BloEx - Journal
Britain International of
EXACT Sciences Journal
Publish: | January - May - September |
Chemical Physics
Engineering
Agriculture
Biological
Medical
E-ISSN: 2686-1208
P-ISSN: 2686-1216
http://biarjournal.com/index.php/bioex

Phytonutraceutical composition of dark green, light green and white varieties of Sechium edule (Jacq.) Sw (Chayote) cooked by different methods from the Vontovorona market, Alakamisy Fenoarivo Commune, in the context of a zero-waste circular economy

Rakotomamonjy Pierre[1,2], Ralaibia Boniface Erménégilde3, Letsara Rokiman[1,2,4], Razafindrazanakolona Daniel[3], Rakotomalala Iarivontsoa Nekena Sahaza[2], Koto-te-Nyiwa Ngbolua[5,6], Robijaona Rahelivololoniaina Baholy[1,2,7]

[1]Engineering and Industrial Process, Agricultural and Food Systems, Polytechnic High School of Antananarivo, University of Antananarivo, Antananarivo, Madagascar

[2]Polytechnic High School of Antananarivo, University of Antananarivo, Antananarivo, Madagascar

[3]Geochemistry and Medicinal Chemistry Graduate School, University of Fianarantsoa, Fianarantsoa, Madagascar

[4]Botanical and Zoological Park of Tsimbazaza, Antananarivo, Madagascar

[5]Department of Biology, Faculty of Science, University of Kinshasa, Kinshasa, Democratic Republic of the Congo

[6]National Scientific Council, Ministry of Scientific Research and Technological Innovation, Democratic Republic of the Congo

[7]Laboratory for the Valorization of Natural Resources, Polytechnic High School of Antananarivo, Madagascar

Correspondance to: baholy.robijaona@univ-antananarivo.mg

Abstract:

Three distinct varieties of Sechium edule (dark green, light green, and white) were procured from the Vontovorona open-air market. The coyotes were thoroughly washed and peeled, and their peel, flesh, and seed, whether raw, boiled, or steamed, were analyzed for their phytonutraceutical components. Each part was then dried in a dehydrator at 41°C for 48 hours, ground, and placed in sachets. Mineral micronutrient content was assessed using portable X-ray fluorescence equipment, revealing magnesium as the predominant element across all varieties. Specifically, magnesium content in the dark green variety ranged from 1.01% to 2.32%, in the light green variety from 1.13% to 2.32%, and in the white variety from 1.64% to 3.42%. Macronutrient analysis, performed via the Kjeldahl method, indicated moisture content variations in the dark green variety from 84.58% to 90.37%, in the light green variety from 72.87% to 91.74%, and in the white variety from 84.93% to 92.87%. Phytochemical screening identified the presence of flavonols, specifically in the raw white variety.

Keywords:
Sechium edule; micronutrients; macronutrients; phytochemical screening; peel; flesh; seed

DOI: *https://doi.org/10.33258/bioex.v6i3.1162*

I. Introduction

The bioavailability and efficacy of nutrients in foods can vary significantly between raw and cooked states, a critical consideration in nutrition science. Raw foods often retain essential nutrients like vitamins, minerals, and enzymes that are sensitive to heat; for instance, vitamin C, a potent antioxidant, degrades upon exposure to high temperatures, making raw consumption more effective in preserving its potency (Buratti et al., 2020). Despite this, cooking can sometimes enhance the availability and absorption of certain nutrients by breaking down cell walls in plant-based foods (Türkmen et al., 2005).

The traditional Malagasy cooking method, known as "nahandro gasy," involves water cooking, commonly referred to as "well cooked," and is used extensively for preparing various dishes. Sechium edule, a vegetable frequently boiled in this method, has seen a diversification in cooking techniques, including boiling, steaming, and even raw consumption. This raises the problem of determining the most effective cooking method for maximizing nutritional benefits and exploring the underutilized peel and seed of Sechium edule.

The traditional practice of discarding the peel and seed of Sechium edule results in a potential loss of beneficial phytonutrients. This study addresses the need to evaluate different cooking methods for their impact on this vegetable's nutritional value and explore ways to valorize its discarded parts. Tradition is something that is passed down from the heritage of the ancestors to the next generation in a relay descends performed by the indigenous communities that have become deeply entrenched the culture in life. (Purba, N. 2020). There are also traditional factors which appear from this study to influence the relationship between home and school in general and consequently have an impact on children's behaviour one way or another. (Gadour, A. 2011)

Understanding how various cooking methods affect the nutritional content of Sechium edule and assessing the nutritional and environmental value of its peel and seed is crucial for improving culinary practices and promoting sustainable food resource management.

The study aims to explore the impact of various cooking methods—specifically raw, boiled and steamed—on the nutritional value of Sechium edule. It will also assess the potential nutritional and environmental benefits of utilizing this vegetable's peel and seed. Additionally, the research seeks to evaluate the carbon footprint associated with each cooking method to provide a comprehensive understanding of their environmental implications. By addressing these aspects, the study will offer insights into optimizing culinary practices and enhancing sustainable food resource management.

This comparative study seeks to provide a comprehensive understanding of how cooking methods influence the nutritional quality of Sechium edule and to propose strategies for better utilizing its entire form while considering environmental sustainability.

II. Reserach Methods

2.1 The chayote

The chayote, also known as "christophine," is a vegetable native to Central America, belonging to the Cucurbitaceae family, which also includes squash and cucumbers. The term "chayote" is derived from the Spanish word "chayote," which refers to both the fruit and the plant, originating from the Nahuatl word "chayotli," referring to the spiny fruit. In Nahuatl, "chinchayote" in Spanish denotes its edible root.

The name "Christophine" is attributed to the European discovery of this vegetable by Christopher Columbus in Central America at the end of the 15th century.

Chayote (*Sechium edule* (Jacq.) Sw.), is originating in Middle America; Mexico is the place of greatest biodiversity (**Ortega-Paczka et *al.*, 1998; Cruz-León 1985-1986**)

Sechium edule is a vigorous, herbaceous, perennial creeper with tuberous roots. Its stems, which can extend up to 12 meters or more, bear angular palmate leaves with pointed lobes and trifid tendrils that cling to any support. The plant produces flowers quite late, emerging from the leaf axils. These flowers are unisexual, although *Sechium edule* is capable of self-fertilization.

While *Sechium edule* is pollinated by insects, the christophine fruit appears and develops rather slowly. The fruit is pendulous, large, obovoid, or pyriform, with a variable number of longitudinal depressions, white surface, and light or dark, brilliant green; it may be glabrous, with fine hair or with a variable number of spines and contains only one seed resembling a flattened nut, that remains attached to the fruit (**LiraSaade, 1996; Flores, 1989; Maffioli, 1981**). This unique feature makes it viviparous, distinguishing it from other members of the Cucurbitaceae family.

The chayotes analyzed in this study were purchased from the Vontovorona market in the Alakamisy Fenoarivo commune.

Sechium edule (Jacq.) Sw. *nigrum jalapenos* dark green	*Sechium edule* (Jacq.) Sw *virens levis* light green	*Sechium edule* (Jacq.) Sw *albus dulcis* white

***Figure 1**. The Sechium edule varieties studied*

The study was conducted on the peel, flesh, and seed of three varieties of *Sechium edule* (christophine): dark green, light green, and white.

2.2 Methods

The fruits of *Sechium edule* underwent meticulous pre-treatment procedures to ensure sample integrity. Initially, the fruits were thoroughly washed with potable water and subsequently wiped with a clean cloth. They were then carefully peeled, with the peel, flesh, and seed collected separately for further analysis.

Two distinct cooking methods were employed: boiling for 10 to 15 minutes and steaming for an additional 10 to 15 minutes. Raw samples were utilized as controls to provide a baseline for comparison.

To prevent contamination from external sources such as dust, insects, and rodents, a food dryer was employed. The drying process was conducted at a controlled temperature of 41°C over two days. Upon drying, the raw materials were finely ground to a particle size of less than 5 mm using a blender. The resulting powder was then meticulously packaged into sachets for subsequent analysis.

a. Determination of elemental micronutrients by X-ray fluorescence

Micronutrient analysis of *Sechium edule* fruit was meticulously conducted at the OMNIS laboratory (Office des Mines Nationales et des Industries Stratégiques) using a portable X-ray fluorescence spectrometer. This sophisticated analysis technique involves subjecting a sample to a beam of X-rays, which excites the atoms within the sample. As these atoms return to their initial state, they emit energy in the form of X-ray photons. Each type of atom emits photons with characteristic energy levels and wavelengths, a phenomenon known as X-ray fluorescence. By analyzing this secondary X-ray emission, it is possible to accurately determine the chemical elements present in the sample and their respective mass concentrations (**Santana et *al.*, 2014**).

For the analysis, the clean, fingerprint-free polyester film was meticulously folded in half and positioned between the hollow cylinders of the apparatus. Subsequently, 20 grams of sample powder were carefully introduced. The instrument was set to 'mineral' mode to analyze the coded sample. The analysis process, lasting one minute, involved real-time calculations by a device connected to the X-ray machine, with results displayed directly on a reading screen.

Each part of the *Sechium edule*, whether raw, boiled, or steamed, underwent the same rigorous analysis process, ensuring consistency and accuracy across all samples.

b. Determination of macronutrients

- **Extraction of fats (lipids)**

The fat content of *Sechium edule* was analyzed at the Laboratoire de Chimie et de Microbiologie (LCM) in Nanisana—the fat determination method involved solvent extraction using a Soxhlet apparatus by percolation.

- **Determination of the humidity content**

The moisture analysis method involves drying the samples at 103°C in an oven under atmospheric pressure until a nearly constant mass is achieved. The difference in weight between the sample before and after drying is used to determine the water content, employing a gravimetric approach.

Initially, 5 grams of the sample is placed into a previously dried and tared capsule. The capsule containing the sample is then placed in the oven and dried for 48 hours until a constant weight is attained. Following drying, the capsule is allowed to cool in a desiccator for 30 minutes and subsequently weighed.

The water content (H%), expressed in grams per hundred grams of sample, is calculated using the formula:

$$H\% = \frac{(W_{\text{initial}} - W_{\text{final}})}{W_{\text{initial}}} \times 100$$

Where $W_{initial}$ is the initial weight of the sample, and W_{final} is the weight of the sample after drying.

The dry matter content *DM* is calculated by subtracting the moisture content from the total weight of the sample, as expressed by the following relationship:

$$DM\ \% = 100 - H\%$$

- **Determination of protein content**

The analysis to determine nitrogenous compounds and mineralization level was conducted at the FOFIFA laboratory (FOibem-pirenena momban'ny FIkarohana ampiharana amin'ny Fampandrosoana ny eny Ambanivohitra) or the National Center for Applied Research for Rural Development (CENRADER) in Ampandrinomby, Analamanga region.

Total protein content was indirectly derived from nitrogen content determined using the Kjeldahl method, applying a conversion factor of 6.25, as specified by the Association of Official Agricultural Chemists (AOAC) international standards.

The principle is based on the mineralization of all organic forms of nitrogen into ammonium sulfate ($(NH_4)_2SO_4$) through the oxidative action of concentrated sulfuric acid at high temperature, facilitated by a catalyst to accelerate the reaction. This is followed by the displacement of sulfate into ammonia (NH_3) using sodium hydroxide (NaOH), distillation, and titration of the liberated ammonia with sulfuric acid (H_2SO_4) solution.

$$\text{Organic nitrogen} + H_2SO_4 \xrightarrow{CuSO_4\ ;\ K_2SO_4} (NH_4)_2SO_4$$

- Potassium sulfate (K_2SO_4) raises the boiling temperature of H_2SO_4 up to 430°C.
- Copper sulfate ($CuSO_4$) acts as a catalyst.

Ammonium nitrogen is converted into ammonia by excess sodium hydroxide.

$$(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH3 + 2H_2O + Na_2SO_4$$

<u>First step</u>: Mineralization

In the Kjeldahl flask, 0.3g of the sample is added with 2.7g of potassium sulfate and 0.3g of copper sulfate, totaling approximately 3.3g. The exact weight is noted for precise calculations. Then, 10 ml of concentrated sulfuric acid (H_2SO_4) is added under a fume hood. The mixture is heated on a mineralization apparatus for 3 hours until the solution becomes clear and devoid of boiling.

After mineralization, the flask and its content are allowed to cool before proceeding to the second step.

Second step: Distillation

The mineralized solution is transferred into a 20ml volumetric flask and diluted with distilled water to the mark. Then, 10 ml of this solution is placed in a distillation apparatus with 10 ml of 30% sodium hydroxide to release ammonia.

Third step: Titration

The distillate is collected in a 125ml Erlenmeyer flask containing 20ml of 4% boric acid solution (40g H_3BO_3 in 1800ml distilled water) and two drops of indicator. The amount of ammonia nitrogen in the solution is titrated with 0.1N sulfuric acid until a persistent pink color change indicates the endpoint.

The total nitrogen content is obtained from the following formula:

$$N\% = (N \times V \times 50/10) \times 0.014 \times 100$$

Where

N represents the normality of the sulfuric acid employed in the titration, with a value of 0.01N,

V denotes the volume of acid utilized.

This gives:

$$N\% = V \times 0.07$$

The total protein content is determined by multiplying the total nitrogen content by the conversion factor 6.25. Therefore, protein containing 16% nitrogen would equate to:

$$P\% = N\% \times 6.25$$

With:

N%: Total nitrogen content in g per 100g of sample

P%: Total protein content in g per 100g of sample

V: Volume in ml of sulphuric acid required to obtain the color change

0.014 g: milliequivalent of nitrogen.

- **Degree of mineralization**

The C/N ratio can define the degree of mineralization. While the percentage of nitrogen (N) was measured using the previously mentioned Kjeldahl method, the percentage of carbon (C) is determined as follows:

The Walkley-Black method is employed to measure the organic carbon content in soil or organic matter, not the total carbon content. This method involves converting all organic carbon into carbon dioxide (CO_2). Organic carbons are oxidized by an excess of potassium dichromate ($K_2Cr_2O_7$) solution in an acidic medium. The excess dichromate is subsequently titrated with ferrous sulfate solution ($FeSO_4$).

A sample weighing less than 0.02 g of plant material is mixed with 10 ml of 1N $K_2Cr_2O_7$ and 20 ml of concentrated H_2SO_4. CO_2 evolution is observed during the reaction. The mixture is stirred for 1 minute and allowed to stand under a fume hood for 30 minutes. After this incubation period, 200 ml of distilled water and three drops of ortho-phenanthroline (color indicator) are added. The excess dichromate is then titrated with 0.5N ferrous sulfate solution until a distinct color change from intense green to coca red is observed.

A blank control was prepared under identical conditions.

The solution “sample mass + 20 ml H_2SO_4 + 200 ml water + 3 drops color indicator” is titrated with the ferrous sulfate solution, observing the color change indicative of the endpoint.

Typically, the optimal C/N ratio varies depending on the specific application and the materials involved.

- **Composting:** The ideal C/N ratio for composting is typically around 25-30:1, with some variations depending on the materials used. (**Haug, 1993**)
- **Soil Amendment:** Different soils and crops may require different C/N ratios. For example, green manures might have a lower C/N ratio (e.g., 15:1) to provide readily available nitrogen. (**Syein et *al.*, 2023**)
- **Crop Residue Management**: Crop residues with a C/N ratio around 25-30:1 are generally considered optimal for decomposition. (**Kriaučiūnienė, 2012**)
- **Bioenergy Production**: Biomass for bioenergy typically requires a higher carbon content relative to nitrogen, with C/N ratios varying widely based on feedstock and conversion technology. (**Perlack et *al.*, 2005**)
- **Mulching**: Mulch materials often have a higher C/N ratio (e.g., 30:1 or higher) to ensure slow decomposition and long-lasting weed suppression. (**Gaitanis et *al.*, 2023**)
- **Livestock Feed**: Livestock feed may require balanced C/N ratios to optimize nutrient availability and digestion, depending on the animal species. (**Baris, 2023)**
- **Environmental Remediation**: Organic amendments for soil remediation often aim for a balanced C/N ratio to support microbial activity and pollutant degradation. (**Sustainable Soil Remediation Using Organic Amendments, 2021**)
- **Green Chemistry**: Bio-based chemicals may utilize biomass with specific C/N ratios tailored to optimize chemical production efficiency. (**Kobli et *al.*, 2019**)
- **Biocarburant (Biofuel Production)**: Biofuel production typically involves biomass feedstocks with varying C/N ratios depending on the feedstock and conversion process. For example, lignocellulosic biomass used in biofuel production may have C/N ratios ranging from 50:1 to 200:1, depending on the composition and treatment. (**Demirbas, 2009**)
- **Materials for Building**: Biomass used for construction materials, such as particleboard or fiberboard, requires a specific C/N ratio to ensure proper bonding and durability. The C/N ratio varies based on the type of biomass and the manufacturing process. (**Mohanty et *al.*, 2002; Skaar, 1988**)
- **Charcoal Production**: Charcoal production involves pyrolysis or carbonization of biomass with a focus on high carbon content relative to nitrogen. The C/N ratio can vary widely depending on the feedstock and pyrolysis conditions. (**Li et *al.*, 2020; Bridgwater, 2012**)

The C/N ratios are relevant to each valorization possibility, ensuring a solid foundation for understanding the applications and their requirements in biomass utilization.

c. Phytochemical screening

Numerous studies have demonstrated that a significant majority of phytochemical compounds possess potent antioxidant and anti-inflammatory properties. These activities confer pharmacological potential, providing both preventative and therapeutic benefits for a range of diseases. Among these compounds, phenolic compounds, which are especially abundant in vegetables, constitute the largest group of natural antioxidants. Their efficacy in neutralizing free radicals and modulating inflammatory responses underscores their critical role in disease prevention and health promotion (**Boeing et *al.*, 2012; Zhao et *al.*, 2011**).

Therefore, this study conducts a comprehensive phytochemical screening to investigate these properties further further.

Phytochemical screening encompasses a variety of methods and techniques aimed at preparing and analyzing the different chemical families present in plants. Chemical evaluations during phytochemical analysis focus on detecting chemical groups in various aqueous, alcoholic, and acidic extracts.

- **Aqueous extract:**

In a beaker, 20 ml of distilled water is added to 1 g of sample powder. The mixture is heated on a hot plate with a magnetic stirrer until boiling. After 20 minutes of heating, the operation is stopped, and the mixture is cooled to approximately +4°C. Finally, the extract is filtered to obtain the aqueous extract for analysis.

- **Hydroethanolic extract**:

In a beaker, 10 ml of 96% ethanol is added to 1 g of sample powder, and the mixture is allowed to macerate for 24 hours. Subsequently, the solution is filtered to obtain the alcoholic extracts.

Saponin screening:

The foam test is employed to identify the presence of saponins. 5 ml of aqueous extract is placed in a test tube, vigorously shaken for 30 seconds, and then left to rest for 30 minutes. Expected results: the formation of foam measuring 3 cm or more indicates the presence of saponins.

Anthraquinone screening:

The Bornträger test is conducted to detect anthraquinones. 1 ml of benzene is added to a test tube, followed by 0.5 ml of aqueous extract. The solution is vigorously shaken and allowed to settle for a few seconds. Then, the benzene phase is transferred to another test tube containing 0.5 ml of 25% ammonia (NH_4OH). Expected results: the appearance of red color in the upper phase or alkaline phase confirms the presence of anthraquinones.

Tannin and polyphenol analysis:

Detection of tannins and polyphenols involves three distinct tests using 0.5 ml of aqueous extract each: the first tube serves as a control, the second for the 1% gelatin test, the third for the salted gelatin test, and the fourth for the $FeCl_3$ test in methanol. A negative reaction in the salted gelatin test but a green or black-blue color with $FeCl_3$ indicates the presence of other phenolic compounds apart from tannins.

Polysaccharide screening:

5 ml of aqueous extract is mixed with three volumes of ethyl alcohol, totaling 15 ml. Expected results: precipitation indicates the presence of polysaccharides. The following figures illustrate the procedure during polysaccharide screening.

Desoxyose screening:

Desoxyose screening, using the Keller-Kiliani test, involves adding 0.5 ml of 10% $FeCl_3$ and 0.5 ml of acetic acid to 0.5 ml of aqueous extract, followed by the addition of 0.5 ml of concentrated 4N H_2SO_4—expectedThe expected result is the appearance of a purple-red ring.

Flavonoid and leucoanthocyanin screening:

The alcoholic extract is distributed into 5 test tubes, each containing 1 ml. Four distinct tests are performed, and the expected results are summarized in the following table.

Table 1. Summary of reagents and expected results for flavonoid and leucoanthocyanin screening

Tube number	**Reagents**	**Expected Results**
1	Control	
2	**Wilstater's reagent**: Add 0.5 ml concentrated HCl and two turns of magnesium, followed by a 10-minute rest before observation.	- Flavones: red color - Flavonols: red to purple color - Flavanones and flavonols: violet-red color
3	**Modified Wilstater's reagent**: Add 0.5 ml concentrated HCl and two turns of magnesium. After dissolution, add 1 ml distilled water and 1 ml isoamyl alcohol.	- Flavones: red color - Flavonols: purple color
4	**Bate Smith's reagent:** Addition of 0.5 ml concentrated HCl to the hydroethanolic extract, followed by heating at 100°C for 30 minutes in a water bath	- Presence of leucoanthocyanins: violet-red color
5	**Bate Smith's cold reagent**: Addition of 0.5 ml concentrated HCl at cold temperatures.	- Presence of anthocyanins: red color

Flavonones and flavonols are detected using the Wilstater and modified Wilstater tests, respectively. Leucoanthocyanins and anthocyanins are detected using the Bate-Smith and cold Bate-Smith tests, respectively.

III. Results and Discussion

3.1 Results

a. Drying yield

The drying yield reflects the amount of moisture removed relative to the total moisture content present in the skin, flesh, and seed of *Sechium edule*. The following relationship expresses it:

$$r(\%) = \frac{M_f}{M_i} \times 100$$

Where:

- *r (%)* represents the drying yield percentage.

- M_f is the final mass after drying.
- M_i is the initial mass before drying.

The results of the drying yield for each part of *Sechium edule* are presented in Table 2:

Table 2. Drying yields results of the dark green, light green, and white variety of *Sechium edule*

	Peel raw	**Flesh raw**	**Seed raw**	**Peel cooked**	**Flesh cooked**	**Seed steamed**
Dark green						
Initial weight (g)	267.00	956.00	45.00	103.00	903.00	601.00
Final weight (g)	21.00	59.00	8.00	13.00	66.00	32.00
Drying yield (%)	7.87	6.17	17.78	12.62	7.31	5.32
Light green						
Initial weight (g)	138.00	14.00	38.00	42.00	272.00	285.00
Final weight (g)	13.00	17.00	3.00	3.00	20.00	17.00
Drying yield (%)	9.42	21.43	7.89	7.14	7.35	5.96
White						
Initial weight (g)	165.00	900.00	46.00	212.00	900.00	448.00
Final weight (g)	12.00	55.00	11.00	18.00	68.00	24.00
Drying yield (%)	7.27	6.11	23.91	8.49	7.56	5.36

The drying yield data for the different parts of *Sechium edule* across three color varieties, dark green, light green, and white, demonstrate significant variability influenced by the initial moisture content and the physical properties of each plant part.

b. Results of elemental micronutrients by X-ray fluorescence

Understanding the nutritional quality of food products is vital, and X-ray fluorescence (XRF) spectroscopy is a precise method for analyzing elemental micronutrients. This section presents the XRF results for essential micronutrients in dark green, light green, and white varieties of *Sechium edule* (Jacq.) Sw (chayote) after different cooking methods. These findings highlight the nutritional value of chayote and its potential dietary benefits within a zero-waste circular economy.

The main elements necessary and sufficient for human health include a variety of essential macronutrients and micronutrients. These elements are required in varying amounts and are vital for various physiological processes, including metabolism, growth, and development. They can be broadly categorized into macronutrients (needed in larger quantities) and micronutrients (needed in trace amounts).

Table 3. Elemental micronutrients in the skin, flesh, and core across the dark green, light green,
and white varieties of *Sechium edule*

Sample	**skin raw**	**flesh raw**	**Seed raw**	**skin cooked**	**flesh cooked**	**Seed steamed**	**skin raw**	**flesh raw**	**Seed raw**	**skin cooked**	**flesh cooked**	**Seed steamed**	**skin raw**	**flesh raw**	**Seed raw**	**skin cooked**	**flesh cooked**	**Seed steamed**
Mg(%)	1.77	2.32	1.43	2.02	1.77	1.77	2,17	1,72	1,64	2,30	1,70	1,81	2,35	2,36	1,64	2,49	2,43	2,13
Al(%)	0.42	0.87	0.93	0.80	0.23	0.42	0,96	0,82	0,95	0,74	0,09	0,61	0,25	0,54	0,34	0,87	0,63	0,65
Si(%)	0.30	0.07	0.00	0.16	0.65	0.30	0,34	0,50	0,00	0,10	0,56	0,51	0,00	0,00	0,00	0,00	0,00	0,07
P(%)	0.61	0.85	1.53	0.77	0.69	0.61	0,93	0,49	1,27	0,58	0,48	0,51	0,80	0,52	1,23	0,82	0,64	0,75
S(%)	0.00	0.00	0.30	0.00	0.00	0.00	0,00	0,00	0,10	0,00	0,00	0,00	0,00	0,00	0,30	0,00	0,00	0,00
K(%)	1.90	2.70	3.85	2.85	1.93	1.90	4,38	2,42	4,32	2,91	2,09	2,43	4,20	1,89	2,80	2,88	1,90	2,52
Ca(%)	0.00	0.01	0.00	0.01	0.00	0.00	0,01	0,00	0,00	0,01	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,01
Ti(%)	0.15	0.12	0.14	0.16	0.16	0.15	0,12	0,16	0,13	0,12	0,16	0,15	0,12	0,12	0,12	0,12	0,12	0,16
V(%)	0.01	0.00	0.01	0.01	0.01	0.01	0,01	0,01	0,01	0,02	0,01	0,01	0,01	0,00	0,01	0,01	0,00	0,01
Cr(%)	0.02	0.03	0.03	0.03	0.02	0.02	0,03	0,02	0,04	0,05	0,02	0,02	0,05	0,03	0,04	0,04	0,02	0,03

Mn(%)	0.00	0.00	0.00	0.00	0.00	0.00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,00	0,00	0,00	0,00	0,00
Fe(%)	0.58	0.50	0.53	0.67	0.58	0.58	0,49	0,58	0,64	0,55	0,55	0,59	0,40	0,37	0,39	0,40	0,37	0,55
Co(%)	0.00	0.00	0.00	0.00	0.00	0.00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Ni(%)	0.04	0.04	0.05	0.04	0.04	0.04	0,04	0,04	0,05	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04
Cu(%)	0.01	0.01	0.02	0.01	0.01	0.01	0,01	0,01	0,02	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Zn(%)	0.01	0.01	0.02	0.01	0.01	0.01	0,01	0,01	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
As(%)	0.01	0.01	0.01	0.01	0.01	0.01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Se(%)	0.00	0.00	0.00	0.01	0.01	0.00	0,01	0,01	0,00	0,00	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Sn(%)	0.00	0.00	0.00	0.00	0.00	0.00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Sb(%)	0.00	0.00	0.00	0.00	0.00	0.00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Ag(%)	0.02	0.02	0.02	0.02	0.02	0.02	0,02	0,01	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
Mo(%)	0.00	0.01	0.00	0.00	0.00	0.00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Zr(%)	0.06	0.07	0.08	0.08	0.06	0.06	0,07	0,06	0,08	0,08	0,06	0,06	0,07	0,06	0,07	0,07	0,05	0,07
Rb(%)	0.04	0.04	0.08	0.05	0.03	0.04	0,05	0,03	0,06	0,04	0,03	0,03	0,05	0,03	0,04	0,04	0,03	0,04
Sr(%)	0.04	0.05	0.06	0.06	0.04	0.04	0,05	0,05	0,08	0,07	0,04	0,05	0,05	0,04	0,04	0,05	0,03	0,05
Ba(%)	0.03	0.03	0.02	0.03	0.03	0.03	0,04	0,03	0,02	0,02	0,03	0,02	0,03	0,02	0,03	0,03	0,02	0,02
W(%)	0.05	0.05	0.05	0.05	0.04	0.05	0,04	0,05	0,05	0,04	0,05	0,05	0,05	0,04	0,05	0,05	0,04	0,04
Ta(%)	0.00	0.00	0.00	0.00	0.00	0.00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Au(PPM)	0.00	0.00	0.00	0.00	0.00	0.00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hg(PPM)	0.00	0.00	0.00	0.00	0.00	0.00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Pb(%)	0.00	0.00	0.00	0.00	0.00	0.00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Cd(%)	0.00	0.00	0.00	0.00	0.00	0.00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0.00

c. Results of macronutrients and the level of mineralization

The following table presents the moisture (H) and dry matter (DM) content of dark green, light green, and white varieties of *Sechium edule*. It compares the skin, flesh, and seed in both raw and cooked states. Moisture content increases with cooking and steaming, while dry matter decreases accordingly. Notably, the steamed seed has the highest moisture content and lowest dry matter across all varieties.

Table 4. Moisture, dry matter content, lipid, proteins, and levels of mineralization of the dark green, light green, and white variety of *Sechium edule*

Sample	skin raw	flesh raw	Seed raw	skin cooked	flesh cooked	Seed steamed	skin raw	flesh raw	Seed raw	skin cooked	flesh cooked	Seed steamed	skin raw	flesh raw	Seed raw	skin cooked	flesh cooked	Seed steamed

H (%)	84.58	90.37	84.97	86.63	90.01	90.14	85.27	91.67	72.87	87.09	88.96	91.74	90.94	92.87	86.20	84.93	87.76	91.76
DM (%)	15.42	9.63	15.03	13.37	9.99	9.86	14.73	8.33	27.13	12.91	11.04	8.26	9.06	7.13	13.80	15.07	12.24	8.24
L (%)	0.86	1.02	1.68	0.88	0.92	0.48	0.86	1.02	1.68	0.88	0.92	0.48	0.86	1.02	1.68	0.88	0.92	0.48
N (%)	1.56	0.28	2.50	0.95	0.59	0.26	1.49	0.53	2.91	1.49	0.29	0.56	1.49	0.52	2.59	1.30	1.01	1.25
Pr (%)	9.75	1.77	15.65	5.96	3.69	1.61	9.29	3.31	18.17	9.32	1.80	3.50	9.30	3.25	16.18	8.12	6.32	7.78
C (%)	23.02	48.75	28.61	32.28	52.06	47.59	25.63	51.11	29.40	27.52	47.80	47.96	27.30	64.93	29.58	22.52	50.18	45.28
C/N	14.76	172.46	11.43	33.88	88.20	185.32	17.23	96.53	10.11	18.46	165.80	85.70	18.34	125.01	11.42	17.33	49.67	36.36

H: Humidity **DM:** Dry Materials **L**: Lipid **N**: Nitrogen
Pr: Proteins **C** ; Carbon **C/N**: Level of mineralization

The moisture (H) and dry matter (DM) content of *Sechium edule* varieties show significant variations among the different parts of the plant (skin, flesh, seed) and their preparation states (raw, cooked, steamed). The dark green variety has a slightly lower moisture content and higher dry matter in its raw skin, flesh, and seed compared to the light green and white varieties. Cooking and steaming generally, increase moisture content while decreasing dry matter across all varieties and parts. Notably, the steamed seed consistently exhibits the highest moisture content and lowest dry matter, indicating a substantial water uptake during the steaming process.

The lipid content varies significantly among the different parts and varieties of *Sechium edule*. Generally, the seed exhibits the highest lipid content compared to the skin and flesh across all varieties. Cooking and steaming processes decrease the lipid content in both the skin and flesh, while the seed shows a notable reduction in lipid content after steaming. This variation highlights how cooking methods can influence the nutritional composition of *Sechium edule*, particularly in terms of lipid content.

The protein content varies significantly across different parts and varieties of *Sechium edule*. Generally, the seed exhibits the highest protein content compared to the skin and flesh across all varieties. Cooking and steaming processes generally lead to reductions in protein content in the skin and flesh, while the seed shows more varied responses. For instance, steaming often results in decreased protein content in the seed compared to raw forms. This variation underscores how cooking methods impact the nutritional composition of *Sechium edule*, particularly in terms of protein content.

The carbon-to-nitrogen (C/N) ratio is a pivotal metric in environmental science and agriculture. It delineates the nutrient balance crucial for organic matter decomposition and resource utilization. Understanding C/N ratios informs strategies for biogas production, composting, biochar formation, and bioplastic synthesis, ensuring efficient and sustainable utilization of plant residues.

The analysis of mineralization levels across the skin, flesh, and core of dark green, light green, and white varieties of *Sechium edule* reveals notable variations in carbon (C) and nitrogen (N) contents and their ratio (C/N).

Across all varieties and parts examined, the flesh consistently shows the highest carbon content, followed by the seed and then the skin. Conversely, nitrogen content tends to be highest in the seed, with the flesh and skin exhibiting lower levels. This pattern suggests differential allocation of these elements within the plant.

The C/N ratio, which serves as an indicator of mineralization degree, varies significantly across different parts and varieties. Generally, a higher C/N ratio indicates lower mineralization, suggesting that the flesh and seed tend to be less mineralized compared to the skin and seed. Steaming and cooking processes generally reduce carbon and nitrogen content and alter their ratios, reflecting changes in mineral availability and biochemical composition due to heat-induced alterations.

d. Results of phytochemical screening

Phytochemical screening identifies bioactive compounds in plant-based foods cooked using different methods. These findings highlight chayote's potential health benefits.

Table 5. *Phytochemical screening of saponins, polysaccharides, deoxy oses, tannins, and polyphenols* of the dark green, light green, and white variety of Sechium edule

Chemical family	**Saponins**	**Polysaccharides**	**Deoxyoses**	**Tannins and polyphenols**			**Flavonoids**				**Anthraquinones**
Dark Green Skin Raw	(+ + +)	(+)	(+)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Dark Green Flesh Raw	(+ +)	(+ +)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Dark Green Kernel Raw	(-)	(+)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Dark Green Skin cooked in water	(-)	(+)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Dark Green Flesh cooked in water	(-)	(+)	(-)	(-)	(-)	(-)	(-)	(-)	(+)	(-)	(-)
Dark Green Kernel steamed.	(-)	(+)	(-)	(-)	(-)	(-)	(-)	(-)	(+)	(-)	(-)
Light Green Skin Raw	(+)	(+)	(-)	(-)	(-)	(-)	(-)	(-)	(+)	(-)	(-)
Light Green Flesh Raw	(+)	(+ +)	(+)	(-)	(-)	(-)	(-)	(-)	(+)	(-)	(-)
Light Green Kernel Raw	(+)	(+ + +)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Light Green Skin cooked in water	(+ +)	(+ + +)	(+)	(-)	(-)	(-)	(-)	(-)	(+)	(-)	(-)
Light Green Flesh cooked in water	(-)	(+)	(+)	(-)	(-)	(-)	(-)	(-)	(+)	(-)	(-)
Light Green Kernel steamed.	(-)	(+)	(-)	(-)	(-)	(-)	(-)	(-)	(+)	(-)	(-)
White Skin Raw	(+ +)	(+)	(+)	(-)	(-)	(-)	(+) flavonols	(-)	(+)	(-)	(-)
White Flesh Raw	(+)	(+ +)	(-)	(-)	(-)	(-)	(+) flavonols	(+) flavonols	(+)	(+)	(-)
White Kernel Raw	(+)	(+)	(-)	(-)	(-)	(-)	(-)	(+) flavonols	(+)	(-)	(-)
White Skin cooked in water	(+)	(+)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
White Flesh cooked in water	(+)	(+)	(+)	(-)	(-)	(-)	(-)	(-)	(+)	(-)	(-)
White Kernel steamed	(+ +)	(+)	(+)	(-)	(-)	(-)	(-)	(-)	(+)	(-)	(-)

(-) : négative (+) : low presence **(++)** : présence **(+++)** : abundant

test	moyenne	presence

According to research by Vieira et *al.*, the peel contains phenols (all phenolic compounds:167.03 ± 8.35 mg/ 100 g dw (dry weight)).

According to Vieira et *al.*, research indicates that the peel contains flavonols at a concentration of 4.92 ± 1.75 mg per 100 g of dry weight (dw). The analysis using HPLC (High-Performance Liquid Chromatography) of the chayote peel extract treated with UAE (Ultrasound-Assisted Extraction) revealed that tocopherol esters were the predominant type of carotenoids present (1047.20 ± 121.41 µg/g dw extract), followed by retinol esters (245.89 ± 34.85 µg/g dw extract) and α-tocopherol (219.13 ± 12.80 µg/g dw extract). The concentration of α-tocopherol in the extract exceeded that found in spinach (75-88 µg/g dw), suggesting that chayote peel could be a valuable dietary source of vitamin E.

3.2 Discussion

a. Drying of the three varieties

Across all varieties, the initial weights indicate a predominant biomass contribution from the flesh, followed by the peel and the seed. The initial weights of cooked and steamed components highlight the differential water absorption capacities, which are critical in understanding the drying dynamics. The data suggest that flesh consistently has the highest initial weight and potential moisture content, significantly influencing the drying yield. The variation in initial weights across different parts and treatments underscores the necessity to tailor drying processes based on specific biomass characteristics.

- **Dark Green Variety**

The dark green variety exhibits a notable range in drying yields. The raw seed achieved the highest yield at 17.78%, suggesting a higher initial moisture content or denser structure that retains less water post-drying. In contrast, the raw flesh presented a much lower drying yield of 6.17%, indicating a greater retention of moisture or a more fibrous composition that traps water. The peel, both raw and cooked, demonstrated moderate yields of 7.87% and 12.62%, respectively, with cooking enhancing the yield, likely due to cell structure breakdown facilitating moisture removal. The steamed seed had the lowest yield at 5.32%, suggesting a denser or more water-retentive structure post-steaming.

- **Light Green Variety**

For the light green variety, the drying yield of the raw flesh is exceptionally high at 21.43%, implying a high initial moisture content or a more porous structure that releases water easily. Conversely, the raw seed yield is much lower at 7.89%, indicating a less efficient drying process, possibly due to its compact structure. The raw peel also shows a relatively higher yield at 9.42%. The yields for the cooked parts, peel, flesh, and seed, are 7.14%, 7.35%, and 5.96%, respectively. These lower values compared to raw flesh suggest that the cooking process either reduces the initial moisture content or alters the tissue structure, making water removal more challenging.

- **White Variety**

In the white variety, the raw seed again shows the highest drying yield at 23.91%, which is the highest among all samples, indicating a very efficient moisture removal process. The raw flesh and raw peel show lower yields of 6.11% and 7.27%, respectively. Cooked parts exhibit varied yields, with the cooked peel at 8.49%, cooked flesh at 7.56%, and steamed seed at 5.36%. These results suggest that the cooking process has a significant impact on the moisture retention of the white variety, particularly in the peel and flesh. At the same time, the steamed seed retains more water compared to the other parts.

b. Elemental micronutrients in the three varieties

In contrast to macronutrients like carbohydrates, fats, and proteins, micronutrients do not provide energy directly. Instead, they play critical roles as cofactors and integral parts of enzymes, assisting in metabolic reactions. Sufficient consumption of these micronutrients is vital for the proper functioning and overall health of the immune system. (Gibney et al. 2009; Campbell 2017).

Mineral micronutrients are essential for normal metabolic processes and must be obtained through the diet. While minerals such as calcium, phosphorus, magnesium, and sodium are required in larger amounts, others like copper, zinc, selenium, fluorine, and chromium are needed in trace amounts.

Calcium is particularly important for maintaining fluid balance, blood coagulation, blood pressure regulation, enzyme activity, muscle contraction, and nerve transmission (Marcus, 2013; Gibney et al., 2009). Additionally, calcium is crucial for bone development and maintenance and helps prevent osteoporosis (WHO/FAO, 2004a, b; Marcus, 2013). Furthermore, calcium reduces the absorption of dietary fats, thereby lowering serum total cholesterol and low-density lipoprotein cholesterol levels (Vaskonen 2003).

Magnesium is crucial for numerous cellular processes that underpin various physiological functions. It plays a pivotal role in a range of enzymatic reactions, including glycolysis, lipid and protein metabolism, and the hydrolysis of adenosine triphosphate (ATP), facilitating the metabolism of food and the formation of new compounds (Shils 1998).

Iron is vital for growth, immune function, and energy production. It serves as an integral component of enzymes involved in biological oxidation during cellular respiration (Malhotra 1998)

Although potassium is highly bioavailable due to its solubility, it is prone to significant loss during cooking and food processing (Gibney et al. 2009; Titchenal et al. 2018).

c. Macronutrients in the skins, flesh, and seeds of the three varieties

The data provided outlines the macronutrient composition of different parts (skins, flesh, seeds) of three varieties (dark green, light green, white) of *Sechium edule*, commonly known as chayote.

- **Moisture and Dry Matter Content**:

The moisture content (H%) varies across all varieties and parts of *Sechium edule*, indicating the water content present in each sample.

The flesh of all varieties generally has the highest moisture content, ranging from 90.01% to 91.67% in raw form and up to 92.87% when steamed.

Conversely, seeds consistently have the lowest moisture content across varieties, ranging from 72.87% to 87.76%.

Dry matter (DM%) content, which represents the non-water fraction of the samples, shows an inverse relationship to moisture content. Seeds generally have the highest dry matter content, indicating they are more concentrated in non-water components.

- **Lipid Content**

Lipid content in *Sechium edule* samples is relatively low across all parts and varieties, ranging from 0.48% to 1.68%. Seeds tend to have slightly higher lipid content compared to skin and flesh, especially in the raw state.

- **Protein Content:**

Protein content (N% and Prot%) varies significantly among the different parts and varieties. Seeds consistently show the highest protein content, ranging from 1.25% to 18.17%, depending on the variety and cooking method. Flesh generally has lower protein content compared to seeds but varies across varieties.

The high moisture content in the flesh suggests it contains a significant amount of water, making it hydrating but less nutrient-dense in terms of dry matter.

Seeds are richer in dry matter and protein, indicating that they may provide a more concentrated source of nutrients than skin and flesh.

Lipid content is low across all parts and varieties, suggesting that *Sechium edule* is a low-fat food.

Variations in protein content highlight the potential nutritional diversity across different parts and varieties of chayote, which could influence dietary choices and culinary uses.

Overall, these findings provide valuable insights into the nutritional composition of *Sechium edule*, supporting further exploration into its dietary benefits and culinary applications.

d. Exploring the degree of mineralization

Understanding the C/N ratio of plant residues is fundamental to unlocking their full potential for sustainable valorization. This ratio, which denotes the balance between carbon (C) and nitrogen (N) within organic materials, plays a critical role in determining their suitability for various applications in resource management. By assessing the C/N ratio, researchers and practitioners can make informed decisions about the most effective pathways for utilizing plant residues, thereby enhancing environmental sustainability and economic viability. This scientific metric guides choices ranging from composting and biogas production to the creation of biochar, bioplastics, and construction materials. Each application benefits from a specific C/N range that optimizes microbial activity, nutrient availability, and material stability. Thus, a comprehensive understanding of the C/N ratio empowers stakeholders to tailor valorization strategies to maximize efficiency and minimize environmental impact.

- **For high C/N Ratio (Above 30:1)**

It is for soil amendment and mulching: Materials with high C/N ratios, like cooked flesh (88.20), steamed seed (185.32), and raw flesh (172.46), decompose slowly. They are ideal for use as soil amendments or mulches where a slow release of nutrients is beneficial. These materials can help improve soil structure, retain moisture, and suppress weeds without causing a rapid release of nitrogen, which can be advantageous in certain agricultural practices.

- **Moderate C/N Ratio (20-30:1)**

It is for balanced composting material: Raw skin (17.23), cooked skin (18.46), and raw seed (11.43) fall within or close to the ideal range for composting (25-30:1). They can be composted effectively on their own or with minimal adjustment. These materials provide a balanced supply of carbon and nitrogen, facilitating a steady decomposition process that produces nutrient-rich compost suitable for various agricultural applications.

- **Low C/N Ratio (Below 20:1)**

It is for green manure: Raw seed (11.43) and similar low C/N ratio materials are rich in nitrogen, making them ideal for use as green manure. They decompose quickly, providing an immediate boost of nitrogen to the soil, which is beneficial for the rapid growth of subsequent crops.

It is also for livestock feed: The low C/N ratio of raw seed (11.43) suggests it could be used as livestock feed, providing a good balance of nutrients for optimal digestion and nutrient availability, depending on the specific dietary needs of the livestock.

- **Application in Specific Sectors**

It is for biochar Production: Biochar, a form of charcoal used as a soil amendment, can be made from various biomass types. The skins and seeds, especially those with moderate C/N ratios, can be pyrolyzed to create biochar. This can improve soil health, sequester carbon, and enhance water retention in soils.

It is also for biocarburant (biofuel) production: Materials with a moderate to high C/N ratio could be suitable for biofuel production, particularly through anaerobic digestion. This process breaks down organic material in the absence of oxygen, producing biogas that can be used as a renewable energy source.

e. Phytochemical families in the skins, flesh, and seeds of the three varieties

Tannins and polyphenols are generally absent or present in minimal amounts across all parts and cooking methods. Tannins can sometimes interfere with nutrient absorption but are not significantly detected here, suggesting minimal impact. (**Kumar et *al.*, 2013**)

Polysaccharides are found in varying amounts across different parts and cooking methods. They can contribute to dietary fiber, which supports digestive health and may help manage blood sugar levels. They are particularly abundant in raw flesh and kernels (light green variety), indicating potential benefits for gut health and overall digestion.

Joven et *al.*'s study explores the presence and potential health benefits of polysaccharides and other phytochemicals in fruits and vegetables, including their role in gut health and overall digestion.

Flavonoids are detected in some varieties, such as white skin and flesh (raw and cooked). They are antioxidants known for their anti-inflammatory and potentially anticancer properties. Their presence in certain parts of Chayote suggests potential health benefits associated with antioxidant activity.

Anthraquinones are present in some cooked forms (e.g., white flesh cooked in water). They have been studied for their laxative effects and potential use in treating constipation. Their detection in cooked white flesh suggests a possible role in promoting digestive regularity. (**Lhoste et *al.*, 1991; Awouters et *al.*, 1979**)

IV. Conclusion

In conclusion, this study provides comprehensive insights into the drying behavior, elemental micronutrient composition, macronutrient distribution, degree of mineralization, and phytochemical content across three varieties of Sechium edule. These findings highlight the diverse nutritional profiles and potential applications of each variety. The drying analysis revealed significant variability in moisture removal efficiency among different plant parts and treatments, emphasizing the influence of initial moisture content and structural composition on drying yields. Elemental micronutrient assessments underscored the essential roles of minerals such as calcium, magnesium, and iron in physiological processes critical for immune function and metabolism. Macronutrient analysis demonstrated varying moisture, lipid, and protein contents across skins, flesh, and seeds, reflecting their nutritional diversity and implications for dietary choices.

Exploration of C/N ratios provided critical insights into the suitability of Sechium edule residues for diverse applications like composting, biochar production, and green manure, which is crucial for enhancing agricultural sustainability. Furthermore, the identification of phytochemical families such as flavonoids and polysaccharides highlighted potential health benefits linked to antioxidant properties and digestive health support.

Additionally, the study's comparison of dark green, light green, and white varieties, considering different cooking methods, underscored how variety and culinary preparation impact nutrient retention and bioavailability. Each variety exhibited distinct characteristics in drying efficiency, elemental micronutrient content, macronutrient composition, and phytochemical profile, influenced by their genetic makeup and responses to cooking. These variations emphasize the importance of tailored processing techniques to optimize nutritional outcomes and culinary applications. Ultimately, this research provides valuable scientific knowledge for stakeholders in agriculture, nutrition, and health sectors, guiding informed decisions and suggesting avenues for further exploration of the Sechium module's potential in sustainable food systems and dietary practices.

References

Awouters, F., Niemegeers, C. J., Lenaerts, F. M., & Janssen, P. A. (1979). Delay of castor oil-induced diarrhea in rats: A new way to evaluate inhibitors of prostaglandin biosynthesis. Journal of Pharmacy and Pharmacology, 31(1), 60-62.

Baris, A. (2023). Impact of feed quality on livestock productivity. Journal of Livestock Policy, 2(1). https://doi.org/10.47604/jlp.v2i1.2112

Boeing, H., Bechthold, A., Bub, A., Ellinger, S., Haller, D., Kroke, A., Leschik-Bonnet, E., Müller, M. J., Oberritter, H., Schulze, M., & others. (2012). Critical review: Vegetables and fruit in the prevention of chronic diseases. European Journal of Nutrition, 51(6), 637-663. https://doi.org/10.1007/s00394-012-0380-y

Bridgwater, A. V. (2012). Biomass Pyrolysis Liquids Upgrading and Utilization. Elsevier.

Buratti, S., Cappa, C., Benedetti, S., & Giovanelli, G. (2020). Influence of cooking conditions on nutritional properties and sensory characteristics interpreted by E-Senses: A case study on selected vegetables. Nourriture, 9(5), 607. https://doi.org/10.3390/foods9050607

Campbell, I. (2017). Macronutrients, minerals, vitamins, and energy. Anaesthesia & Intensive Care Medicine, 18(3), 141-146.

Crozier, A., Jaganath, I. B., & Clifford, M. N. (2009). Dietary phenolics: Chemistry, bioavailability, and effects on health. Natural Product Reports, 26(8), 1001-1043. https://doi.org/10.1039/B802662A

Cruz-León, A. (1985-1986). Chayote o cruzas intergenéricas? Hallazgo y características. Revista Geografía Agrícola, 9, 100-106.

Demirbas, A. (2009). Biofuels securing the planet's future energy needs. Springer Science & Business Media.

Flores, M. E. (1989). El Chayote, Sechium edule Swartz (Cucurbitaceae). Revista de Biología Tropical, 37, 1-54.

Gadour, A. (2011). Parents' Perspectives of Children's Emotional and Behavioural Difficulties. Konfrontasi Journal: Culture, Economy and Social Changes, 1(1) January

Gaitanis, D., Lukac, M., & Tibbett, M. (2023). Fragment size and diversity of mulches affect their decomposition, nutrient dynamics, and mycorrhizal root colonization. Scientific Reports, 13, 9383. https://doi.org/10.1038/s41598-023-36457-x

Gibney, M. J., Lanham-New, S. A., Cassidy, A., & Vorster, H. H. (Eds.). (2009). Introduction to human nutrition (2nd ed.). Wiley-Blackwell.

Haug, R.T. (1993). The Practical Handbook of Compost Engineering. CRC Press.

Joven, J., Rull, A., Rodriguez-Gallego, E., Camps, J., Riera-Borrull, M., Hernandez-Aguilera, A., & Segura-Carretero, A. (2014). Multifunctional targets of dietary polyphenols in disease: A case for the chemokine network and energy metabolism. Food and Chemical Toxicology, 69 67-74.

Kohli, K., Prajapati, R., & Sharma, B. K. (2019). Bio-Based Chemicals from Renewable Biomass for Integrated Biorefineries. Energies, 12(2), 233. https://doi.org/10.3390/en12020233

Kriaučiūnienė, Z., Velička, R., & Raudonius, S. (2012). The influence of crop residue type on their decomposition rate in the soil: A litterbag study. Žemdirbystė=Agriculture, 99(3), 227–236. ISSN 1392-3196. UDK 631.417.2:579.26

Kumar, S., Pandey, A. K., & Sharma, S. (2013). Chemistry and biological activities of flavonoids: An overview. The Scientific World Journal, 2013, Article ID 162750. https://doi.org/10.1155/2013/162750

Lhoste, E. F., Robbana-Barnat, S., & Benezra, C. (1991). Short-term effects of senna compared with lactulose and other laxatives in the treatment of chronic constipation. Current Medical Research and Opinion, 12(5), 290-297.

Li, Z., Liu, Y., Zhang, C., Zhang, Y., Wang, Z., Liu, S., & Xia, Z. (2020). Biomass Pyrolysis for Biochar, Bio-oil and Biogas Production in China: A Review. Renewable and Sustainable Energy Reviews, 117, 109477.

Lira-Saade, R. (1996). Chayote Sechium edule (Jacq.) Sw. We are promoting the conservation and use of underutilized and neglected crops. Report No. 8. Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy—58 pp.

Maffioli, A. (1981). Recursos genéticos de Sechium edule (Jacq.) Sw (Cucurbitaceae). Turrialba, Costa Rica: CATIE, Unidad de Recursos Genéticos. 151 pp.

Malhotra, V. (1998). Biochemistry for students (10th ed.). Jaypee Medical Publishers Limited. ISBN 10: 9350255049.

Marcus, J. B. (2013). Culinary nutrition: The science and practice of healthy cooking (1st ed.). Academic Press - Elsevier. ISBN: 9780123918826.

Marín, L., Miguélez, E. M., Villar, C. J., & Lombó, F. (2015). Bioavailability of dietary polyphenols and gut microbiota metabolism: Antimicrobial properties. BioMed Research International, 2015, Article ID 905215. https://doi.org/10.1155/2015/905215

Mohanty, A. K., Misra, M., & Drzal, L. T. (2002). Sustainable Bio-Composites from Renewable Resources: Opportunities and Challenges in the Green Materials World. Journal of Polymers and the Environment, 10(1-2), 19-26.

Ortega-Paczka, R., Martínez-Alfaro, M. A., & Rincón-Enriquez, G. (1998). Principales cultivos de México y sus regiones mundiales de mayor diversidad. In XVII Congreso de Fitogenética. Memoria Sociedad Mexicana de Fitogenética (pp. 321). Acapulco, México.

Pollack, R. D., Wright, L. L., Turhollow, A. F., Graham, R. L., Stokes, B. J., & Erbach, D. C. (2005). Biomass as feedstock for a bioenergy and bioproducts industry: The technical feasibility of a billion-ton annual supply (DOE/GO-102005-2135, ORNL/TM-

2005/66). Oak Ridge National Laboratory, Environmental Sciences Division. Sponsored by the U.S. Department of Energy and the U.S. Department of Agriculture. Managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725.

Purba, N. (2020). The Use of Simalungun Language by Anak Boru Sanina in the Simalungun Wedding Ceremony (Sociolinguistic Studies). Lakhomi Journal: Scientific Journal of Culture. 1-7

Santana, M. L. T., Carvalho, G. S., Guilherme, L. R. G., Curi, N., & Ribeiro, B. T. (2019). Elemental concentration via portable x-ray fluorescence spectrometry: Assessing the impact of water content. Ciência e Agrotecnologia, 43, e029218. http://dx.doi.org/10.1590/1413-7054201943029218

Shils, M. E. (1998). Magnesium. In O'Dell, B. L., & Sunde, R. A. (Eds.), Handbook of nutritionally essential mineral elements (p. 117). Marcel Dekker.

Skaar, C. (1988). Wood-water relations. Springer Science & Business Media.

Stein, S., Hartung, J., Perkons, U., Möller, K., & Zikeli, S. (2023). Plant and soil N of different winter cover crops as green manure for subsequent organic white cabbage. Nutrient Cycling in Agroecosystems, 127(2), 285–298. https://doi.org/10.1007/s10705-023-10306-9

Sustainable Soil Remediation Using Organic Amendments. (2021). In Handbook of Assisted and Amendment: Enhanced Sustainable Remediation Technology (Chapter 15). doi: 10.1002/9781119670391.ch15

Titchenal, A., Calabrese, A., Gibby, C., Fialkowski Revilla, M. K., & Meinke, W. (2018). Human nutrition. University of Hawaii at Manoa Food Science and Human Nutrition Program. http://pressbooks.oer.hawaii.edu/humannutrition/

Türkmen, N., Sari, F., & Velioglu, Y. S. (2005). The effect of cooking methods on total phenolic compounds and antioxidant activity of selected green vegetables. Food Chemistry, 93(4), 713-718. https://doi.org/10.1016/j.foodchem.2004.12.038

Vaskonen, T. (2003). Dietary minerals and modification of cardiovascular risk factors. Journal of Nutritional Biochemistry, 14(9), 492-506.

Vieira, E. M., Moreira, M. M., Cruz, R., da Silva, A. B., Casal, S., & Matos, C. (2023). An insight into chayote (Sechium edule) peels valorization: Phytochemical characterization and bioactive potential. The 4th International Electronic Conference on Foods session Food Analysis, Biotechnology, and Engineering. MDPI. https://doi.org/10.3390/Foods2023-15147

Vieira, E. M., Moreira, M. M., Cruz, R., da Silva, A. B., Casal, S., & Matos, C. (2023). An insight into chayote (Sechium edule) peels valorization: Phytochemical characterization and bioactive potential. The 4th International Electronic Conference on Foods session Food Analysis, Biotechnology, and Engineering. MDPI. https://doi.org/10.3390/Foods2023-15147

World Health Organization/Food and Agriculture Organization (WHO/FAO). (2004a). Vitamin and mineral requirements. In Human nutrition, Report of a Joint FAO/WHO expert consultation, Bangkok, Thailand (2nd ed.).

Zhao, L., Lee, J. Y., & Hwang, D. H. (2011). Inhibition of pattern recognition receptor-mediated inflammation by bioactive phytochemicals. Nutrition Reviews, 69(6), 310-320. https://doi.org/10.1111/j.1753-4887.2011.00394.x