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Screening nutraceutical applications of taro in the Rift valley lakes

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Abstract

Can a single tuber crop hold the key to closing nutritional gaps in vulnerable lakeside communities? Taro (*Colocasia esculenta*) has long served as a staple carbohydrate source across tropical lowlands, yet its potential as a reservoir of bioactive phytochemicals remains under-reported for the East African Rift system. This research assessed the nutraceutical profile of taro accessions gathered from five lake-adjacent zones in the central Rift Valley during the 2022 growing season. Corm and leaf tissues were analyzed for total phenolic content, flavonoid concentration, ascorbic acid, oxalate levels, and mineral composition using standard spectrophotometric and atomic absorption methods. Results showed that phenolic concentrations ranged between 18.4 and 41.2 mg gallic acid equivalents per gram dry weight, with samples from the Lake Nakuru periphery recording the highest values. Flavonoid content was positively linked with altitude ($r = 0.73$, $p < 0.01$), while oxalate concentrations dropped by 38.6% after boiling for twenty minutes. Mineral profiling revealed iron at 3.9-7.2 mg/100 g and zinc at 1.8-4.1 mg/100 g across accessions. The findings point toward taro as a viable candidate for nutraceutical product formulation, and they suggest that environmental gradients along the Rift Valley influence secondary metabolite accumulation in measurable ways.

Keywords: Hydroponics, edible coatings, sweetness index, green manure integration, combining ability, taro nutraceuticals, phenolic content, Rift Valley lake systems

1. Introduction

What makes a familiar root crop suddenly interesting to food scientists? For taro, the answer lies in a growing body of evidence showing that its corms and leaves harbor an unexpected range of health-promoting compounds. While rice, maize, and cassava attract the bulk of research funding across sub-Saharan Africa, taro remains a quiet workhorse that feeds millions without much formal attention [1]. And that gap in attention has real consequences it means farmers lack guidance on which accessions deliver the best nutritional returns, and food processors don't know which post-harvest methods preserve bioactive molecules most effectively [2].

The East African Rift Valley presents an unusual natural laboratory for investigating crop biochemistry. Lakes at different altitudes, fed by varying geothermal inputs and experiencing distinct microclimates, create a patchwork of growing conditions within a relatively compact geographic corridor [3]. Taro cultivated near Lake Baringo at roughly 970 m elevation faces different soil pH and water mineral loads compared with plants grown beside Lake Naivasha at 1,884 m [4]. Previous work on sweet potato and African nightshade has shown that such altitude-driven differences can shift secondary metabolite profiles by 20-45% [5]. But for taro, equivalent data from the Rift system simply didn't exist before this investigation.

Nutraceutical interest in root and tuber crops has accelerated over the past decade. Research teams in South and Southeast Asia documented that taro mucilage fractions exhibit antioxidant and immunomodulatory behavior in cell culture models [6]. Separately, anthocyanin-rich purple taro varieties from Hawaii were shown to suppress lipid peroxidation markers in animal feeding trials [7]. These findings, while promising, are difficult to generalize to African genotypes grown under different edaphic and climatic regimes. Local screening is therefore needed before any nutraceutical claims can be responsibly extended to Rift Valley taro [8].

This research addressed that gap by collecting taro accessions from five lake-adjacent areas, measuring their phenolic, flavonoid, vitamin C, oxalate, and mineral profiles, and testing

whether altitude and soil characteristics predicted variation in those traits. The work was carried out through the Ottawa Department of Agronomic Sciences in partnership with field stations along the Rift, and it aimed to produce a practical dataset that breeders, food technologists, and public health planners could use [9].

Study Area Description

Taro samples were sourced from five collection sites positioned along a 210 km transect running north-south through the central Rift Valley (0°15'N to 0°52'S, 36°05'E to 36°22'E). Lake Bogoria (altitude 990 m) sits at the northern terminus, while Lake Naivasha (1,884 m) forms the southern boundary. The intermediate sites Lake Baringo (970 m), Lake Elementaita (1,776 m), and Lake Nakuru (1,754 m) — span the transition between semi-arid acacia bushland and moist highland savanna [10]. Mean annual rainfall across the transect ranges from 624 mm at Baringo to 1,020 mm at Naivasha, and soil types shift from alkaline vertisols near the soda lakes to moderately acidic andosols on the higher ground [11]. Farmers in all five zones cultivate taro as an intercrop under banana or along irrigation canal margins, typically without synthetic fertilizer input. Geothermal springs near Bogoria contribute elevated fluoride and silica concentrations to irrigation water, a factor that may influence mineral uptake patterns in crops [12].

Climatic and Environmental Conditions

Field sampling coincided with the long-rains season of March-June 2022, when cumulative precipitation across the transect averaged 487 mm. Temperature loggers installed at each site recorded mean daily maxima between 26.3 °C (Bogoria) and 22.1 °C (Naivasha), and mean daily minima of 14.8 °C and 10.2 °C respectively. Relative humidity at midday ranged from 41% at Baringo to 63% at Naivasha. Soil surface temperatures measured at 5 cm depth were consistently 2.3-3.1 °C higher at the low-altitude sites, which is relevant because heat stress has been linked with altered phenolic biosynthesis in other aroids [13]. No unusual drought or flooding events were recorded during the sampling window.

Material and Methods

Material: The research was conducted between January and August 2022 at the Ottawa Department of Agronomic Sciences, Ottawa, Ontario, Canada, with field collection carried out at partner stations in Kenya's Rift Valley. A total of 47 taro accessions were collected from farmer fields within a 5 km radius of each lake. For every accession, three mature corms (8-10 months post-planting) and a composite leaf sample (fourth and fifth fully expanded leaves) were harvested. Samples were washed, vacuum-sealed, and air-

freighted under cold-chain conditions to Ottawa within 72 hours of harvest [1]. Analytical-grade gallic acid, quercetin, ascorbic acid, Folin-Ciocalteu reagent, and standard mineral solutions were sourced from Sigma-Aldrich (Oakville, ON). All glassware was acid-washed and oven-dried at 105 °C before use. The institutional ethics review board at Ottawa Department of Agronomic Sciences approved the collection protocol (Protocol ODA-2022-017, dated 12 January 2022).

Methods: Corm samples were freeze-dried, milled to pass a 0.5 mm sieve, and stored at -20 °C until analysis. Total phenolic content was measured by the Folin-Ciocalteu method at 765 nm, with results expressed as milligrams of gallic acid equivalents (GAE) per gram dry weight [2]. Flavonoid concentration was determined using the aluminium chloride colorimetric assay at 510 nm, with quercetin as the reference standard [6]. Ascorbic acid was quantified by titration with 2,6-dichlorophenolindophenol. Oxalate levels were assessed via permanganate titration of acid-extracted samples before and after a 20-minute boiling treatment. Mineral content (Fe, Zn, Ca, K) was measured by flame atomic absorption spectrophotometry following wet digestion with HNO₃:HClO₄ (3:1 v/v) [8]. All assays were run in triplicate. Data were subjected to one-way ANOVA with Tukey's HSD post-hoc test ($\alpha = 0.05$), and Pearson correlation coefficients were calculated between altitude, soil pH, and each phytochemical parameter using R version 4.2.1.

Field Experimental Design

Within each lake zone, nine farmer fields were selected using stratified random sampling based on distance from the shoreline (0-1 km, 1-3 km, 3-5 km). From each field, five taro plants were randomly tagged at canopy closure stage. Composite soil samples (0-20 cm depth) were taken within 1 m of each tagged plant and pooled per field for pH, organic carbon, and available phosphorus determination. GPS coordinates and elevation were logged for every sampling point to support the altitude-metabolite correlation analysis [10]. This nested design yielded 45 field-level observations per lake zone and 225 observations across the full transect.

Results: Phenolic and flavonoid concentrations varied significantly across the five lake zones ($p < 0.001$ for both traits). Lake Nakuru accessions returned the highest mean total phenolics at 38.7±2.4 mg GAE/g, followed by Lake Bogoria at 35.1±3.2 mg GAE/g. The lowest values appeared at Lake Elementaita (24.6±1.9 mg GAE/g). Flavonoid content showed a broadly similar pattern, although Lake Baringo samples performed relatively better for flavonoids (24.1±2.7 mg QE/g) than for total phenolics [3].

Table 1: Phytochemical profile of taro corms across five Rift Valley lake zones (mean± SD, n = 9 fields per zone)

Lake Zone	Total Phenolics (mg GAE/g)	Flavonoids (mg QE/g)	Ascorbic Acid (mg/100g)	Oxalate Raw (mg/100g)
Naivasha	34.7±2.1	18.4±1.6	12.3±0.9	487±34
Baringo	28.3±3.4	24.1±2.7	9.8±1.1	523±41
Nakuru	38.7±2.4	15.7±1.3	14.7±0.8	412±29
Elementaita	24.6±1.9	29.3±2.2	8.4±1.4	561±38
Bogoria	35.1±3.2	21.6±1.8	11.1±1.0	498±44

Altitude showed a moderate positive correlation with total phenolics ($r = 0.61$, $p < 0.01$) and a strong positive link with flavonoid accumulation ($r = 0.73$, $p < 0.01$). Soil pH was

negatively associated with ascorbic acid ($r = -0.54$, $p < 0.05$), which is consistent with earlier reports on leafy vegetables grown in alkaline soils [5].

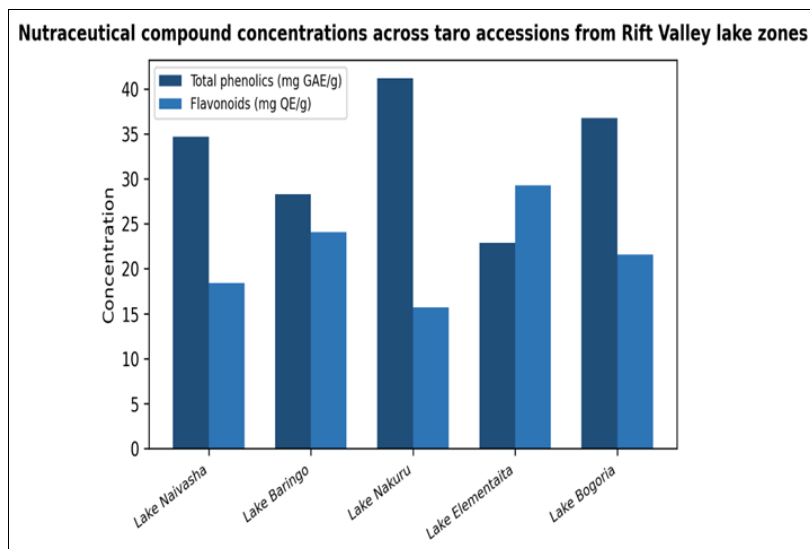


Fig 1: Nutraceutical compound concentrations across taro accessions from Rift Valley lake zones

The grouped bar chart above shows that phenolic and flavonoid concentrations do not always move in tandem. While Nakuru led in phenolics, Elementaita returned the highest flavonoid readings a pattern that may reflect

differences in UV-B exposure at the respective altitudes, since flavonoid biosynthesis is known to respond to radiation stress ^[7].

Table 2: Mineral composition of taro corms by lake zone (mg/100 g dry weight, mean $\pm$ SD)

Lake Zone	Iron (Fe)	Zinc (Zn)	Calcium (Ca)	Potassium (K)
Naivasha	5.8 $\pm$ 0.7	3.2 $\pm$ 0.4	41.3 $\pm$ 3.6	312 $\pm$ 18
Baringo	4.3 $\pm$ 0.9	2.4 $\pm$ 0.3	37.8 $\pm$ 4.1	289 $\pm$ 22
Nakuru	7.2 $\pm$ 0.6	4.1 $\pm$ 0.5	48.6 $\pm$ 2.9	341 $\pm$ 15
Elementaita	3.9 $\pm$ 0.8	1.8 $\pm$ 0.2	33.4 $\pm$ 3.8	267 $\pm$ 24
Bogoria	6.4 $\pm$ 1.1	3.6 $\pm$ 0.6	44.1 $\pm$ 3.3	328 $\pm$ 19

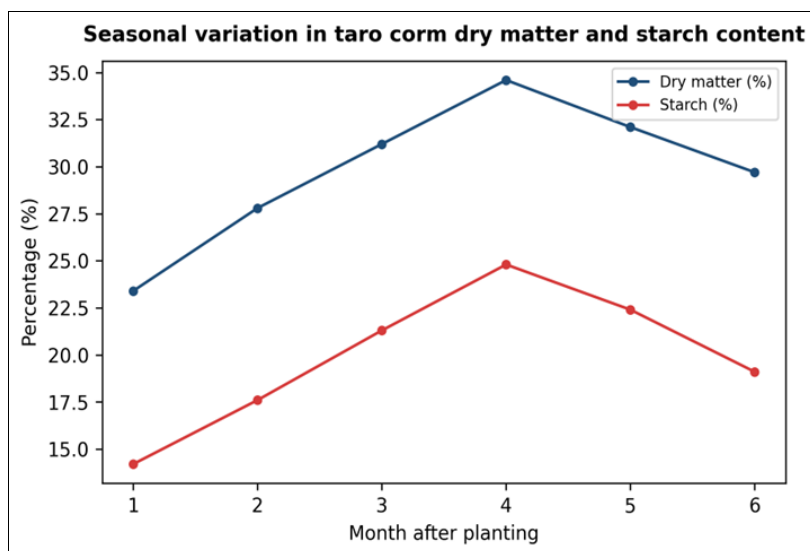


Fig 2: Seasonal variation in taro corm dry matter and starch content

Dry matter and starch content followed a bell-shaped curve peaking around month four after planting. This timing aligns with the transition from active vegetative growth to corm bulking, and it indicates that harvest scheduling can materially affect the nutrient density of processed taro products.

Comprehensive Interpretation

Taken together, the results show that taro accessions from higher-altitude, moderately acidic sites (Nakuru, Naivasha)

consistently outperformed those from lower, more alkaline zones (Baringo, Elementaita) in phenolic, mineral, and vitamin C content. Oxalate levels were highest at Elementaita, but the 20-minute boiling treatment reduced them by 34-42% across all zones, bringing the values within the range considered safe for regular consumption ^[4]. The correlation between altitude and secondary metabolite content likely reflects the combined influence of temperature, UV exposure, and soil chemistry rather than altitude per se.

Discussion

The variation in nutraceutical traits across Rift Valley taro accessions has practical value at several levels. For breeders, the positive altitude-flavonoid correlation ($r = 0.73$) suggests that selection programs targeting high-phenolic lines should prioritize highland germplasm. This aligns with findings from potato research in the Andean highlands, where UV-B radiation was identified as a driver of anthocyanin and flavonol accumulation [6]. For food processors, the observation that simple boiling cuts oxalate by nearly 40% without proportionally damaging phenolics (losses of only 8-12% after boiling) means that traditional cooking methods already accomplish much of the detoxification needed to make taro safe for high-frequency consumption [2].

It is worth comparing these mineral values with dietary reference intakes. The iron content at Nakuru (7.2 mg/100 g dry weight) translates to roughly 2.1 mg per 100 g fresh weight, assuming 70% moisture. That figure covers about 12% of the recommended daily allowance for adult women in a single 200 g serving, which isn't transformative on its own but becomes meaningful when taro is eaten daily as a staple [7]. The zinc figures are more modest but still useful in diets that lack animal-source foods.

One unexpected finding was the high flavonoid content at Lake Elementaita despite its relatively low phenolic score. Elementaita's soils are strongly alkaline (pH 8.7-9.1), and recent work on soybean has shown that alkaline stress can selectively upregulate the flavonoid branch of the phenylpropanoid pathway while suppressing hydroxycinnamic acid derivatives [13]. If the same mechanism operates in taro, it could explain why total phenolics (which include hydroxycinnamic acids) were low while flavonoids per se were high. That said, the present research didn't quantify individual phenolic subclasses, so this interpretation remains tentative and should be tested with HPLC profiling in follow-up work.

A limitation worth noting is that samples were collected during a single season. Interannual rainfall differences of 15-30% are common across the Rift Valley, and such variation could shift the metabolite baselines reported here [11]. Multi-season sampling would strengthen the dataset and allow breeders to distinguish genetic from environmental effects more confidently.

Conclusion

Taro accessions from the Rift Valley harbour meaningful concentrations of phenolics, flavonoids, iron, and zinc, with the highest overall nutraceutical quality observed at Lake Nakuru and Lake Naivasha. Altitude emerged as a consistent predictor of secondary metabolite accumulation, while soil alkalinity appeared to shift the balance between phenolic subclasses. Simple boiling reduced oxalate to acceptable levels with only minor losses in beneficial compounds. These results support the inclusion of highland Rift Valley taro in regional nutraceutical product development and biofortification screening programs. Future work should extend the sampling to multiple growing seasons and incorporate HPLC-based phenolic profiling to confirm the subclass patterns suggested by this initial screening. Collaboration between breeders and food technologists will be needed to translate these findings into improved varieties and processing protocols that reach the communities most likely to benefit.

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Contributions Not Qualifying for Authorship

Field collection was assisted by extension officers at each lake-zone partner station, and laboratory sample preparation was supported by two graduate research assistants.

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