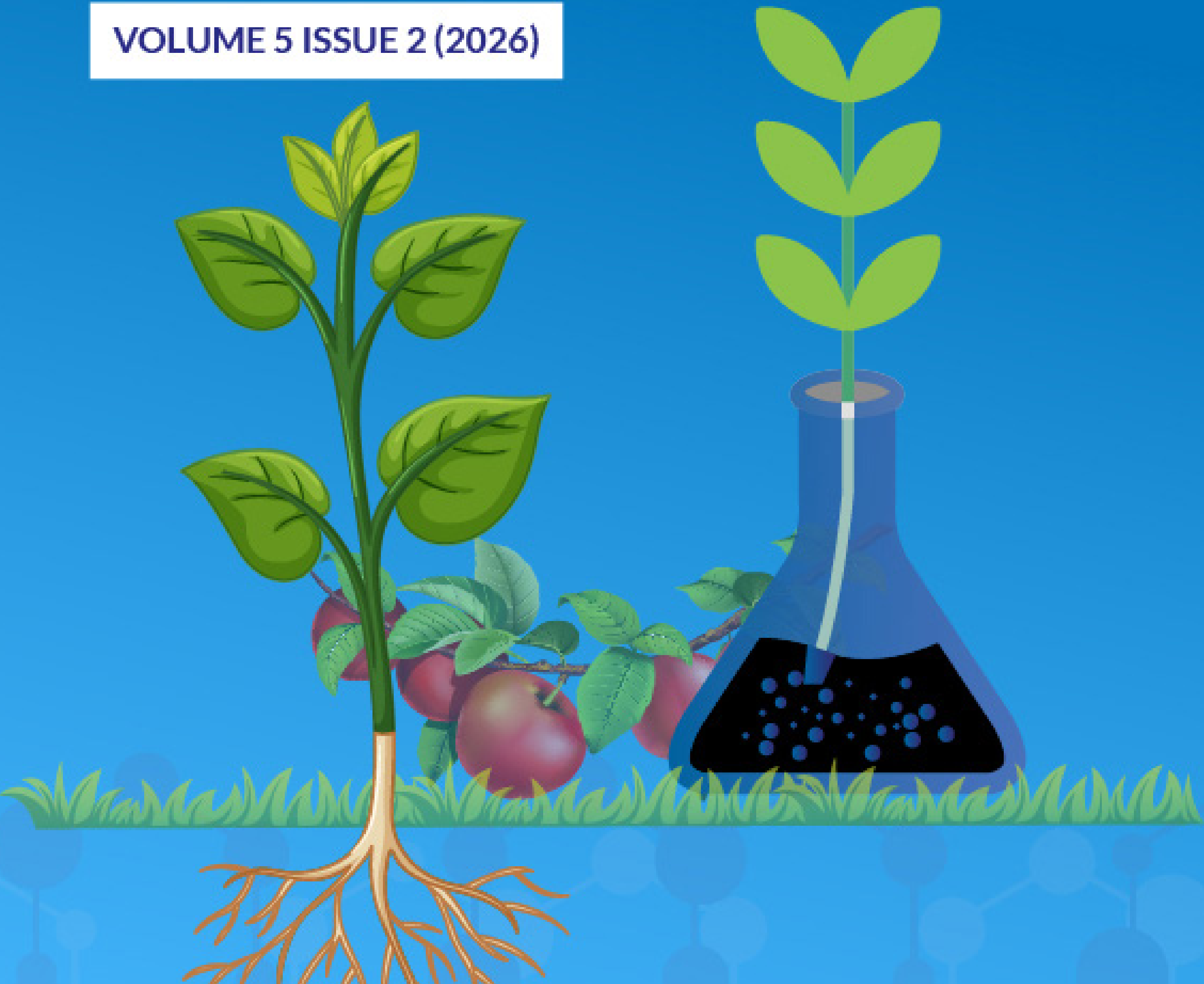
American Journal of Food Science and Technology (AJFST)

ISSN: 2834-0086 (ONLINE)

VOLUME 5 ISSUE 2 (2026)



PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Food Science and Technology (AJFST)

Volume 5 Issue 2, Year 2026
ISSN: 2837-0295 (Online)
DOI: https://doi.org/10.54536/ajfst.v5i2.7334
https://journals.e-palli.com/home/index.php/ajfst

Impact of Food Processing Methods on Antinutrient Reduction in *Colocasia Esculenta* Leaves

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Article Information

Received: January 02, 2026

Accepted: March 26, 2026

Published: July 16, 2026

Keywords

Antinutrients, Blanching, Boiling, Colocasia esculenta, Food Processing

ABSTRACT

The impact of food processing methods on antinutrient reduction in *Colocasia esculenta* leaves harvested from a vegetable garden in the University of Port Harcourt, Choba, Rivers State, Nigeria, was assayed in this study. The anti-nutrients - cardiac glycoside, hydrocyanin, oxalate, phenol, phytate, and saponin were measured in the raw sample and the samples processed by blanching, boiling, treatment with activated charcoal and vinegar respectively. The cardiac glycoside, hydrocyanin, phenol, and saponin content were measured spectrophotometrically, while oxalate and phytate were quantified using titration method. The result of the analyses showed that activated charcoal reduced hydrocyanin, oxalate, phenol, phytate, and saponin concentrations by 26.08%, 8.20%, 23.22%, 1.10%, and 13.95% respectively, but did not reduce cardiac glycoside. Blanching reduced the cardiac glycoside, hydrocyanin, oxalate, phenol, phytate and saponin concentrations by 16.67%, 75.33%, 22.95%, 34.92%, 28.73% and 33.95% respectively. The concentrations of cardiac glycoside, hydrocyanin, oxalate, phenol, phytate and saponin in *C. esculenta* leaves sample were reduced by 83.33%, 79.32%, 29.51%, 37.44%, 56.35% and 34.88% respectively after boiling. Meanwhile, vinegar reduced the concentrations of hydrocyanin, phenol, phytate and saponin by 33.80%, 18.45%, 5.52% and 1.86% respectively, but showed no reduction effect on cardiac glycoside, whereas oxalate concentration was increased by 1.61%. The result showed that boiling and blanching are more efficient processing methods that can effectively reduce the assayed antinutrients content in *C. esculenta* leaves sample. This is clear indication that adequate food processing technique can significantly reduce antinutrients and thus improve the nutritional values of non-edible vegetables.

INTRODUCTION

Bioavailability of essential nutrients such as minerals and vitamins are known to be suppressed by natural compounds referred to as antinutrients. These compounds have the ability to interfere with the absorption of essential nutrients when present in significant amount in plants and its products, thereby limiting the potential amount of the available nutrients. The antinutrient content varies with plants. The common antinutrients include saponins, hydrocyanin, phytate, phenol cardiac glycosides, and oxalate. According to Tiwari & Dubey (2025), these compounds may lead to various adverse effects when consumed in significant amount, including interfering with nutrient absorption and potential toxicity. This has led to the unjustifiable limitation in consumption of some leaves such as cocoyam leaves. *Colocasia esculenta* (cocoyam) leaves may contain notable amounts of antinutrients such as saponins, cardiac glycosides, and oxalate, amongst others which may significantly affect its nutritional potential and also impact negatively on the health status of populations that rely heavily on it as a plant-based diet. Cardiac glycosides can lead to symptoms such as vomiting, diarrhoea, abdominal pain, and, in severe cases, life-threatening arrhythmias. Cliff *et al.* (2015), reported that chronic exposure to hydrocyanins (a product of cyanogenic glucoside hydrolysis) through regular consumption of unprocessed plant products can induce goitre and hypothyroidism, as cyanide interference with iodine absorption inhibits thyroid function. According to Thakur *et al.* (2019), hydrogen cyanide inactivates the enzyme cytochrome oxidase in the mitochondria of cells by binding to the Fe^{+3}/Fe^{+2} contained in the enzyme leading to a decrease in the utilization of oxygen in the tissues. Cyanide causes an increase in blood glucose and lactic acid levels and a decrease in the ATP/ADP ratio indicating a shift from aerobic to anaerobic metabolism. The cyanide ions inhibit several enzyme systems, depress growth through interference with certain essential amino acids and utilization of associated nutrients. It also can lead to dysfunction of the central nervous system, respiratory failure and cardiac arrest (Thakur *et al.*, 2019). Mitchell *et al.* (2019), stated that high oxalate content can lead to formation of complexes with calcium, which can reduce calcium absorption and increase the risk of kidney stones. Binding of phytates and phenols can interfere with iron and zinc absorption, which are critical micronutrients needed to prevent anaemia and support immune function (Majumdar *et al.*, 2025). According to Sarkhel & Roy (2022), phytic acid reduces bioavailability of essential minerals and convert them into insoluble compounds whose absorption and digestion is less in the small intestine. Phytic acid also acts as a strong chelator,

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forming protein and mineral-phytic acid complexes; resulting to reduced protein and mineral bioavailability (Veer *et al*., 2021). According to Abu Hafsa *et al.* (2022), phytic acid also inhibits the action of gastrointestinal tyrosinase, trypsin, pepsin, lipase and amylase. Zhang *et al.* (2022), stated that phytic acid significantly affect human nutrition by reducing zinc bioavailability. Gemede & Ratta (2014), posited that dietary phytate may be beneficial to diabetic patients as it lowers blood glucose response by reducing the rate of starch digestion and slowing gastric emptying. Pujol *et al.* (2023), stated that phytate is believed to reduce blood clots, cholesterol, and triglycerides, and thus prevents heart diseases, and also prevents renal stone development. Guayjarernpanishk & Sampanpanish (2024), stated that phytate is used as a complexing agent for removal of traces of heavy metal ions. According to Thakur *et al.* (2019), phenol (gossypol) toxicity can lead to depressed appetite, loss of weight, laboured breathing and cardiac irregularity. Also, death due to gossypol toxicity is usually associated with reduced oxygen carrying capacity of the blood, haemolytic effects on erythrocytes and circulatory failure. Another phenolic compound tannins are heat stable and they decreased protein digestibility in animals and humans, probably by either making protein partially unavailable or inhibiting digestive enzymes and increasing fecal nitrogen (Zayed *et al*., 2025). Salim *et al.* (2023), stated that tannins interfere with digestion by displaying anti-amylase activity. Also, Hoque *et al.* (2025), affirmed that tannins can lead to inhibition of digestive enzymes, digestive tract malfunctions, increase excretion of endogenous protein, and other toxicity of absorbed tannin or its metabolites. Notwithstanding the cholesterol-lowering and immune-boosting properties of saponin as reported by some researchers, its high concentration can disrupt cell membranes and affect nutrient absorption (Iwuoha & Kalu, 1995). Saponins are anti-nutrient constituents with adverse effects such as growth impairment and throat-irritating activity due to its bitterness which reduce their intake (Shi *et al*., 2004). According to Gilani *et al.* (2012), saponins were found to reduce the bioavailability of nutrients and decrease enzyme activity and it affects protein digestibility by inhibiting various digestive enzymes such as trypsin and chymotrypsin. On the other hand, Hamid *et al.* (2017), stated that saponins reduce the uptake of certain nutrients including glucose and cholesterol at the gut through intralumenal physicochemical interaction, hence it has been reported to possess hypocholesterolemic and immunostimulatory properties. Considering the negative impacts of anti-nutritional factors which limit the wider dietary adoption of cocoyam leaves, as well as the paucity of published scientific research on the effective processing techniques that can significantly minimize these indices, this study investigated the efficiency of some food processing techniques (such as boiling, blanching, treatment with activated charcoal and vinegar respectively) in reducing the antinutrient content in *Colocasia esculenta* (cocoyam) leaves as to improve its nutritional profile and safety.

MATERIALS AND METHODS

Materials

The equipment, reagents and chemicals used in this study were of standard analytical grade.

Collection and Preparation of Plant Sample

Colocasia esculenta leaves were collected from a farm in the University of Port Harcourt, Choba in Obio/Akpor Local Government Area, Rivers State, Nigeria. The leaves were plucked, washed and drained. The unprocessed leave samples were divided into five portions. One portion remained unprocessed (raw), while the remaining four portions were processed by blanching, boiling, treatment with activated charcoal and vinegar respectively. Blanching was achieved by immersing the sample in a pot of heated water for about 10 minutes, afterwards the sample was removed and immediately immersed in a bowl of ice water to stop further cooking. Boiling was done by immersing the sample in a pot of boiling water set on a hot plate and was allowed to heat for about 20 minutes, after which it was drained of water and allowed to cool. The fourth portion was soaked in 5% activated charcoal solution for 1 hour, after which it was removed and thoroughly rinsed with distilled water to eliminate any residual activated charcoal. The last portion was soaked in a vinegar solution for a duration of 1 hour. After which it was rinsed with distilled water to remove any remaining vinegar traces. 1.5g each of the unprocessed and processed samples was weighed with an electronic weighing balance. The individual samples were crushed, after which 10ml of distilled water was added to the respective crushed samples before mixing. The individual mixtures were then filtered using Whattman filter paper (11 micrometre) into different test tubes which were labelled accordingly as raw, blanched, boiled, activated charcoal and vinegar treated respectively and kept in a test tube rack. The extracts were afterwards centrifuged at an RPM (Rotation per minute) of 4000 for about 15 minutes to ensure even separation of the liquid extract from left over leaf particles. The respective supernatants were then assayed for antinutrients such as cardiac glycoside, hydrocyanin, oxalate, phenol, phytate and saponin.

Methods

Quantification of Cardiac Glycoside

The cardiac glycoside content was estimated according to the method of Solich *et al.* (1992), with some modification by Sahoo & Marar (2018). Based on the method, 1ml of Baljet's reagent (95 ml of 1% picric acid + 5 ml of 10% NaOH) was added to each of the standard and extract solution. The mixture was diluted with 20ml distilled water after 1 hour of incubation, and absorbance read at 495 nm against distilled water blank. The total glycoside content was calculated with the formula;

Quantification of Hydrocyanin

$$\text{Total glycosides (mg/100g)} = \frac{\text{Absorbance x 100}}{77}$$

Hydrocyanin concentration was determined using the method described by Ubwa *et al.* (2015). According to the method, 1ml each of the plant extract was mixed with 10ml of freshly prepared Baljet's reagent which was made from a mixture of 95ml of 1% picric acid and 5ml of 10% NaOH (sodium hydroxide) and kept for an hour. The mixture was then diluted with 20ml of distilled water and the absorbance measured at 495nm using a UV/VIS spectrophotometer. Hydrocyanin concentration was estimated using freshly prepared sodium cyanide solution as standard.

Quantification of Oxalate

Oxalate content was quantified using the method of Mishra *et al.* (2017). According to the method, 1 g of the leaf sample was boiled in 50 mL of 1 M hydrochloric acid for 30 minutes. The extract was then filtered and allowed to cool. To this extract was added 10 mL of sulfuric acid and the mixture was heated to 70°C. Titration was performed immediately with a 0.05 M potassium permanganate ($KMnO4$) solution until a faint pink colour, which persisted for 5 minutes was observed. The oxalic acid concentration was calculated using the formular:

Quantification of Phenol

$$\% \text{ Oxalic acid (O. A)} = \frac{\text{Amount of oxalic acid} \times 100}{\text{Sample weight}}$$

Where:

$$\text{Amount of O. A} = \frac{\text{Vol. of } KMnO_4 \times \text{Normality of } KMnO_4 \times \text{Equivalent weight of O. A}}{1{,}000} \times \frac{100}{1}$$

The total phenolic content was determined using the Folin-Ciocalteu's reagent (FCR) as described by Sankhalkar & Vernekar (2016). According to the procedure, 2ml of each of the filtrate was mixed with 0.4ml FCR (diluted 1:10 v/v). 4ml sodium carbonate solution was added after 5 minutes. The volume of the mixture was made up to 10ml with distilled water and allowed to stand for 90 minutes at room temperature. The absorbance of the samples was measured at 750nm using a UV-VIS spectrophotometer. A calibration curve was prepared using catechol solutions as standard and total phenolic content of the extract was expressed in milligrams of catechol per gram of dry weight.

Quantification of Phytates

The method established by Reason *et al.* (2016) was adopted in the estimation of phytic acid. According to the method, sample weighing 2g was crushed in a crucible, and placed in a 250 mL conical flask. To this was added 100 mL of 2% concentrated hydrochloric acid, and the mixture was allowed to stand for 3 hours. The solution was then filtered through a double layer of hardened filter paper, and 50 mL of the filtrate was transferred to a 250 mL beaker. 100 ml of distilled water was added to the filtrate to adjust its acidity. 10 mL of 0.3% ammonium thiocyanate solution was used as an indicator, and the filtrate was titrated with a standard iron (III) chloride solution containing 0.00195 g of iron per mL. The titration continued until a slight brownish-yellow colour persisted for 5 minutes. The percentage of phytic acid was calculated using the formula:

Where:

$$\% \text{ Phytic acid} = \frac{(X \times 1.19 \times 100)}{2}$$

X = titre value (ml) x 0.00195 (g iron/ml)

1.19 = conversion factor (phytic acid/iron)

2 = sample weight (g)

Quantification of Saponins

Saponin was quantified with the established method of Du *et al.* (2017). According to the method, 0.5 g of the sample was extracted with 50 mL of 80% methanol for a duration of 2 hours. The extract was then evaporated to dryness, and the residue was dissolved in 5 mL of ethanol. A 0.5 mL portion of this extract was mixed with 0.5 mL of an 8% vanillin solution in ethanol, after which 5 mL of 72% sulfuric acid was added, and the mixture was incubated in a water bath at 60°C for 10 minutes. The absorbance of the resulting solution was measured at 544 nm using a spectrophotometer. Saponin concentration was deduced from a standard curve of freshly prepared commercial saponin.

Statistical Analysis

Data were analysed using SPSS (Version 23). Descriptive statistics, including means and standard deviations were used to analyse the levels of cardiac glycoside, hydrocyanin, oxalate, phenol, phytate, and saponin in the unprocessed and processed *Colocasia esculenta* samples. Analysis of variance (ANOVA) was conducted to determine significant differences among the treatment groups, whereas significant differences were observed using Duncan post hoc tests. The significance level was set at $p < 0.05$. Results were expressed as mean ± standard deviation.

RESULTS AND DISCUSSION

Impact of processing methods on antinutrient content of *Colocasia esculenta* Leaves

The result of the antinutrient content of the unprocessed and processed *C. esculenta* leaves were presented in Table 1. From the result, boiling significantly ($p<0.05$) reduced cardiac glycoside content from 0.06 ± 0.01 mg/100g to 0.01 ± 0.00 mg/100g. There was no significant difference in the cardiac glycoside content among the raw sample and the other treated samples. The hydrocyanin and phenolic content were significantly ($p<0.05$) reduced by the four processing methods but most efficiently by boiling and blanching. The oxalate content was significantly ($p<0.05$) reduced by boiling, blanching and activated charcoal treatment from 0.61 ± 0.03 g/100g to 0.43 ± 0.01 g/100g, 0.47 ± 0.02 g/100g and 0.56 ± 0.01 g/100g respectively. Boiling and blanching significantly (p<0.05) reduced the phytate content from 1.81 ± 0.07 g/100g to 0.79 ± 0.03 g/100g and 1.29 ± 0.06 g/100g respectively. The saponin content of the sample was significantly (p<0.05) reduced by boiling, blanching and activated charcoal treatment from 2.15 ± 0.07 g/100g to 1.40 ± 0.01 g/100g, 1.42 ± 0.04 g/100g and 1.85 ± 0.01 g/100g respectively. Treatment with vinegar showed no significant (p<0.05) reduction when compared to the raw (unprocessed) sample.

Discussion

Table 1: Antinutrient reduction capacity of processing methods in *C. esculenta* Leaves

Anti-nutrients	Raw Sample	Activated Charcoal Treated	Blanched	Boiled	Vinegar Treated
Cardiac glycoside (mg/100g)	0.06 ± 0.01^{b}	0.06 ± 0.00^{b}	0.05 ± 0.00^{b}	0.01 ± 0.00^{a}	0.06 ± 0.01^{b}
Hydrocyanin (g/100g)	12.04 ± 0.18^{e}	8.90 ± 0.13^{d}	2.97 ± 0.16^{b}	2.49 ± 0.17^{a}	7.97 ± 0.19^{c}
Oxalate (g/100g)	0.61 ± 0.03^{d}	0.56 ± 0.01^{c}	0.47 ± 0.02^{b}	0.43 ± 0.01^{a}	0.62 ± 0.01^{d}
Phenol (mg/100g)	11.11 ± 0.09^{e}	8.53 ± 0.23^{c}	7.23 ± 0.13^{b}	6.95 ± 0.18^{a}	9.06 ± 0.10^{d}
Phytate (g/100g)	1.81 ± 0.07^{c}	1.79 ± 0.03^{c}	1.29 ± 0.06^{b}	0.79 ± 0.03^{a}	1.71 ± 0.09^{c}
Saponin (g/100g)	2.15 ± 0.07^{c}	1.85 ± 0.01^{b}	1.42 ± 0.04^{a}	1.40 ± 0.01^{a}	2.11 ± 0.03^{c}

Values represent mean ± standard deviation. Values with different superscripts indicate significant differences (p<0.05) between the two samples for each antinutrient, while values with similar superscript are not significantly different from each other.

Plants such as vegetables are rich sources of bioactive compounds associated with the prevention and management of chronic health conditions such as hypertension, cardiovascular disease, inflammation, and cancer (Adobe *et al.*, 2026). Consumption of vegetables in their fresh form is believed to contain more micronutrients than processed vegetables but the high levels of anti-nutrients and toxic substances in unprocessed vegetables is a major health concern because of the associated health complications (Thakur *et al.*, 2019). Tropical root crops like cocoyam (*Colocasia esculenta*) are grown extensively for their starchy corms and rich vital nutrients such as vitamins, minerals, fibre and antioxidants. According to Ukwu *et al.* (2022), cocoyam leaves are commonly used as a traditional vegetable in many tropical and subtropical countries, notwithstanding the reported nutritional composition of cocoyam leaves. Its use as food is severely hindered by the presence of anti-nutritional compounds such as phenol, hydrocyanin and cardiac glycoside that hinder nutrient absorption. Anti-nutrients can decrease the nutritional value of leaves by preventing the bioavailability of minerals that are essential for human health. The current study investigated the reduction impact of different processing techniques - blanching, boiling, treatment with activated charcoal, and vinegar treatment on some antinutrients (cardiac glycoside, hydrocyanin, oxalate, phytate, phenol and saponin) in *C. esculenta* leaves. From the results presented in the table above, there was no significant reduction in cardiac glycoside (0.00%) and phytate (1.10%) concentrations after processing the sample with activated charcoal. According to Olaniyii and Rufai (2020), higher concentrations of cardiac glycoside and phytate can reduce nutrient bioavailability. The stability of cardiac glycoside and phytate after treatment suggests that activated charcoal selectively adsorbs certain compounds while leaving others unaffected. This selectivity could be attributed to the molecular size, polarity, and binding affinities of the compounds to the activated charcoal's surface. Meanwhile Nnadiukwu *et al.* (2025), reported phytate reduction by activated charcoal treatment suggesting that the processing method could be used to reduce phytate level in various plant foods. Nevertheless, activated charcoal significantly (p<0.05) reduced hydrocyanin, oxalate, phenol and saponin concentrations by 26.08%, 8.20%, 23.22%, and 13.95% respectively. The substantial reduction in hydrocyanin level demonstrated the effectiveness of activated charcoal in adsorbing toxic compounds. The result aligns with previous studies that reported activated charcoal's high adsorption capacity for cyanogenic compounds, which is primarily due to its large surface area and high porosity (Tahir *et al.*, 2024). Olayeni *et al.* (2023), demonstrated that the addition of activated charcoal, a non-nutritive adsorptive material to diets decreased the sorption of HCN from the GIT. Hydrocyanin, a precursor of hydrogen cyanide, is known to interfere with cellular respiration when consumed in significant amounts (Lachowicz *et al.*, 2024). Thus, its high content in leafy vegetables is a concern for populations that rely on these plants for essential diet. The significant (p<0.05) reduction in oxalate concentration suggests the ability of activated charcoal in mitigating oxalate-related risks, such as kidney stone formation. This observation is in line with the findings of

Huynh *et al.* (2022), which confirmed that activated charcoal is an effective treatment method for reducing oxalate contents in plant foods. The observed decrease in phenolic content is an indication that activated charcoal can effectively reduce this antinutritional factor and its negative effects. Treatment with activated charcoal can reduce phenolic content in plant materials through adsorption, thereby improving their palatability and digestibility. The recorded saponin reduction in the sample after treatment with activated charcoal in line with the report of Nnadiukwu *et al.* (2025), which stated that activated charcoal can effectively reduce saponin content in plant foods. Blanching on the other hand significantly ($p<0.05$) reduced hydrocyanin, oxalate, phenol, phytate and saponin concentrations by 75.33%, 22.95%, 34.92%, 28.73% and 33.95% respectively, but slightly reduced cardiac glycoside by 16.67%. This result indicated that blanching had a notable reduction impact on the antinutrient profile of *Colocasia esculenta* leaves. According to Tahir *et al.* (2024), reduction in hydrocyanin can be through thermal degradation of cyanogenic glycosides or inactivation of β-glucosidase, the enzyme that hydrolyses cyanogenic glycosides to release free hydrocyanin. Also, antinutrients can be reduced by blanching via leaching of water-soluble compounds into the blanching water, and volatilisation of any releases hydrocyanin gas during heating. The oxalate reduction can be attributed to the mild heat exposure and the subsequent leaching of oxalates during the blanching process. According to Sharma *et al.* (2025), there is a reduction in oxalate content of leafy greens subjected to blanching. The reduction in phenolic content by blanching as recorded in this study contradicts the report of Quaye *et al.* (2021), that blanching does not have significant reduction effect on the total phenolic content in *C. esculenta* leaves rather it preserves the phenolic content in this vegetable. This stability may vary slightly depending on the leaf variation and specific phenolic compounds. The decrease in phytate indicates the effectiveness of blanching in reducing phytate which is likely through partial hydrolysis and leaching. This outcome is in agreement with the findings of Tyohemba *et al.* (2019), that reported similar reductions in phytate content following blanching. In another study by Waseem *et al.* (2022), blanching significantly reduced oxalate, and phytate content in cabbage powder, and suggested that the apparent decline in anti-nutrients could be attributed to the greater extent of water solubility and thermal degradability of the nutrients–toxicants complexes. The reduction in saponin content suggests that the limited heat intensity and shorter processing time of blanching was adequate in disrupting the structure of saponins. The moderate reduction in cyanogenic glycoside concurred with the report of Lola (2009), that blanching performed at lower temperatures and for shorter duration results in slight reductions in cyanogenic glycoside levels. Boiling significantly ($p<0.05$) reduced all the antinutrients concentrations in the cocoyam sample. Cardiac glycoside, hydrocyanin, oxalate, phenol, phytate and saponin concentrations were reduced by 83.33%, 79.32%, 29.51%, 37.44%, 56.35% and 34.88% respectively. The effectiveness of boiling in reducing the aforementioned antinutrients could be attributed to its increased heat and temperature. Urugo and Tringo (2023), reported that boiling was very effective in reducing cardiac glycosides due to the sustained high temperatures and water contact that facilitate their leaching. Agbai *et al.* (2021), reported the reduction of hydrocyanin content in rubber seed meal after boiling. The efficiency of boiling in reducing hydrocyanin could be attributed to the long heating time and high temperature and thus supports the report of Narale *et al.* (2024), which stated that boiling at high temperatures allows for nearly complete elimination of cyanogenic compounds as they are water-soluble and heat-sensitive. The reduction of oxalate content highlights the efficiency of boiling in minimizing oxalate content, likely due to its water solubility and the leaching of oxalate into the boiling medium. This outcome confirms the report of Eze *et al.* (2020), that oxalate content of Amaranthus hybridus was reduced after boiling, and thus attributed it to the water-soluble oxalate leaching. Also, Agbai *et al.* (2021), reported that boiling significantly reduced oxalate content in rubber seed meal. Noviasari *et al.* (2024), reported that physical treatment such as boiling reduced calcium oxalate content of Kimpul taro flour. However, current finding contradicts the results of Rahman *et al.* (2018), that recorded limited oxalate reduction in Spinacia oleracea during boiling, suggesting that boiling duration and initial oxalate concentration may significantly influence the outcome. The reduction in phenol concentration indicates that boiling was very effective in reducing the phenol content of the sample. Phytate reduction suggests its degradation during boiling. The notable reduction in phytate content is in tandem with the result of Igwe and Ojiako (2021), that reported nearly complete phytate degradation in Moringa oleifera leaves after prolonged boiling. Agbai *et al.* (2021), also reported the efficiency of boiling in reducing phytic acid content in rubber seed meal. According to Liu *et al.* (2019), boiling was the most effective cooking treatments that reduced phytate level. This could be attributed to hydrolysis of phytic acid by heat (Cheng & Langrish, 2025). Boiling was also effective in lowering saponin level. Saponin reduction after boiling can be attributed to the heat-induced breakdown of saponins and their partial solubility in water. This outcome agrees with the work of Osunde and Balami (2022), that recorded significant decrease in saponin levels in Solanum nigrum leaves after boiling, due to thermal breakdown and leaching. Agbai *et al.* (2021), also reported reduction of saponin content in rubber seed meal after boiling. Treatment with vinegar significantly ($p<0.05$) reduced hydrocyanin and phenol by 33.80% and 18.45% respectively. Vinegar treatment showed no significant reduction effect on cardiac glycoside, oxalate, phytate and saponin. However, phytate and saponin were slightly reduced by 5.52% and 1.86%

respectively. The effectiveness of vinegar treatment in reducing the concentrations of hydrocyanin may be attributed to its acidic nature, which likely stimulates the breakdown and volatilization of cyanogenic glycosides, rendering the compound less toxic (Tahir *et al.*, 2024). Recall, hydrocyanin is a cyanogenic compound that can release toxic hydrogen cyanide upon hydrolysis. This result aligns with previous research that identified acidic solutions, such as vinegar, as effective agents for reducing cyanogenic compounds in plant-based foods (Raji *et al.*, 2020). As per phenol, the acidic nature of vinegar may have facilitated the hydrolysis of phenolic compounds, making them less bioactive as antinutrients (Atuna *et al.*, 2025). These findings support earlier studies that explored the use of acidic treatments to modify phenolic content in plant-based foods, improving their digestibility and tolerability. The stability of the other assayed antinutrients after vinegar treatment suggests that vinegar selectively targets specific antinutrients without altering others. Cardiac glycosides, though toxic in high amounts, are often present in minimal, non-toxic levels in leafy vegetables, providing potential pharmacological benefits (Akinwumi & Ambali, 2024). The result indicates that vinegar treatment is non-destructive and preserves the plant's biochemical integrity for this class of compounds. This aligns with the report of Salgado *et al.* (2023), which indicated vinegar's primary action was more on mineral-binding anti-nutrients such as phytates rather than glycosides. The weak adsorption capacity of vinegar over oxalate in the current experiment that led to no observable reduction in oxalate content may be attributed to the insolubility of certain oxalate compounds in the acidic condition. Mirahmadi *et al.* (2022), also reported the reductive effect of vinegar treatment on oxalate in Spinacia oleracea. According to Ghanati *et al.* (2024), vinegar significantly reduced the oxalate content and also improved calcium bioavailability which is commonly inhibited by oxalate in vegetables. The slight phytate reduction (~5.52%) recorded in this study is in line with the findings of Bester (2023), that reported vinegar as an effective agent that can reduce phytate levels in plant-based foods. Pandey *et al.* (2023), had reported that vinegar reduced the phytate content of Triticum aestivum, thereby improving the bioavailability of essential minerals such as iron and zinc, which are often bound by phytates. This effect can be attributed to the acidic nature of vinegar that contributed to the partial degradation of phytates, thus making minerals more available for the body's absorption. Also, the slight reduction in saponin concentration (1.86%) recorded in this study after vinegar treatment affirms the findings of Faizal *et al.* (2023), that vinegar can reduce saponin levels in plant-based foods. The recorded saponin reduction by vinegar can be attributed to the acidic environment created by vinegar which facilitated the degradation of saponin molecules, thereby can improve mineral bioavailability, particularly calcium, which is often bound by saponins in legumes and other plant foods. The current study indicated that vinegar treatment was more effective in reducing hydrocyanin and phenol, with slight effect on phytate and saponin, and no observable effect on cardiac glycoside and oxalate.

CONCLUSIONS

The current study highlighted the impact of various food processing techniques in reducing antinutrients in *Colocasia esculenta* leaves. The reduction potential of activated charcoal, blanching, boiling and vinegar treatment against cardiac glycoside, hydrocyanin, oxalate, phenol, phytate, and saponin was investigated and the result revealed varied effects of the different processing techniques applied. The study revealed that boiling was more effective than the other processing methods as it showed remarkable reduction potential on all the assayed antinutrients. Blanching also showed promising reduction potential on all the antinutrients except for cardiac glycoside. Treatment with activated charcoal demonstrated some reduction effect on hydrocyanin, oxalate, phenol and saponin, but had no significant effect on phytate and cardiac glycoside. Vinegar's antinutrient reduction ability was significantly potent on hydrocyanin and phenol only. Meanwhile, its slight effect was observed in the reduction of phytate and saponin, with no impact showed on cardiac glycoside and oxalate. The study has emphasized boiling and blanching as valuable processing technique that can enhance the nutritional quality of *C. esculenta* leaves. The investigation also revealed the reduction impact of all the processing methods on hydrocyanin and phenol. The study established that the antinutritive components of non-consumable vegetables and food products can be reduced to a tolerable level by applying any of the suitable processing techniques. Hence, will improve the safety and nutritional value of such food products, thereby encouraging its consumption as part of local diets which will reduce food wastage. Further investigations should explore the optimisation of the various processing methods in reducing antinutrients to improve dietary benefits.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Funding Statement

This research did not receive any funding.

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