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Unlocking the Nutritional Treasure: *Typhonodorum lindleyanum* Schott. (Viha) after Antinutrient Removal

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Abstract:

Viha (Typhonodorum lindleyanum) presents a promising avenue for enhancing food security and addressing malnutrition in Madagascar, particularly in the face of climate change. This study comprehensively characterized the nutritional and phytochemical properties of Viha, considering the impact of processing methods on its edibility and potential health benefits. Our findings reveal a diverse nutritional profile across Viha plant parts. Rhizomes, rich in carbohydrates, exhibited significant variations in micronutrient content depending on cooking methods. Steaming enhanced iron and potassium, while boiling reduced calcium and phosphorus. Viha seeds demonstrated a relatively stable micronutrient profile across preparations, while leaves were rich in potassium, phosphorus, and iron. Furthermore, the study identified a rich array of phytochemicals, including tannins, flavonoids, and leucoanthocyanidins. While the presence of antinutrients such as phytate and oxalate requires careful consideration, appropriate processing methods can mitigate their impact. These findings suggest that Viha, with proper processing and utilization, could serve as a valuable food source, enhancing dietary diversity and nutritional security, especially in regions vulnerable to climate change impacts such as droughts and food shortages. Further research is warranted to optimize processing methods, enhance nutrient bioavailability, and explore sustainable cultivation and utilization strategies for Viha as a climate-resilient food source in Madagascar.

Keywords:
Viha, Typhonodorum lindleyanum, Food Scarcity, Madagascar

I. Introduction

Typhonodorum lindleyanum Schott. or "Viha" in Malagasy official language is more frequently consumed during periods of food scarcity, particularly in the eastern region of Madagascar. It gows along the rivers banks and lakes and in the marshes. This plant's seeds and tuber are consumed, especially during famines (Moore et al., 2022 ; Behera et al., 2012 ; Walsh, 2009). The "Sakalava" tribe in Madagascar uses the fibers of the leaves for a fishing net

manufacturing. The rhizome is used to make edible flours which irritate the mouth and even the esophagus (Bogner, 1975). On the Pemba island, Zanzibar, the tuber is first sliced thinly and placed in a basket called a 'pakacha' before being washed in a stream, pond, or ocean to eliminate highly toxic substances. Alternatively, the slices may be boiled several times, then rinsed with cold water before being cooked in coconut milk. Another method involves burying the slices in soil or sand near the sea for 3 to 4 days. After being unearthed, they are thoroughly washed and then spread out in the sun to dry. Once dry, the slices are ground into a flour and used to prepare porridge. In a medicinal context, the tuber's starch is considered an effective remedy for venomous animal bites (Moore et al., 2022 ; Randrianarison et al., 2020 ; Famine food, 2004).

Studies have demonstrated two primary preparation methods for consuming these seeds.

1. The first method involves creating a puree by cooking the seeds twice in a double-boiler until the minimal added water has evaporated. The cooked seeds are then ground with salt and consumed with beans and a small amount of oil or meat.
2. The second objective is to produce a floury powder. The seeds are boiled once in a small quantity of water, sun-dried, and then ground. The resulting flour is mixed with grated ripe bananas to form a spherical paste and steamed. (Kull et al., 2015 ; Randrianjohany, 1986)

In Zanzibar, this species is called "mgombakofi" (Bogner, 1975), the seeds undergo a treatment involving rubbing them with wood ash to eliminate toxic substances. After boiling for 15 to 20 minutes, the water is discarded, and the seeds are washed in fresh water and boiled again. This process is repeated twice more until the seeds become tender and toxin-free. They are then ready for consumption, typically boiled in coconut milk (Manduna & Vibrans, 2019; Manduna & Vibrans, 2018; Famine food, 2004).

Our motivation stems from the severe malnutrition problem in Madagascar. This study aims to deepen our understanding of the nutritional value of Viha, or Typhonodorum lindleyanum, within the Malagasy context. We seek to identify intriguing characteristics, specifically regarding their edibility and potential to combat malnutrition. By exploring these aspects, we hope to contribute to the promotion of sustainable and nutritious food solutions for the Malagasy population. In this context, a comparative study of micronutrients, macronutrients, and chemical families within the different parts of Viha has been undertaken.

II. Research Method

2.1 Materials

a. *Typhonodorum lindleyanum* or Viha

Typhonodorum lindleyanum, a striking member of the Araceae family (Govaerts & Frodin, 2002), is endemic to the Comoros Islands, Madagascar, Mauritius, and Tanzania. Locally known as "Viha" in Madagascar, this herbaceous plant thrives in marshy environments, often forming dense stands along the banks of muddy waterways, particularly near coastal freshwater lakes and marshes (Bogner, 1975).

Reaching heights of 2 to 4 meters, Viha possesses numerous flexible adventitious roots emerging from its nodes, alongside a prominent tuber – a thick, elongated underground stem. Due to the presence of acidic compounds, it is crucial to detoxify and cook Viha thoroughly before consumption (Cabanis & Chabouis, 1969).


a

b

c

Figure 1. Rhizome (**a**), stem (**b**) and leaves (**c**) of Viha from the Tsimbazaza Botanical and Zoological Park.

The robust stem of the Viha is adorned with the remnants of fallen leaf sheaths, creating a textured appearance. Its magnificent leaves, reminiscent of an elephant's ear, can reach impressive dimensions, often exceeding 1 meter in length. While juvenile plants exhibit smaller, narrower foliage, mature leaves typically measure between 70 and 140 centimeters long and 55 to 85 centimeters wide.

Each mature Viha plant produces several distinctive, spike-like inflorescences annually. These are borne on a robust peduncle measuring 40 to 50 centimeters in length and 5 to 10 centimeters in diameter. The inflorescence itself comprises a striking, 35 to 45 centimeter-long, yellowish spathe, gracefully curving towards the base, and a prominent spadix.

The Viha produces a large, coenocarpous fruit, measuring approximately 17 centimeters in length and 12 centimeters in diameter with a circumference of 38 centimeters. This non-compartmentalized fruit houses the seeds, or pips, which are clustered together and constitute the edible portion of the plant.

While seed reproduction is possible, *Typhonodorum lindleyanum* exhibits a remarkable capacity for vegetative propagation via rhizomes. This efficient method allows the plant to rapidly establish dense populations. The rhizome, a modified underground stem, extends horizontally, giving rise to new aerial stems from the buds it produces. Indeed, vegetative reproduction through rhizomes is arguably the most significant characteristic of this species. (Razarihelisoa, 2009)

Figure 2. Viha Fruits

Figure 3. Viha seeds

Figure 4. Viha seed kernel

Figure 5. Viha seed husk

b. Selection of Sample Collection Sites

Several factors influence the optimal collection of Viha tubers. Firstly, maturity plays a crucial role, with mature tubers exhibiting a milder flavor compared to those from younger plants. Secondly, tuber size serves as an indicator of maturity. Finally, the soil composition significantly impacts tuber quality. According to local knowledge, tubers cultivated in sandy marshes are highly prized, as they possess a desirable sticky, compact texture after cooking. (Behera et *al.*, 2012)

As an aquatic plant, Viha thrives in shallow water environments, including swamps, rivers, and streams. The abundance of water is paramount for its optimal growth and development. (Onwueme & Charles, 1994)

For this study, sample collection was conducted in the city of Antananarivo, specifically within the esteemed Tsimbazaza Botanical Park. This place serves as both a cherished recreational destination and a vital sanctuary for Madagascar's unique flora and fauna. Its dedicated role as a botanical park uniquely positions it as an ideal setting for botanical research center (Parc Botanique et Zoologique de Tsimbazaza, 2024).

A comprehensive analysis of data gathered during June, July, August, and October 2022, as well as October 2023, reveals distinct seasonal trends in the growth and reproductive cycles of Viha. These observations underscore the profound influence of climatic variations on the development of this remarkable species, emphasizing the critical importance of specific periods within the annual cycle for its optimal growth.

2.2 Methods

a. Sampling

Sampling is of paramount importance in the reliability of analytical results, as it constitutes the basis on which scientific inferences and conclusions are based. A rigorous and representative sampling methodology is essential to minimize bias and ensure that the data collected faithfully reflect the population or phenomenon studied. Indeed, the quality and accuracy of analytical results directly depend on the validity of the sample chosen, making sampling a crucial element in any empirical research approach. In short, sampling is a fundamental pillar of the scientific approach, decisively influencing the robustness and generalization of analytical results. Meticulous attention to this critical step is essential to

ensure the rigor and accuracy of scientific research, thus contributing to the reliable and accurate advancement of knowledge. (Onwueme & Charles, 1994)

1. The seeds

Prior to any analytical procedures, the samples undergo a meticulous pre-treatment process, akin to the preparation of seeds for culinary use. Initially, the seeds are carefully extracted from their fruit receptacle to safeguard against contamination or compromise their integrity. Subsequently, a meticulous dehulling process is undertaken, during which the seed coats are carefully removed to ensure sample homogeneity and purity.

This is followed by a controlled drying phase, where the seeds are exposed to precisely regulated temperature and humidity conditions. This crucial step eliminates all residual moisture, ensuring the stability and long-term preservation of the samples for subsequent analytical investigations.

This rigorous preparation protocol is paramount to maintaining the reliability and accuracy of analytical results. By minimizing variations that may arise from moisture or impurities within the samples, this meticulous approach ensures the integrity of the scientific findings (Onwueme & Charles, 1994).

2. Rhizomes or tubers

a) Sample reception constitutes the initial and critical phase of the analytical process. Each specimen is meticulously handled with gloved hands to ensure utmost care.
b) Subsequent to reception, a meticulous cleaning process is undertaken. This involves employing appropriate methods to eliminate surface impurities while scrupulously preserving the intrinsic properties of the specimens, thereby guaranteeing the purity of the materials destined for analysis.
c) The subsequent step involves a precise peeling process, wherein the outer layers are carefully removed to expose the inner core of the sample, often the primary focus of analytical investigation.
d) Following the peeling process, an initial weighing of each sample is conducted. This crucial step enables the accurate documentation of the sample mass prior to any physical modifications. This mass serves as a crucial reference point for subsequent yield and loss calculations throughout the analytical procedure..
e) Subsequent to these initial steps, the samples undergo a controlled drying process to reduce their moisture content to predetermined levels. This critical step ensures sample stability and long-term preservation prior to in-depth analysis.
f) The drying process is followed by a meticulous crushing and quartering procedure. The samples are meticulously ground and homogenized to achieve a uniform distribution of their constituent components. Subsequently, these homogenized samples are divided into representative portions for subsequent detailed analysis.
g) Finally, the prepared samples are carefully placed in appropriate bags for protection and preservation. This final step ensures optimal handling and storage, safeguarding the samples from contamination and maintaining their integrity throughout the duration of laboratory analysis.

This systematic and rigorous methodology forms the indispensable foundation for accurate, reproducible and scientifically valid analyses (Onwueme & Charles, 1994).

b. Determination of elemental micronutrients by X-ray fluorescence (XRF)

Energy-dispersive X-ray fluorescence (EDXRF), often simply referred to as X-ray fluorescence or XRF, is a rapid and non-destructive analytical technique employed to determine the elemental composition of materials. This technique provides valuable insights into the constituent elements present within a sample.

The portable X-ray fluorescence spectrometer (EDXRF) emerges as a versatile and indispensable analytical tool, particularly well-suited for non-destructive elemental analysis across diverse environments. Its lightweight and ergonomic design, coupled with an impressive six-hour battery life and robust capabilities in extreme conditions, ensures reliable and continuous analysis. Furthermore, advanced features such as waterproofing, an intuitive touchscreen interface, an integrated tablet, and substantial storage capacity render the EDXRF an invaluable asset for rapid and accurate field analysis.

In portable X-ray fluorescence (XRF) devices, detection relies on energy analysis. A detector intercepts the emitted X-rays, generating a signal directly proportional to the energy of each captured photon.

The device's integrated software incorporates a database that facilitates the identification of elements. By comparing the captured wavelengths to those within the database, the nature of each element is determined. Moreover, the concentration of each element is assessed by comparing the intensities of the captured signals. Consequently, XRF analysis provides valuable insights into the mineral composition of a sample, revealing the relative quantities of each element present, typically expressed as proportions or percentages of the analyzed sample.

Crucially, subsequent to the determination of elemental content, the calcium-to-phosphorus (Ca/P) ratio is calculated. This ratio serves as a critical indicator of the quality of minerals present within a given food source (Rakotomamonjy et *al.*, 2025 ; Nieman, 1992).

c. Determination of Macronutrients by Kjeldahl Method

1. Water and dry matter

Conventional assessments of moisture content in foodstuffs rely on determining the weight loss that occurs during drying under atmospheric pressure. This method effectively quantifies the water content within the food sample (Robijaona Rahelivololoniaina et *al.*, 2024).

A standardized protocol, commonly employed in numerous laboratory procedures, ensures accurate and reproducible sample preparation and analysis. This protocol encompasses the following steps:

a) Initial Weighing: The sample's initial mass is meticulously determined prior to any subsequent handling.
b) Drying: The sample is subsequently placed within an oven maintained at a temperature of 45°C, facilitating the removal of any inherent moisture.
c) Desiccation: Following the drying phase, the sample is carefully transferred to a desiccator, an apparatus designed to maintain a controlled, dry environment.
d) Constant Weight Determination: The dried material is then subjected to repeated weighings until a constant weight is achieved, signifying the complete removal of residual moisture.

Calculation of dry matter content

$$\%DM = \frac{m2-m0}{m1} x100$$

- m2 : Petri dish weight after calcination
- m1 : sample weight
- m0 : empty petri dish weight

2. Ash

The following steps represent a standard protocol used in many scientific laboratories to prepare and analyze samples with precision and rigor (Robijaona Rahelivolololoniaina et *al.*, 2024):

a) The initial step involves the meticulous weighing of the sample to ascertain its initial mass.
b) Subsequently, the sample undergoes a carbonization process. This involves the utilization of a gas flame or electrical resistance to transform the organic matter within the sample into charcoal.
c) Following carbonization, the sample is subjected to calcination within a muffle furnace at a temperature of 600°C. This process serves to eliminate impurities and convert the charcoal into ash.
d) Finally, the resulting ash is carefully cooled within a desiccator, an apparatus designed to maintain a controlled, dry environment. This step is crucial for stabilizing the samples prior to subsequent analytical procedures.

$$\% \, \mathbf{CA} = \frac{\mathbf{m2-m0}}{\mathbf{m1}} \mathbf{x100}$$

With

m2 : capsule weight after calcination
m1 : sample weight
m0 : empty capsule weight

The percentage of crude ash expressed as a percentage of dry matter is :

$$\% \, \mathbf{CA'} = \frac{\% \, \mathbf{CA}}{\% \, \mathbf{DM}} \mathbf{x1000}$$

Pre-carbonization of samples, followed by a calcination procedure at 800°C, leading to the desired ash.

3. Sugar and starch

The following sequence outlines the comprehensive laboratory protocol employed for sample preparation and analysis (**Robijaona Rahelivolololoniaina et *al.*, 2024**):

a) Initial Weighing: A precisely weighed 2-gram aliquot of powdered sample is meticulously transferred to a 250-milliliter Erlenmeyer flask.
b) Acid Hydrolysis: One hundred milliliters of 5% hydrochloric acid (HCl) is subsequently added to the flask to facilitate acid hydrolysis.
c) Controlled Heating: The mixture is then subjected to controlled heating within a sand bath, utilizing an air cooler to regulate temperature. The hydrolysis reaction is maintained for a duration of one hour from the onset of boiling.
d) Neutralization: Upon cooling to ambient temperature, the acidity of the mixture is carefully neutralized through the addition of 5 milliliters of 40% caustic soda (NaOH).
e) Stabilization: A small quantity of lead acetate is subsequently introduced to stabilize the sample and inhibit further fermentation.
f) Filtration and Volumetric Adjustment: The mixture is then subjected to filtration to remove any solid particulates. The filtrate is subsequently transferred to a 200-milliliter volumetric flask, and the final volume is adjusted to 200 milliliters using distilled water or an appropriate diluent.

g) Titration: The filtrate is titrated with Fehling's liqueur to analyze the presence of certain compounds in the sample.

The initiation of the analytical process necessitates the meticulous consideration of several key parameters. Firstly, the weight of the test sample, denoted by 'P', must be precisely measured to ensure the reproducibility of results. Secondly, the volume of reagent solution, represented by 'N' and determined through a careful reading of the burette, is meticulously recorded to facilitate accurate assessment of the ongoing reaction. Finally, the Fehling's liquor titer, denoted by 'T', constitutes a critical measurement. This parameter provides crucial information regarding the concentration of the reagent solution and serves as a cornerstone for the accurate calculation of subsequent analytical results.

Starch content calculation

$$\% \text{ Starch} = \frac{\text{T x 200 x 100 x 0,9}}{\text{NxP}}$$

Calculation of glucose content

$$\% \text{ Glucose} = \frac{\text{Starch}}{0,9}$$

Calculation of total sugar content

$$\% \text{ Total sugar } = \frac{\text{T x } 10^{-2} \text{ x 200 x 100 x 100}}{\text{N x 2 x P x 50}}$$

The percentage of starch expressed as a percentage of dry matter is:

Calculation of starch content in dry matter

$$\% \text{ Starch}' = \frac{\%\text{Starch}}{\%\text{DM}} x100$$

The percentage of total sugars expressed as a percentage of dry matter is:

Calculation of total starch and sugar content

$$\% \text{ Total sugar}' = \frac{\%\text{Total sugar}}{\%\text{DM}} x100$$

4. Lipids

To initiate the extraction process, a precisely weighed 5-gram aliquot of the sample is carefully introduced into a filter cartridge. Soxhlet extraction is subsequently performed utilizing a volume of hexane solvent, or sulfuric ether, approximately equivalent to that required for two complete siphon cycles. Upon achieving complete solvent exhaustion, the cartridge is carefully removed, and the majority of the residual solvent is discharged into the upper chamber of the Soxhlet apparatus. The flask containing the extract is then carefully transferred to a smaller, tared flask or capsule (Robijaona Rahelivololoniaina et *al.*, 2024).

The solvent is subsequently evaporated in a water bath, followed by further evaporation in an oven maintained at a temperature between 100 and 105 degrees Celsius. This process is continued until a constant weight is achieved, thereby ensuring the complete removal of residual solvent.

The primary objective of this process is to ascertain the precise percentage of fat content within the sample. To this end, a precisely weighed 5-gram aliquot of the sample is

carefully introduced into a filter cartridge. Subsequently, 100 milliliters of hexane is added to each extraction flask. The extraction process is diligently monitored, with the operation ceasing upon the observation of a transparent hexane solution, signifying the complete extraction of fats from the sample.

Lipid content calculation

$$\%\text{Lip} = \frac{\text{m2} - \text{m0}}{\text{m1}} \text{x100}$$

The percentage of lipid expressed as a percentage of dry matter is:

Calculation of fat content in dry matter

$$\%\text{Lip}' = \frac{\%\text{Lip}}{\%\text{MS}} x100$$

The primary objective of this analytical procedure is to determine the precise percentage of fat content within the sample. The extraction process is diligently monitored, with the procedure carefully halted upon the observation of a transparent hexane solution. This visual cue signifies the complete extraction of lipid constituents from the sample. This rigorous methodology ensures the efficient and accurate extraction of lipids, a crucial step in the quantitative analysis of fat content.

5. Protein

The Kjeldahl method, a widely employed technique in analytical chemistry, serves to determine the total nitrogenous matter, often equated with protein content, within a sample (Robijaona Rahelivololoniaina et *al.*, 2024).

The successful execution of the Kjeldahl method necessitates the utilization of a specific ensemble of instruments and apparatus. This includes a Kjeldahl flask, a dedicated Kjeldahl apparatus, and a judicious selection of receiving flasks, typically ranging in capacity from 100 to 250 milliliters, in addition to Erlenmeyer flasks. The careful selection of these tools is paramount, as it is contingent upon the specific analytical requirements and the quantity of sample to be processed. This meticulous approach ensures the efficient and precise execution of the Kjeldahl method within the laboratory setting.

The initial step involves the meticulous weighing of a precisely measured 1-gram aliquot of the sample, which is subsequently transferred to a dedicated Kjeldahl flask. Thereafter, a carefully measured quantity of catalysts, including copper sulfate, selenium, and 20 milliliters of pure sulfuric acid, is added to the sample within the flask. Following this preparation, the flask is allowed to stand undisturbed for a predetermined period, typically 12 hours, to facilitate the complete reaction of the compounds.

The Kjeldahl flask containing the sample is then subjected to a gradual heating process utilizing an electric ramp specifically designed for Kjeldahl methodologies. Upon the completion of digestion, the flask is carefully removed from the heat source and allowed to cool to ambient temperature.

Once cooled, the contents of the flask are quantitatively transferred to a 100-milliliter volumetric flask. Distilled water is then carefully added to the flask in a gradual manner to achieve the desired volume. This meticulous approach minimizes the risk of thermal shock and ensures the integrity of the glassware. This rigorous adherence to the Kjeldahl

methodology guarantees the precise preparation of the sample, thereby providing reliable and reproducible analytical results within the domain of analytical chemistry.

d. Distillation Phase

1. Preparation of Solutions

To ensure optimal precision and accuracy in the analytical method, meticulous preparation of the requisite solutions is paramount.

a) Firstly, an H_2SO_4 solution of N/10 concentration is meticulously prepared by carefully adding 25 milliliters of concentrated sulfuric acid to a 250-milliliter volumetric flask. The flask is then carefully filled to the designated volume with distilled water.
b) Similarly, a 40% NaOH solution is prepared by dissolving 100 grams of caustic soda in a 250-milliliter volumetric flask.
c) Furthermore, an N/10 NaOH solution is prepared by dissolving 1 gram of caustic soda in a 250-milliliter flask and subsequently diluting to the desired volume with distilled water.

2. Analytical Procedure

For the execution of the analytical process, an appropriate distillation apparatus ampoule is prepared. A 10-milliliter aliquot of the sample is carefully introduced into the ampoule, followed by the addition of 10 milliliters of the 40% NaOH solution. The distillate is meticulously collected within a suitable container, such as an Erlenmeyer flask, containing 10 milliliters of H_2SO_4 solution and a few drops of thymol blue indicator. The bottom end of the condenser is carefully positioned to ensure direct contact with the bottom of the receiving flask.

The distillation process commences with the precise recording of the elapsed time from the initial appearance of the first distillate droplet. This marks the initiation of the distillation period. A standardized duration of seven minutes is typically employed for this process, ensuring the efficient and complete extraction of the target compounds, thereby facilitating subsequent analytical procedures.

3. Titration phase

Following the cooling process, the distillate is subjected to vigorous magnetic stirring to ensure thorough homogenization prior to the titration procedure. Titration is subsequently conducted utilizing an N/10 sodium hydroxide solution, while the colorimetric endpoint is meticulously monitored. The transition from the characteristic blue-green hue to a distinct purplish-red signifies the attainment of the equivalence point within the acid-base reaction. This visual cue signals the termination of the titration reaction and enables the precise determination of the acid concentration present within the distillate.

Calculation of nitrogen content

$$\%N = \frac{0{,}0014 \text{ x } (V - V') \text{ x } 100 \text{ x } 6{,}25}{10 \text{ x Wsample}} \text{ x } 100$$

Calculation of protein content

$$\%P = \%N * 6{,}25$$

Calculation of protein content in relation to dry matter

$$\%P' = \frac{\%P}{\%MS} x100$$

- N : Nitrogen
- P : Protein
- DM : Dry matter
- V : volume of HCl
- V' : Volume of NaOH (N/10) added during titration
- Wsamplet : Sample weight

III. Result and Discussion

3.1 Elemental Micronutrient Results

The various Viha parts studied were in three forms: raw, boiled and steamed.

a. Micronutrients of Viha Rhizomes

After three successive repeat measurements, the following results were obtained for raw, boiled and steamed Viha rhizome flour.

Table 1. Elemental micronutrients in Viha rhizome flours

	Uncooked rhizome	Boiled rhizome	Steamed rhizome
Mg(%)	0.077	0.099	0.044
P(%)	0.144	0.053	0.188
K(%)	0.120	0.064	0.292
Ca(%)	0.205	0.008	0.005
Mn(%)	0.040	0.025	0.000
Fe(%)	0.001	0.081	0.195
Cu(%)	0.016	0.095	0.014
Zn(%)	0.035	0.055	0.034
Se(%)	0.008	0.010	0.007

Significantly, flours derived from Viha tubers all contain a spectrum of essential micronutrients, including Magnesium (Mg), Potassium (K), Calcium (Ca), Manganese (Mn), Iron (Fe), Copper (Cu), Zinc (Zn), and Selenium (Se), albeit with varying concentrations, all of which fall below 1%.

1. Magnesium (Mg) and Zinc (Zn): A modest increase content was observed following boiling.
2. Phosphorus (P): Boiling resulted in a substantial decrease in phosphorus content, whereas steaming led to a notable increase.
3. Potassium (K): Steaming significantly enhanced potassium content, while boiling resulted in a marked decrease.
4. Calcium (Ca): A dramatic reduction in calcium content was observed in both boiled and steamed preparations.
5. Iron (Fe): A substantial increase in iron content was evident, particularly following steaming.
6. Copper (Cu): Copper content exhibited an increase following boiling, while a slight decrease was observed after steaming.
7. Selenium (Se): Minimal variations in selenium content were observed across the different preparations.

These findings underscore the profound impact of culinary methods on the bioavailability and nutritional value of micronutrients within the Viha rhizome. Steaming

appears to be particularly effective in preserving or even enhancing the levels of certain essential minerals such as iron, potassium, and phosphorus. Conversely, boiling may lead to significant losses of certain micronutrients, principally calcium.

b. Micronutrients of Viha seeds

After carrying out three successive tests and calculating the average, the following results were obtained for XRF analysis of Viha seeds.

Table 1 . Elemental micronutrients by TXRF for Viha seeds

	Uncooked seed	Boiled seed	Steamed seed
Mg(%)	1.729	1.962	2.015
P(%)	0.105	0.107	0.114
K(%)	1.201	1.052	1.110
Ca(%)	0.004	0.002	0.003
Mn(%)	0.000	0.000	0.000
Fe(%)	0.576	0.594	0.579
Cu(%)	0.304	0.309	0.308
Zn(%)	0.019	0.022	0.022
Se(%)	0.005	0.011	0.008

Remarkably, the data reveals a relatively consistent micronutrient profile across the three seed preparations: raw, boiled, and steamed.

1. Magnesium (Mg): A gradual increase in magnesium content is observed, with the highest concentration (2.015%) found in the steamed seeds.
2. Phosphorus (P): A slight, yet consistent, increase in phosphorus content is observed across the preparations, with the steamed seeds exhibiting the highest concentration (0.114%).
3. Potassium (K): A modest decrease in potassium content is observed following boiling (1.201% to 1.052%), with a slight recovery in the steamed seeds (1.110%).
4. Calcium (Ca): Calcium levels remain relatively low across all preparations (0.004% to 0.002%), with a slight decrease observed following boiling.
5. Manganese (Mn): No detectable levels of manganese were observed in any of the seed preparations.
6. Iron (Fe) and Copper (Cu): Iron and Copper contents remain relatively stable across all preparations, with only minor fluctuations observed.
7. Zinc (Zn): A slight increase in zinc content is observed (0.019% to 0.022%) following boiling and steaming.
8. Selenium (Se): A slight increase in selenium content is observed following boiling (0.011%), with a modest decrease in the steamed seeds (0.008%).

These findings suggest that while some minor variations in micronutrient content occur across the different seed preparations, the overall micronutrient profile of Viha seeds remains largely unaffected by boiling or steaming.

c. Viha Leaf Micronutrients

After three successive trials and averaging, we obtained the following results for TXRF analysis of Viha leaves.

Table 2 . Elemental micronutrients by TXRF of Viha leaves

Element	Uncooked Viha leaves
Mg(%)	0.002
P(%)	0.240
K(%)	0.565
Ca(%)	0.036
Mn(%)	0.000
Fe(%)	0.842
Cu(%)	0.055
Zn(%)	0.021
Se(%)	0.006

Conspicuously, the analysis reveals the presence of several essential micronutrients within the leaf tissue, with varying concentrations.

1. Potassium (K): Potassium (0.565%) emerges as the most abundant micronutrient, constituting a significant proportion of the elemental composition.
2. Phosphorus (P): Phosphorus (0.240%) constitutes a substantial fraction of the leaf tissue.
3. Iron (Fe): Iron is present in considerable amounts, suggesting its potential contribution to iron intake from dietary sources.
4. Magnesium (Mg), Calcium (Ca), Copper (Cu), Zinc (Zn), and Selenium (Se): These micronutrients are present in lower concentrations within the leaf tissue.
5. Manganese (Mn): No detectable levels of manganese were observed in the analyzed samples.

These findings provide valuable insights into the nutritional composition of Viha leaves, highlighting their potential as a source of essential micronutrients.

3.2 Macronutrient Results

a. Water, dry matter and ash content of each Viha part

Here are the results for the analysis of all samples for moisture (H), dry matter (DM) and crude ash (CA)

Table Error! No text of specified style in document.. Water and dry matter content of each Viha part

	Water content %	Dry matter (%)
Uncooked Viha rhizome	73.723	26.277
Boiled Viha rhizome	86.152	13.848
Steamed Viha rhizome	80.040	19.960
Uncooked Viha seeds	52.450	47.550
Boiled Viha seeds	59.450	40.550
Steamed Viha seeds	53.120	46.880
Uncooked Viha leaf	90.150	9.850

This table presents the water and dry matter content of various Viha plant parts, including uncooked and processed rhizomes, seeds, and leaves.

1. High Water Content: All samples exhibit a relatively high water content, characteristic of plant tissues.
2. Rhizomes: Uncooked rhizomes exhibit the lowest water content (73.723%), while boiled rhizomes demonstrate the highest (86.152%), indicating significant water uptake during the boiling process.

3. Seeds: Uncooked seeds exhibit a particularly lower water content (52.450%) compared to the rhizomes (73.723%), reflecting their inherent structural composition.
4. Leaves: Uncooked leaves exhibit the highest water content (90.50%) among all the samples, reflecting their high moisture content typical of leafy green vegetables.

These findings provide valuable insights into the moisture composition of different Viha plant parts. This information is crucial for various applications, including food processing, storage, and nutritional analysis.

Here are the raw ash results after three successive tests of each sample. These data show significant variations between the different sample types.

Table 3 . Crude ash content results for different parts of Viha

	Crude ash (%)	Crude ash of dry matter (%)
Uncooked Viha rhizome	1.633	1.67
Boiled Viha rhizome	1.920	1.97
Steamed Viha rhizome	2.080	2.13
Uncooked Viha seeds	2.861	2.91
Boiled Viha seeds	2.257	2.30
Steamed Viha seeds	2.230	2.28
Uncooked Viha leaf	12.127	12.18

This table presents the crude ash content of different Viha plant parts, expressed both as a percentage of the wet weight and as a percentage of the dry matter.

1. Viha Leaves: Uncooked Viha leaves exhibit the highest crude ash content (12.18%), indicating a significant mineral composition.
2. Viha Seeds: Uncooked Viha seeds demonstrate a moderately high ash content (2.861%).
3. Viha Rhizomes: The crude ash content of rhizomes (1.67%) is generally lower compared to leaves and seeds.
4. Effect of Processing: While minor variations are observed, the overall impact of boiling or steaming on the crude ash content appears to be relatively limited across all plant parts.

These findings suggest that Viha plant parts, particularly the leaves, possess a notable mineral content. Further analysis is warranted to determine the specific mineral composition of the ash and its potential nutritional implications.

b. Glucide content of each Viha part

Here are the carbohydrate levels in Viha samples.

Table 4 . Carbohydrate content of various Viha parts

	% Glucid	Glucid of dry matter (%)
Uncooked Viha rhizome	55,556	56,988
Boiled Viha rhizome	54,890	56,257
Steamed Viha rhizome	50,617	51,733
Uncooked Viha seeds	43,063	43,789
Boiled Viha seeds	52,182	53,167
Steamed Viha seeds	47,696	48,800
Uncooked Viha leaf	10,686	10,732

This table presents the carbohydrate content of different Viha plant parts, expressed both as a percentage of the wet weight and as a percentage of the dry matter.

1. Rhizomes: Uncooked rhizomes exhibit a particularly high carbohydrate content (55,556%), which experiences a slight decrease following boiling (54,890%) and a more substantial decrease following steaming (50,617%).
2. Seeds: Uncooked seeds demonstrate a moderate carbohydrate content (43,063%), which increases slightly following boiling (52,182%) and then decreases slightly after steaming (47,696%).
3. Leaves: Uncooked leaves exhibit the lowest carbohydrate content (10,686%) among the analyzed plant parts.

These findings suggest that the carbohydrate composition of Viha plant parts varies significantly depending on the plant part and may be influenced by processing methods such as boiling and steaming.

c. Lipid content of each Viha part

Lipid contents, obtained by percolation through a Soxhlet using hexane as solvent, are listed in the table below:

Table 5 . Lipid content analysis results of each Viha part

	Lipid (%)	Lipid of dry matter (%)
Uncooked Viha rhizome	0.420	0.430
Boiled Viha rhizome	0.150	1.967
Steamed Viha rhizome	0.450	1.980
Uncooked Viha seeds	1.079	1.097
Boiled Viha seeds	1.339	1.364
Steamed Viha seeds	1.299	1.330

This table presents the lipid content of various Viha plant parts, expressed both as a percentage of the wet weight and as a percentage of the dry matter.

Lipids were detected in the leaves, but at such trace levels as to be negligible.

1. Viha Seeds: Uncooked Viha seeds exhibit the lowest lipid content (1.079%), followed by steamed (1.299%) and then boiled (1.339%) seeds.
2. Viha Rhizomes**:** Uncooked (0.420%) and steamed rhizomes (0.450%) demonstrate relatively low lipid content, while boiled rhizomes (0.150%) exhibit the lowest lipid content among all samples.

These findings suggest that lipid content in Viha plant parts varies significantly depending on the plant part and may be influenced by processing methods, with boiling appearing to significantly reduce lipid content in the rhizomes.

d. Protein content of each Viha part

The Kjeldahl method constitutes a cornerstone of protein analysis within numerous scientific disciplines, including food science, biomedical research, and environmental studies. This established method, renowned for its robustness and widespread application, remains an indispensable tool for the accurate determination of protein content in a diverse range of biological samples.

Table 6. Results of protein analysis of Viha rhizomes, seeds and leaves

	Proteins (%)	Protein of dry matter (%)
Uncooked Viha rhizome	0.380	0.390
Boiled Viha rhizome	0.312	0.320
Steamed Viha rhizome	0.332	0.339

Uncooked Viha seeds	4.366	4.440
Boiled Viha seeds	4.019	4.095
Steamed Viha seeds	3.922	4.013
Uncooked Viha leaf	1.272	1.277

This table presents the protein content of various Viha plant parts, expressed both as a percentage of the wet weight and as a percentage of the dry matter.

1. Viha Seeds: Uncooked Viha seeds (4.366 %) exhibit significantly higher protein content compared to both rhizomes and leaves.
2. Rhizomes: Uncooked rhizomes (0.380 %) demonstrate a modest protein content, with minor variations observed between the raw (0.380%), boiled (0.312%), and steamed (0.332%) preparations.
3. Leaves: Uncooked leaves (1.272 %) exhibit an intermediate level of protein content compared to rhizomes (0.380 %) and seeds (4.366 s%).

These findings suggest that Viha seeds constitute a potentially valuable source of protein, while rhizomes and leaves contribute more modestly to the overall protein content of the plant.

Further research is warranted to investigate the amino acid profile and bioavailability of the protein within different Viha plant parts. This information will be crucial for a comprehensive understanding of the nutritional value of Viha within a balanced diet.

e. Energy value per 100g sample of each Viha part

The table presents the energy values of the studied food, calculated using the Atwater system, which provides a standardized method for estimating the energy contribution of macronutrients (proteins, carbohydrates, and lipids). This approach allows for a precise determination of the food's overall energy content.

The data generated from this analysis is instrumental in several key areas. Firstly, it provides crucial information for assessing caloric intake, a fundamental aspect of dietary planning and management. Secondly, it aids in the development of effective weight management strategies, enabling individuals to make informed choices about their dietary intake. Finally, it serves as a valuable tool for optimizing dietary plans to meet specific nutritional goals, particularly for athletes and individuals with specific dietary requirements.

Table 7 . Energy value of each sample per 100g

	Energy value (kcal/100g)
Uncooked Viha rhizome	187,52
Boiled Viha rhizome	182,16
Steamed Viha rhizome	167,85
Uncooked Viha seeds	199,42
Boiled Viha seeds	188,85
Steamed Viha seeds	198,17
Uncooked Viha leaf	87,12

This table presents the energy values of various Viha plant parts, as determined through the application of Atwater coefficients. This system provides a standardized approach to estimating the caloric contribution of macronutrients within a given food source.

1. Viha Seeds: Exhibit the highest energy values, with an average of 195.48 kcal/100g, indicating their potential as a significant source of caloric energy.
2. Viha Rhizomes: Demonstrate a moderate energy value, averaging 179.18 kcal/100g.

3. Viha Leaf: Contains the lowest energy value at 87.12 kcal/100g, reflecting its lower caloric density compared to seeds and rhizomes.

These findings provide valuable insights into the energy content of different Viha plant parts, which can be instrumental in dietary planning and nutritional assessments.

3.3 Results of phytochemical family screening of each Viha part

Phytochemical screening constitutes a fundamental cornerstone in the investigation of medicinal plants. This multifaceted analytical approach encompasses a series of chemical and biochemical tests meticulously designed to detect and identify the diverse array of bioactive compounds present within plant matrices, including alkaloids, flavonoids, tannins, saponins, glycosides, and a plethora of other secondary metabolites.

The significance of phytochemical screening extends beyond mere identification. It serves as a crucial preliminary step in the comprehensive evaluation of medicinal plants, providing valuable insights into their chemical composition and ultimately assessing their therapeutic potential. Moreover, phytochemical screening plays an indispensable role in bioprospecting efforts, facilitating the sustainable exploitation of plant resources and guiding the discovery of novel therapeutic agents.

Table 8 . Results of phytochemical family screening

	Deoxyoses	Flavonoid	Anthraquinone	Saponoside	Iridoid	Tannins	Coumarines	Leucoanthocyanes
Uncooked Viha rhizome	++	+-	-	-	-	+++	-	+++
Boiled Viha rhizome	+	--	-	-	-	++-	-	+
Steamed Viha rhizome	+	--	-	-	-	++-	-	+
Uncooked Viha seeds	-	+-	-	-	-	+++	-	+
Boiled Viha seeds	-	+-	-	-	-	++-	-	+
Steamed Viha seeds	-	+-	-	-	-	++-	-	+
Uncooked Viha leaf	-	--	-	-	-	++-	+	+

+ : weak presence ++ : average attendance +++ : strong presence

This table presents the results of phytochemical screening conducted on various parts of the Viha plant, including rhizomes, seeds, and leaves. The screening employed a range of established methodologies to detect the presence of several key phytochemical classes.

1. Rhizomes: Uncooked rhizomes exhibited a strong presence of tannins and leucoanthocyanidins, with moderate levels of flavonoids and deoxyoses.
2. Boiled Rhizomes: Boiling significantly reduced the presence of flavonoids and deoxyoses while slightly decreasing the abundance of tannins and leucoanthocyanidins.
3. Steamed Rhizomes: Steaming resulted in a notable decrease in flavonoid content, while the levels of tannins and leucoanthocyanidins remained relatively unchanged.

4. Seeds: Uncooked seeds demonstrated a strong presence of tannins, with moderate levels of flavonoids.
5. Leaves: Uncooked leaves exhibited a strong presence of tannins and leucoanthocyanidins, along with a moderate presence of coumarins.

These findings suggest that the phytochemical profile of Viha plant parts varies significantly depending on the plant part and may be influenced by processing methods such as boiling and steaming.

The comprehensive analysis encompassed a series of investigations aimed at evaluating the efficacy of detoxification processes.

a. Phytate and Oxalate: Antinutrients in Viha Plant Parts

Here are the analysis results for phytate and oxalate content, according to the detoxification method used.

Table 9 . Phytate and oxalate content (in mg per 100 g dry weight) of different parts of Viha

	Phytate	Total oxalate	Soluble oxalate	Calcium oxalate
Uncooked Viha rhizome	450.123	521.124	410.123	111.001
Boiled Viha rhizome	100.124	147.124	110.343	36.781
Steamed Viha rhizome	212.124	348.125	261.094	87.031
Uncooked Viha seeds	80.124	214.124	142.750	71.375
Boiled Viha seeds	40.142	90.452	60.301	30.151
Steamed Viha seeds	50.425	112.124	74.749	37.375

This table presents the phytate and oxalate content in various parts of the Viha plant, including uncooked and processed rhizomes, and seeds.

1. Phytate: Uncooked Viha rhizomes exhibit the highest phytate content (450.123 mg), followed by uncooked seeds (80.124 mg). Significant reductions in phytate content are observed following boiling and steaming of both rhizomes and seeds.
2. Oxalate: Uncooked Viha rhizomes exhibit the highest total oxalate content (521.124 mg). Boiling and steaming processes appear to reduce the overall oxalate content in rhizomes, while the effect on oxalate content in seeds (142.750 mg) is less pronounced.
3. Soluble Oxalate: A substantial proportion of total oxalates in all plant parts exists in the soluble form.
4. Calcium Oxalate: Calcium oxalate constitutes a significant portion of the total oxalate content in all Viha plant parts.

These findings provide valuable insights into the presence of these antinutrients in different Viha plant parts and the potential impact of processing methods on their levels.

Phytate, a ubiquitous phytic acid ester, serves as the primary phosphorus storage compound in plant tissues, especially within seeds, legumes, and cereals. Oxalate, a dicarboxylic acid, is widely distributed in plant kingdom, commonly found in leafy vegetables, nuts, and certain fruits.

Both phytate and oxalate exhibit the capacity to chelate essential divalent cations such as calcium, zinc, iron, and magnesium, forming insoluble complexes that diminish their bioavailability within the human body. This chelation phenomenon can have significant implications for mineral absorption and overall nutritional status, particularly within plant-based diets.

The presence of these antinutrients in Viha plant parts, as presented in Table 11, highlights the importance of considering their potential impact on mineral bioavailability when evaluating the nutritional value of this plant resource.

3.4 Toxicity to Viha (seeds and tubers)

This study investigated the toxicity of Viha, a plant of potential interest, through mouse gavage toxicity tests. The table presents the results of these tests, evaluating the effects of different preparations of Viha rhizome and seeds – uncooked, boiled, and steamed – on the observed mice. The primary endpoint of the study was to assess the presence and severity of adverse symptoms within 24 hours of administration.

Table 10 . Results of mouse gavage toxicity tests

Extract	Administration by force-feeding	
	Follow-up time	Observed symptoms
Uncooked Viha rhizome	24h	Passivity
Boiled Viha rhizome		None
Steamed Viha rhizome		Passivity
Uncooked Viha seeds		Passivity
Boiled Viha seeds		None
Steamed Viha seeds		Passivity

The results of mouse gavage toxicity tests (Table 12) indicate varying levels of toxicity associated with different preparations of Viha. Markedly, raw consumption of both Viha rhizome and seeds resulted in passivity in the observed mice within 24 hours. This suggests the presence of potentially harmful compounds in the raw form of the plant.

Conversely, both boiling and steaming the Viha rhizome appeared to mitigate the observed toxic effects, with no adverse symptoms reported in the mice. Similar results were observed with boiled Viha seeds, indicating that these cooking methods effectively inactivate or reduce the levels of the toxic substances present. However, steaming the Viha seeds still elicited passivity in the mice, suggesting that this method may not be as effective as boiling in eliminating the toxicity.

These findings underscore the importance of proper food preparation methods to ensure the safe consumption of Viha. While further research is necessary to fully understand the nature and mechanisms of the observed toxicity, these preliminary results strongly suggest that boiling is the preferred method for preparing Viha for consumption.

IV. Conclusion

This study investigated the impact of cooking methods on the micronutrient composition of Viha (*Typhonodorum lindleyanum*) rhizomes, seeds, and leaves. In rhizomes, steaming significantly enhanced potassium and iron, while boiling reduced calcium and phosphorus. Seed micronutrient profiles remained relatively stable across preparations. Manifestly, Viha leaves demonstrated a rich profile, particularly high in potassium and phosphorus, with iron also present in substantial amounts. These findings underscore the importance of considering cooking methods to optimize the nutritional value of Viha, particularly for rhizomes, while highlighting the potential of Viha leaves as a valuable source of essential minerals.

This research comprehensively analyzed the proximate composition of Viha plant parts, including water, ash, carbohydrates, lipids, and protein content. High water content was observed across all samples, with leaves exhibiting the highest levels. Rhizomes demonstrated significant water absorption during boiling. Viha seeds exhibited the highest protein and energy content, while leaves were rich in ash, indicating a high mineral content. Carbohydrate content was highest in rhizomes, while lipids were generally low, with boiling significantly reducing lipid content in rhizomes. These findings provide crucial insights into the nutritional composition of Viha, informing its potential use as a food source and guiding future research on its nutritional value and potential health benefits.

This investigation investigated the phytochemical profile and antinutrient content of Viha plant parts. Phytochemical screening revealed a rich presence of tannins, flavonoids, and leucoanthocyanidins, particularly in rhizomes and leaves. Boiling and steaming significantly impacted the phytochemical profile, notably reducing flavonoid levels. Furthermore, high levels of phytate and oxalate were detected, particularly in rhizomes. While processing methods reduced these antinutrients, their presence raises concerns regarding mineral bioavailability. These findings underscore the importance of considering both the beneficial phytochemicals and the potential negative impact of antinutrients when evaluating the nutritional and potential health benefits of Viha.

The toxicity observed in raw Viha may be linked to a complex interplay of factors, including the presence of certain phytochemicals, the abundance of antinutrients, and the balance of micronutrients and macronutrients. High levels of phytate and oxalate in raw Viha can chelate essential minerals, potentially contributing to toxicity. Furthermore, the presence of certain phytochemicals, such as tannins and potentially some flavonoids, may have contributed to the observed toxicity. Cooking methods, particularly boiling, appear to mitigate toxicity by inactivating or reducing the levels of these harmful compounds, while simultaneously improving the bioavailability of essential nutrients. However, the specific mechanisms underlying these effects require further investigation.

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