

# Pumpkin and Pastel Wine, A Fruit and A Legume Of The Cucurbitaceous Family in Green Circular Economy With Zero Waste

Robijaona Rahelivololoniaina Baholy<sup>1,2,3,\*</sup>, Letsara Rokiman<sup>1,4</sup>, Herimanantena Miarantsoa Tinah<sup>2</sup>, Razafindrakoto Fanoina Ny Riana<sup>1</sup>, Rabeharitsara Andry Tahina<sup>1,2</sup>, Razafimahefa Mirana Verohanitra<sup>1,2</sup>, Koto-Te-Nyiwa Ngbolua<sup>5</sup>, Rakotomamonjy Pierre<sup>1,2</sup>

<sup>1</sup> Doctoral School of Industrial Agricultural and Food Process Engineering, University of Antananarivo, Antananarivo, Madagascar

<sup>2</sup> Polytechnic High School of Antananarivo, Madagascar

<sup>3</sup> Laboratory for the Valorization of Natural Resources

<sup>4</sup> Tsimbazaza Botanical and Zoological Park

<sup>5</sup> Department of Biology, Faculty of Science, University of Kinshasa, Kinshasa, Democratic Republic of the Congo

Email: valorena1357@gmail.com

## Abstract:

*This study explores the viability of watermelon (*Citrullus lanatus*) and pumpkin (*Cucurbita pepo* subsp. *Pepo*) as unconventional sources for sustainable winemaking, contributing to a zero-waste circular economy in viticulture. The research employs a multidimensional methodology encompassing chemical analyses, sensory evaluations, and environmental impact assessments to scrutinize the entire lifecycle of wine production. The findings reveal watermelon wine's superiority, boasting a 14° alcohol content, while pumpkin wine ranges at 11°. Both wines maintain physico-chemical and organoleptic attributes, with minimal alterations in micronutrient content. The compost generated from processing waste contains essential nutrients for plant growth. The comparative analysis underscores the advantageous nature of this compost, laying the foundation for sustainable winemaking practices in Madagascar and illuminating the untapped potential of tropical fruits in the global viticultural landscape. This study, pioneering the valorization of unconventional fruit and vegetables in Madagascar, strives to contribute to the discourse on environmentally conscious winemaking, fostering a paradigm shift toward ecologically harmonious practices in the agro-industrial sector.*

## Keywords:

*Watermelon; pumpkin; wine; compost; macronutrients; analysis*

## I. Introduction

In the pursuit of sustainable viticulture, the exploration of unconventional fruit and vegetable sources for winemaking has gained momentum. This study conducts a comparative analysis of vinification processes applied to watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai, 1916) and pumpkin (*Cucurbita pepo* subsp. *Pepo*), elucidating their potential contribution to a zero-waste circular economy in winemaking.

The investigation of watermelon and pumpkin as wine production sources arises from the imperative to mitigate environmental impact and optimize resource efficiency in agro-industrial processes. This study broadens viticultural possibilities by exploring alternative, economically viable raw materials with intrinsic qualities suitable for high-quality wine production.

In the framework of a circular economy prioritizing reduction, reuse, and recycling, employing watermelon and pumpkin presents a compelling route for sustainable wine production. Overlooked in viticulture, these fruits offer an opportunity to optimize biomass utilization, minimizing ecological footprints by exploring fermentation processes and valorizing by-products.

This comparative analysis utilizes a multidimensional methodology, involving chemical analyses, sensory evaluations, and environmental impact assessments. Scrutinizing the entire lifecycle of wine production from watermelon and pumpkin provides comprehensive insights for sustainable winemaking practices.

## **II. Research Method**

### **2.1. Materials**

#### **a. Materials for making wine**

This winemaking study utilizes meticulously chosen raw materials—fully ripened watermelons with intensely red interiors and well-matured orange-yellow pumpkins. Serving as fundamental substrates for vinification, these fruits contribute distinct biochemical profiles. Their intricate interplay, guided by scientific parameters in controlled fermentation, aims to unravel physicochemical dynamics governing the transformation into a distinctive wine, offering an opportunity for sensory exploration and oenological advancement.

#### **b. Materials for making compost**

In pursuit of sustainability, this study integrates a zero-waste circular economy into winemaking, employing systematic recycling from raw materials to fermentation residues. The closed-loop system ensures complete organic residue utilization, contributing to environmental conservation and reducing ecological impact, aligning with broader sustainable practices.

### **2.2 Methods**

#### **a. Phytochemical screening**

The phytochemical screening for this investigation occurred at the CNRE (Centre National de Recherches sur l'Environnement) Laboratory in Tsimbazaza, a sanctioned facility for food quality controls.

Recognition of a plant's medicinal, chemical, and economic attributes necessitates a comprehensive phytochemical screening. This essential process seeks to identify the natural substances within a plant, laying the foundation for harnessing its medicinal properties. The screening involves categorizing major compound classes present in the plant, encompassing alkaloids, flavonoids, leucoanthocyanins, tannins, polyphenols, quinones, steroids, terpenoids, cardenolides, bufadienolides, saponosides, polysaccharides, cyanogenic coumarins, heterosides, deoxyoses, iridoids, and more. (Aiyegoro & Okoh, 2009)

By systematically cataloguing these compounds, the study aims to provide a comprehensive understanding of the plant's chemical composition, facilitating insights into its potential applications in medicine, industry, and beyond.

The utilization of the CNRE Laboratory ensures rigorous and reliable analyses, contributing to the scientific integrity of the phytochemical exploration.

The study is based on:

- Either on the formation of insoluble complexes: precipitation reactions,
- Either on the formation of coloured complexes: colouring reactions.

The observed staining results from the formation of conjugated bonds or unsaturation in a molecule induced by a suitable reagent.

Various extracts, prepared according to the described methods, serve as detection agents for testing different substance families. (Robijaona Rahelivololoniaina, 2023a)

This approach enables systematic exploration and identification of specific molecular characteristics.

- Dispense 100 g of dried, crushed plants into a 500 mL flask;
- Introduce 400 mL of 80% ethanol or methanol, and affix a condenser;
- Subject the flask to a one-hour reflux in a boiling water bath;
- Allow the flask contents to cool, followed by filtration using a Büchner funnel;
- Rinse the flask with 50 mL of 80% ethanol, consolidating the alcoholic solutions;
- Quantify the volume of the alcoholic solution and determine the plant equivalent per mL of the alcoholic extract. This prepared solution is slated for conducting various chemical tests, constituting the phytochemical screening process.

#### **b. Screening of alkaloids**

A hydrochloric extract is imperative for this screening process. Conducting a hydrochloric maceration involved the following steps:

- Commence by grinding 5 g of crushed plants and 15 mL of 5% HCl in a mortar with a pestle;
- Optionally, employ hydrophilic cotton for filtration;
- Distribute the resulting mixture into three equal portions in separate test tubes:
  - In the first tube, introduce 5 drops of Mayer reagents, noting an orange to red precipitate indicative of alkaloids.
  - In the second tube, incorporate 5 drops of WAGNER reagent and/or 5 drops of DRAGENDORFF reagent. The emergence of a brown precipitate confirms the presence of alkaloids.
  - In the third tube (serving as an indicator), follow the procedure outlined for the second tube.

#### **c. Screening of flavonoids and leucoanthocyanins**

The screening of flavonoids and leucoanthocyanins involves multiple procedural steps:

- Evapora a hydroalcoholic solution equivalent to 3g of plant in a crystallizer on a water bath;
- Cool the resulting solution to room temperature;
- Treat with 15 mL of n-hexane ether, filtering and repeating until pigments are removed;
- Dissolve the residue with 30 mL of 80% ethanol, then filter. Place 3 mL of the filtrate in four respective test tubes.

For the Wilstater Test (cyanide)

Tube 1: Control solution

Tube 2: Add 0.5 mL of concentrated HCl and a few turns of magnesium. Observe the colour change after 10 minutes; red denotes flavones, red to purple indicates flavonols, and purplish-red signals flavanones and flavanonols.

Tube 3: Repeat in Tube 3, adding 1 mL of distilled water and 1 mL of isoamyl alcohol. Note the colouration of the upper phase.

For Bate Smith Test

Tube 4: Add 0.5 mL of concentrated HCl and place in a double boiler for 30 minutes. Let cool. A purple-red colour indicates the presence of leucoanthocyanes.

#### **d. Screening of tannins and polyphenols**

For the screening of tannins and polyphenols, the following procedural steps are undertaken.

Evaporate the hydroalcoholic solution equivalent to 10 g Ps (sample weight) in a crystallizer.

Add 25 mL of hot distilled water, shake, then pour 3-4 drops of 10% NaCl.

Filter the resulting solution, and dispense 3 mL of the filtered solution (hydroalcoholic solution + hot distilled water + NaCl) into four respective test tubes:

Tube No. 1: Sample solution ;

Tube No. 2: Add 4 to 5 drops of 1% gelatin and observe for potential precipitation;

Tube No. 3: Add 4 to 5 drops of salted gelatin (1% gelatin + 10% NaCl) and observe any precipitation;

Tube No. 4: Add 4 to 5 drops of FeCl<sub>3</sub> in a methanolic solution, observing for changes in colour or possible precipitation.

The precipitation of tannins by salt gelatin signifies their presence, while a non-reactive response with FeCl<sub>3</sub> suggests the absence of these compounds.

Following the introduction of FeCl<sub>3</sub>, a blue-green or green-black colouration indicates the presence of catechols-type tannins, a bluish-black colouration signifies the presence of pyrogallol-type tannins and a negative salt reaction accompanied by a green or black-blue colouration with FeCl<sub>3</sub> points to the presence of other phenolic compounds.

#### **e. Screening of anthraquinones**

This screening employs the Borntrager test and involves the following steps.

Evaporate 1 g equivalent of plant material in a crystallizer on a water bath until dry;

Dissolve the residue in 30 mL of distilled water and subsequently filter;

Extract the filter residue with 10 mL of benzene using a small decanter ampoule, transferring the benzene extract to a test tube;

Introduce 5 mL of NaOH to the test tube and shake vigorously;

Observe the resultant change in colouration of the alkaline phase (lower phase), where red colour indicates the presence of anthraquinones.

#### **f. Screening of unsaturated sterols and triterpenes**

The screening process for unsaturated sterols and triterpenes encompasses the following refined steps:

-Thoroughly evaporate the hydroalcoholic solution equivalent to 10 g of Pe in a crystallizer, utilizing a double boiler;

-Introduce 10 mL of petroleum ether, shaking the mixture for 5 minutes, followed by decantation and discarding of the supernatant. Repeat this process iteratively until pigments are eliminated;

-Add 10 mL of chloroform and shake for 5 to 10 minutes;

-Decant and dry the solution with Na<sub>2</sub>SO<sub>4</sub>. Subsequently, partition the solution equally into three tubes labeled 1, 2, and 3.

For Libermann-Buschard test

The procedure involves:

-Add 3 drops of acetic anhydride to tube 1, shake gently, and subsequently add a drop of concentrated H<sub>2</sub>SO<sub>4</sub>;

-Observe the change in colouration over 1 hour, making comparisons with tube No. 3.  
Colour assessments at intervals of 5, 10, 30, and 60 minutes  
Blue-green colouration indicates the presence of steroids  
Red-purple to pink colouration signifies the presence of triterpenes.  
For Salkowski test

The Salkowski test for unsaturated sterols and triterpenes involves:

- Incline tube No. 2 to a 45° angle and add 1 to 2 mL of H<sub>2</sub>SO<sub>4</sub>. Promptly observe the initial change in colouration;
- Gently shake the tube and monitor the gradual evolution of colour.
- Colour assessments at intervals of 5, 10, 30, and 60 minutes
- The appearance of a red ring after stirring indicates the presence of unsaturated sterols.

In the exploration of potential biological or pharmacological properties, phytochemical screening plays a pivotal role in identifying molecules present in the studied plant parts. This screening method is employed to detect and categorize various families of molecules.

### 2.3 Macronutrient determination method

The determination of macronutrients occurred at the CENRADERU/FOFIFA (Centre National de la Recherche Appliquée au Développement Rural, Foibem-pirenena momba ny Fikarohana ampiarina amin'ny Fampandrosoana ny eny Ambanivohitra) laboratory.

#### a. Moisture content

The method involves measuring the weights of test samples before and after parboiling, utilizing a gravimetric approach. (Robijaona Rahelivololoniaina, 2023b)

Adhering to good laboratory practice (GLP), the procedure commences with the thorough cleaning of all materials.

Six 5 g samples, each coded uniquely, are individually placed in pre-weighed beakers under vacuum.

The oven, preheated to 103 ± 2°C, accommodates the test receptacles for 4 hours.

Subsequently, the test pieces are cooled in a dryer for 1 hour before obtaining the final weight.

The formula for calculating moisture content is provided below:

$$\%Moisture = \left( \frac{m_1 - m_2}{m_1 - m_0} \right) \times 100$$

With:

m<sub>0</sub>: empty beaker mass

m<sub>1</sub>: beaker mass + test sample before steaming

m<sub>2</sub>: capsule mass + test sample after proofing

#### b. Crude ash content

By the principle of incineration, the Ps test samples are combusted to yield raw ashes, with the content determined through gravimetry—analyzing weight gain before and after incineration.

The process sequence involves preparing beakers and preheating the oven to 550°. Approximately 5 g of the Ps test dose is placed on a pre-loaded capsule, which is then incinerated in the muffle oven at 550°C until carbon-free, spanning a duration of 12 to 24 hours. Should samples exhibit shades of grey, yellowish, or white after 7 hours, the process can be halted; in our samples, the transformation to grey occurred around the 12-hour mark. The subsequent formula facilitates the calculation of gross ash.

$$\% \text{Crude ash} = \left( \frac{m_2 - m_0}{m_1} \right) \times 100$$

With:

$m_0$ : empty capsule mass

$m_1$ : mass of test sample

$m_2$ : capsule mass + test sample after incineration furnace

### c. Protein content

The determination of protein content employs the Kjeldahl method, a sequential process comprising mineralization, distillation, and titration.

This procedure involves the conversion of protein nitrogen into ammonia nitrogen through the oxidation of organic matter using hot concentrated sulfuric acid and a catalyst.

The process initiates with the addition of 15 mL of concentrated  $\text{H}_2\text{SO}_4$  (99 or 98%) per matra. The 0.5 g test portion, along with the catalyst, is introduced into the digestion tube. The sealed assembly is then placed on the mineralizer, and elevated to a temperature range of 350 - 400°C for 4 hours.

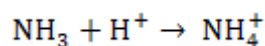
#### -Distillation

Ammonia, initially present in its ammonium sulfate ( $(\text{NH}_4)_2\text{SO}_4$ ) salt form, will be liberated upon the introduction of an excess of concentrated soda. In its volatile state, the ammonia is subjected to steam distillation, followed by condensation through a refrigerant. The resulting liquid is directed through a pipe immersed in a beaker containing a trap solution of boric acid. The introduction of nitrogen induces a colour change in the solution, turning it into a light green hue.

A solution consisting of 400 g/L sodium hydroxide (NaOH), 40 g/L boric acid ( $\text{H}_3\text{BO}_3$ ), and distilled water is prepared. Additionally, a coloured composition indicator is incorporated, comprising 40 mg of methyl red, 10 mg of thymol blue, and 100 cm<sup>3</sup> of ethanol. To the ammonium salt used in mineralization, 20 mL of distilled water is added. Subsequently, in a beaker filled with distilled water until 1 cm of the tube is immersed, 25 mL of boric acid, along with a few drops of coloured indicator, is introduced. The device automatically initiates the addition of 50 mL of excess soda at the onset of the operation, with a preset operating time of 10 minutes. The conclusion of the operation is determined by the complete release of all nitrogen.

#### -Titration

The nitrogen distilled and trapped by boric acid, in the presence of the colored indicator, is subjected to direct titration using sulfuric acid. The solution's color transition, from green to dark red, prompts the measurement of the volume corresponding to the burette drop.



The titrant employed is 0.1 N sulfuric acid, and the solution subjected to titration is the product obtained post-nitrogen distillation.

Before any operation, meticulous rinsing of materials with suitable reagents is imperative; for instance, the burette undergoes rinsing with sulfuric acid.

Following the placement of a volumetric flask on the magnetic stirrer, the agitation speed is finely adjusted, and sulfuric acid is incrementally introduced drop by drop into the solution intended for titration.

The solution undergoes a progressive transition to a dark red hue upon the addition of a few drops of sulfuric acid. The operation concludes promptly upon the complete colour change of the solution. A precise measurement of the volume of sulfuric acid added, termed the burette drop (BD), is recorded.

Subsequently, to ascertain the protein content of the sampled material, an initial determination of nitrogen content in the test sample (Ps) is conducted, serving as the basis for deducing the protein content.

$$N(\%) = \frac{BD \times 0,1 \times 1,4}{P_s}$$

With:

- BD : burette drop (mL)
- 0,1: Test portion (g)
- 1,4:  $M_N \times 10^3 \times 100$
- $M_N$ : Molar mass of nitrogen (g/mol)

$$\text{Protein}(\%) = N(\%) \times 6,25$$

## 2.4 Lipid content

The operational principle involves hexane extraction of lipids from Ps through percolation using a Soxhlet apparatus, with the subsequent determination of the remaining fat percentage following hexane evaporation.

5g of Ps, enclosed in Joseph's paper, is placed within an extraction cartridge. Positioned above is a Soxhlet, featuring a ball refrigerant, and at its base, a balloon housing 150 mL of hexane.

Subsequently, the flask containing the hexane extract is transferred and affixed to a rotary evaporator. The hexane is removed and recovered through evaporation and condensation, with the rotary evaporator water temperature set at 70°C, the boiling point of hexane. The operation concludes upon the absence of any trace of hexane in the condenser. Steam treatment at 103°C is executed to eliminate residual hexane, followed by 1-hour cooling in the dryer. The procedure concludes with the measurement of the balloon's weight and the remaining lipid. The lipid content is determined using the provided formula:

$$\text{Lipid}(\%) = \frac{m_2 - m_0}{m_1} \times 100$$

With:

- $m_0$  = empty flat bottom balloon mass
- $m_1$  = mass of sample taken
- $m_2$  = mass of the flask + test sample after proofing

### a. Carbohydrate content

A sample's nutrient composition comprises carbohydrates, fats, and proteins, alongside ash and water as additional components. The carbohydrate content can be derived by

subtracting the values of all other known components. The ensuing formula facilitates the determination of the carbohydrate content.

$$C (\%) = 100 - [L (\%) + P (\%) + H (\%) + A (\%)]$$

With:

- C (%): carbohydrate content
- L (%): lipid content
- P (%): protein content
- H (%): moisture content
- A (%): crude ash content

### **b. Determination of Na, Ca, Mg, K**

The determination of sodium (Na), calcium (Ca), magnesium (Mg), and potassium (K) was carried out at the CENRADERU/FOFIFA (Centre National de la Recherche Appliquée au Développement Rural, Foibem-Pyrenean momba ny Fikarohana apiarian amin'ny Fampanandrosoana ny any Ambanivohitra) laboratory

To ascertain potassium and other secondary elements such as calcium, magnesium, and sodium, adhere to the subsequent protocol:

### **c. Preparation of solution for dosing:**

- Weigh 1 g of finely ground compost into a 25 mL porcelain crucible;
- Place the crucible in a muffle oven at  $500 \pm 50^\circ\text{C}$  for approximately 5 hours;
- Allow the crucible to cool;

### **d. Solution treatment**

- Add 2mL of concentrated HCl;
- Add 2 mL of concentrated HCl;
- Evaporate on a hot plate for one hour
- Supplement with 5 mL of  $\text{HNO}_3$  (2N), ensuring thorough dissolution;
- Filter the solution using filter paper into a 50 mL vial with hot distilled water;
- After cooling, bring the volume up to the graduated line with cold distilled water;
- Establish a 1/10, 1/100, 1/1000 dilution series.

## **2.5 Dosing the solution**

Utilize the dilution series to determine P, Ca, Mg, K, and Na.

### **a. Analytical measurement**

- Employ an atomic absorption spectrophotometer for measuring Ca and Mg
- Use a flame spectrophotometer for measuring Na and K

The subsequent calculation is executed based on the provided formula:

$$X_{\text{ppm}} = \text{reading} \times \text{dilution} + 50$$

$$X\% = \frac{X_{\text{ppm}}}{10000} \qquad X\%_0 = \frac{X_{\text{ppm}}}{1000}$$

Evaluating macronutrients is pivotal in fruit analysis, providing insights into its suitability for consumption in its natural state or potential transformation. In vinification, determining carbohydrate content becomes essential, serving as a measure of the fruit's capacity for conversion into alcohol.

## b. Micronutrient determination method

The quantification of macronutrients was conducted at the OMNIS (Office des Mines Nationales et des Industries Stratégiques) laboratory through a technique known as X-ray fluorescence, which analyzes the elemental composition of solid and liquid samples.

Upon activation in "mineral mode," the device performs calculations autonomously, displaying results on the screen. If connected to a computer or smartphone, the results are seamlessly transferred to an Excel file.

## 2.6 The stages of the winemaking process of watermelon and pumpkin

### a. Preparation of raw materials

Several unit operations are indispensable to ensure the quality of the final product, which is wine.

- **Sorting (Triage):** The elimination of rotten fruit is crucial as it can impart unpleasant odours and alter the taste of the juice or wine.
- **Washing:** While washing is necessary to remove dust or soil from fallen fruits, excessive washing should be avoided as it may remove yeasts present on the fruit's skin.

### b. Must preparation

- **Hygiene and water treatment:** Ensuring the hygiene and cleanliness of premises, containers, and tools is vital for successful vinification. Boiling water before use helps eliminate limestone and chlorine present in the water.
- **Cutting, trimming and peeling:** Unwanted parts of fruits and vegetables are removed through cutting, trimming, and peeling. Trimming involves cutting pineapples
- **Weighing:** The weights of whole fruit, pulp, bark, and seeds are measured.
- **Grinding:** This operation aims to extract the maximum juice from the pulp and release the sucrose contained in the flesh. Water is added to facilitate grinding,
- **Filtration:** Employed in the white wine method exclusively,
- **Sugar addition (chaptalization):** Involves adding sugar to the must to enhance the wine's alcohol content. The total sugar content is determined through refractometer measurement of the Brix degree.

To determine the precise sugar mass for must enrichment, a calculation based on the anticipated potential alcohol level is necessary. This alcohol content corresponds to yeast yield in ethanol, generally ranging between 0.016 and 0.017 kg/L of sugar per 1 degree (% vol) of ethanol. For computational purposes, the value of 0.017 kg/L for 1% ethanol was employed, to achieve a 12% alcohol content.

- Calculate sugar addition:

1% 17 g/L sugar

12% 204 g/L sugar

If they must already contain X g/L of sugar, the additional amount needed for 12% alcohol is calculated as  $204 - X = Y$  g/L of sugar.

Commercial sugar, sucrose, is used for chaptalization. However, yeasts cannot directly assimilate sucrose; it must be inverted into glucose and fructose through the secretion of invertase. This enzymatic process consumes time and energy, slowing down fermentation.

- **Yeasting:** Yeasting occurs immediately post-chaptalization. Yeasts are added at a rate of 4.2g per litre of must. Rehydration at 10 times their volume of must at 30°C for 15 minutes ensures a lively and active culture. The selected yeast is primarily *Saccharomyces Cerevisiae*.

- **Fermentation:** Fermentation transpires in plastic tanks fitted with pipes for CO<sub>2</sub> release, preventing the entry of air or contaminants. This natural process transforms sugars into alcohol under yeast action, generating carbon dioxide and separating the mixture into juice (two-thirds of the tank's volume) and marc—a compact mass of skin, pulp, seeds, and some stalk pieces.

The optimum vinification temperature ranges between 20 and 30°C. A warm fermentation environment is vital to prevent yeast death, which could lead to fermentation cessation. (Ough & Amerine, 1988)

### c. Wine Processing

- **Filtration:** Filtration involves the use of a strainer to eliminate large particles, followed by refinement with a coffee filter.
- **Sulphite:** To halt fermentation, 40 mg/l of potassium metabisulfite is added.
- **Racking:** This step entails settling for 21 days with a settling agent (bentonite at a quantity of 1 g/L).
- **Clarification:** Achieved by adding a clarifying agent to precipitate particles causing wine disturbance.

The content of a 2g gelatin sachet is employed to clarify 0.5 litres of wine. The wine is heated to 45°C, transferred to another container, and the clarifier is added before energetic stirring. The mixture is left to settle for 2 days, and the formed deposit is then eliminated.

- **Preservation:** After filtration, the wine is kept in sterilized and opaque glass bottles.

Bottled wine is subjected to heating by immersing the bottle in 70°C hot water for 5 minutes, followed by cooling. The bottles are subsequently stored in cool environments.

### d. Chemical Analyses for Winemaking

- **pH evolution** is crucial during fermentation as it influences the development of biological fermentation agents and the stability of finished products. It serves as a key indicator reflecting the success or failure of the fermentation process.
- **Measure of alcohol content:** The degree of alcohol in wine is measured using an alcohol meter.
- **Sugar content:** Brix quantifies the amount of sugar remaining unconverted into alcohol in wine.
- **Total acidity of wine:** Total acidity encompasses all acids present in wine, primarily influencing its taste characteristics. It is expressed as sulfuric acid or tartaric acid using specific formulas.

The formula for calculating total acidity expressed in H<sub>2</sub>SO<sub>4</sub>

$$\text{Total acidity expressed in H}_2\text{SO}_4 = V \times 0,98$$

Where: V is the volume of the NaOH titrating solution (0.1) poured until the colour change to purple is obtained during the 10 mL titration of the wine.

- **Sensory analysis:** Descriptive analyses were conducted to discern the characteristics of the wine, employing a notation system based on a pre-established form.

In this evaluation, a panel of 7 individuals assessed the products, assigning scores on a scale from 0 to 5 based on their perception. Traditionally, panel members possess

specialized training in sensory analysis; nevertheless, in our study, a panel of individuals lacking prior expertise in the field was employed.

## **2.7 Composting waste management**

Composting is a transformative fermentation process of organic waste facilitated by oxygen. This yields a stabilized, humus-rich fertilizing material known as compost, extensively utilized in gardening and agriculture for soil improvement. (**Robijaona Rahelivololoniaina & Elisoamiadana, 2023**).

Compost is a stable, hygienic product and rich in humus, resulting from the amalgamation of various residues of plant or animal origin. These residues undergo slow fermentation to ensure organic matter decomposition, serving as a valuable fertilizer, amendment, or culture medium.

### **a. Composition of compost**

To produce high-quality compost, essential elements include:

- Kitchen waste: damaged fruit and vegetables, peelings, coffee grounds, tea leaves, eggshells, dairy products, etc.;
- Garden waste: dead leaves, grass cutting, wilted flowers, etc.;
- Some household waste: newsprint, tissue, wood ash, etc.

### **b. Conditions for composting**

Optimal conditions for successful composting:

- Balancing brown and green materials is pivotal for successful composting. Brown materials, like dead leaves, provide carbon, while green materials, such as kitchen waste, offer nitrogen. A harmonious ratio ensures efficient decomposition.
- Proper compost pile aeration is essential. Regular turning with a fork promotes microorganism activity, facilitating decomposition efficiency.
- Maintaining a composting temperature between 50 and 65°C is imperative. This temperature range promotes the destruction of pathogenic organisms and weed seeds.
- Maintaining optimal compost moisture is crucial. It should support microorganism growth without excess wetness, ideally around 50-60% humidity.

Successful composting necessitates a balanced blend of brown and green materials, efficient ventilation, optimal temperature, and appropriate humidity. These conditions foster the decomposition of organic waste, leading to the formation of nutrient-rich compost.

### **c. The stages of composting**

Composting emulates the natural humification of organic residues into humic substances in soils, distinguished by accelerated aerobic biological transformations (**Antizar-Ladislao et al., 2006**). The process unfolds in phases, contingent upon raw material quantities, heap temperature evolution, and other parameters. Smaller piles efficiently evacuate heat, leading to minimal temperature variation. In contrast, larger piles conserve heat better, delineating distinct phases through temperature monitoring.

- 1) First phase: This phase involves intense aerobic degradation, bringing the residues to the state of fresh compost.
- 2) Second phase: Characterized by less sustained degradation, this phase transforms the fresh compost into ripe compost, rich in humus.

#### **➤ Degradation**

In the degradation phase, highly degradable compounds like sugars, free amino acids, and starch are initially consumed, causing a decrease in compost mass due to mineralization

and water losses. Initiation requires diverse organic materials, suitable microorganisms, oxygen, and water. Meeting these conditions prompts rapid heat production. The degradation phase encompasses three stages: the mesophilic phase, the thermophilic phase, and the cooling phase.

- **The mesophilic phase**

In this phase, indigenous mesophilic microorganisms, primarily bacteria and fungi, colonize the accumulated piles, intensifying biological activity and elevating the temperature to 50-70°C. Swiftly reaching 40-45°C, aerobic mesophilic microorganisms respire, releasing notable CO<sub>2</sub>, reducing the C/N ratio. Cellulose degradation prevails, constituting over 75% of dry weight loss.

- **The thermophilic phase**

During respiration, the temperature gradually rises to 60-70°C, prompting the replacement of mesophilic microorganisms with thermophiles and thermo-tolerance. This phase involves decreased compost mass through organic matter mineralization, CO<sub>2</sub> release, and substantial water losses via evaporation. Nitrogen losses intensify as ammonia (NH<sub>4</sub><sup>+</sup>) is mineralized, and water evaporates. CO<sub>2</sub> release can result in up to a 50% dry weight loss by the thermophilic phase's end, with high temperatures concentrated in the heap's centre. A practical method to confirm this phase involves using a stick: inserting it into the heap's centre, waiting approximately 5 minutes, and sensing its warmth upon removal. The temperature should notably exceed body temperature (60 to 70°C). If less hot, the heating phase may not have commenced due to material or aeration issues, but the process will proceed to the next phase.

- **The cooling phase**

This transitional phase bridges the thermophilic phase and maturation, culminating in a return to room temperature. Mesophilic microorganisms recolonize, degrading previously intact polymers and incorporating nitrogen into complex molecules. Composting results in mass losses of 30-45% compared to the total starting mass (manure + water). However, when considering only manure mass, losses are minimal, varying between 15-20%. The duration of the cooling phase is influenced by factors such as pile construction, materials used, pile maintenance, and climatic conditions.

➤ **Maturation**

Post-degradation, maturation sees reduced microflora-accessible material. Low microbiological activity, the shift from thermophiles to mesophiles, and a habitat conducive to macrofauna colonization occur. Temperature gradually stabilizes at room temperature. Adequate aeration and homogenization are crucial during maturation to promote decomposition and prevent rot. Mixing and aeration are vital parameters influencing composting dynamics. Once ready, the pile becomes homogeneous, and less biologically active, transforming into a dark brown to black colour with a soil-like texture. Throughout, humus content increases, and the carbon-to-nitrogen ratio stabilizes. The final compost product displays characteristic appearance and quality. The conclusion entails white mushroom growth, volume reduction, and a colour change to dark brown. Despite maturation, some degradation processes persist at a lower rate, resulting in a well-prepared compost with organic components converted into less aggressive and more stable substances. Compost, characterized by its elevated organic matter concentration, plays a pivotal role in replenishing the soil with properties that diminish over time and use.

## 2.8 Compost analyses

Comprehensive analyses of compost encompass both physical and chemical attributes:

- Physical characteristics: quantity, colour, smell, texture
- Chemical analyses:

Determination of Dry Matter, calculated using the following formula:

$$DM(\%) = \frac{W_f - W_d}{W_f} \times 100$$

Where: DM: Dry matter %

W<sub>f</sub>: Fresh sample weight

W<sub>d</sub>: Dry weight of the sample

- pH determination
- Organic carbon determination using the following formula:

$$Organic\ carbon\ (C\%) = \frac{[(Nox \times Vox) - (Nred \times Vred)] \times 0,39}{Compost\ mass} \times 100$$

Where: Nox: Concentration of K<sub>2</sub>CR<sub>2</sub>O<sub>7</sub>

Nred : Concentration of FeSO<sub>4</sub>

Vox: Volume of K<sub>2</sub>CR<sub>2</sub>O<sub>7</sub>

Vred: Volume of FeSO<sub>4</sub> poured

The quantification of organic matter is determined utilizing the following formula:

$$Organic\ matter\ (OM\%) = C\% \times 1,72$$

- Total nitrogen determination: The Kjeldahl method is employed for the accurate determination of total nitrogen

$$\%N = \frac{0,07 \times Vol(sulphuric\ acid\ poured)}{Compost\ mass}$$

- Calcium (Ca), magnesium (Mg), sodium (Na) analysis: The procedure for determining calcium, magnesium, and sodium remains consistent with that applied to the initial raw materials.

## III. Results and Discussions

### 3.1. Results and discussion of phytochemical screening

Phytochemical screening is essential for exploring the potential of plants as sources of bioactive compounds and understanding their medicinal properties.

Phytochemicals in plants can also contribute to nutritional value. Screening helps in understanding the nutritional content of plants, allowing for the development of functional foods that provide health benefits beyond basic nutrition and ensuring the quality of plant-based products used in various industries.

Phytochemical screening is used to assess the quality and authenticity of plant materials. It helps to confirm the presence of specific compounds that are characteristic of a particular plant species and ensures that the plant material used for various purposes is of the desired quality.

The outcomes of phytochemical screening, both pre-and post-fermentation, are delineated in Table 1.

**Table 1.** Scientific presentation of phytochemical screening outcomes pre and post-fermentation

Molecules	Polysaccharides	Saponins	Alkaloids	Flavonoids	Leuco-anthocyanins	Triterenes	Unsaturated stérols	Steroids	Antocyanes	Tannins	Heterozoid	Polyphenols
BEFORE FERMENTATION												
Pumpkin	++	-	-	-	++ +	-	-	++ +	-	-	-	-
Watermelon	++ +	-	-	++ +	++ +	++ +	+	-	++ +	-	-	-
AFTER FERMENTATION												
Pumpkin	++	-	-	-	+	-	-	+	-	++	-	-
Watermelon	++ +	-	-	-	+	+	+	-	+	++ +	-	-

-: negative (absence)

+: in the trace state

++ : average

+++ : very abundant

This analysis reveals a notable presence of polysaccharides and leucoanthocyanins in pumpkin and watermelon, indicative of complex carbohydrates and potential anti-diabetic properties. The decline in concentrations of initial elements post-fermentation suggests a transference of these elements from fruits and vegetables into the wines. Additionally, a significant reduction in flavonoids and anthocyanins is observed in fermentation residues. The fruit wine's phenolic compounds, particularly phenolic acid, exhibit substantial antioxidant capacity, as closely associated with antioxidant activity according to recent studies (Ghosh et al., 2021; Rahman et al., 2016).

Polysaccharides in wine manifest diverse biological activities, intricately influencing human health. These complex carbohydrates contribute to wine's sensory and mouthfeel characteristics, impacting texture and perceived quality. Beyond sensory aspects, research posits potential antioxidant properties, offering potential health benefits. Interactions with gut microbiota may influence digestive processes and foster a healthy gut environment. Moreover, polysaccharides could modulate immune responses. Ongoing studies explore these connections, emphasizing the multifaceted impact of wine polysaccharides on both sensory experiences and potential health outcomes. (Smith et al., 2021)

Leucoanthocyanins are colourless or lightly pigmented flavonoid compounds found in plants. They are the precursor molecules to anthocyanins, which are responsible for the red, purple, and blue colours in many fruits, flowers, and leaves. While leucoanthocyanins themselves are not coloured, they play a crucial role in the biosynthesis of anthocyanins.

The biological activity of leucoanthocyanins is often associated with their conversion to anthocyanins. Leucoanthocyanins, as well as their anthocyanin derivatives, are known for their strong antioxidant properties. They can help neutralize free radicals in the body, which may contribute to reducing oxidative stress and preventing cell damage.

Anthocyanins, derived from leucoanthocyanins, are investigated for their anti-inflammatory effects, potentially modulating inflammatory responses and offering benefits for conditions linked to chronic inflammation. Some research suggests cardioprotective effects, including blood pressure reduction, cholesterol level decrease, and enhanced cardiovascular health. Growing interest surrounds their potential neuroprotective effects, supporting brain health, and cognitive function, and potentially reducing neurodegenerative disease risk. Additionally, studies explore potential anticancer properties, including anti-proliferative and apoptosis-inducing effects in certain cancer cells. (Jiménez et al., 2010)

Within pumpkins, various flavonoids are present, contributing to their potential biological activities that can be advantageous for human health. (Jucá et al., 2020) Flavonoids, a diverse group of polyphenolic compounds found in plants, exhibit various biological activities. Recognized as potent antioxidants, they neutralize harmful free radicals, contributing to reduced oxidative stress linked to ageing and chronic diseases (Li et al., 2023; Rodríguez-García et al., 2019). Flavonoids also possess anti-inflammatory properties, modulating inflammatory pathways and potentially benefiting conditions associated with chronic inflammation, such as arthritis and certain cardiovascular diseases. (Maleki, et al., 2019)

Flavonoids, prevalent in fruits, vegetables, and tea, are linked to cardiovascular health. They may lower blood pressure, reduce cholesterol, and enhance vascular function, promoting heart health. Some display anticancer properties by inhibiting cancer cell growth, inducing apoptosis, and impeding tumor-supporting blood vessel development (Liu et al., 2019). Certain flavonoids, especially in berries and fruits, are associated with cognitive health, protecting nerve cells, reducing brain inflammation, and potentially lowering the risk of neurodegenerative diseases like Alzheimer's and Parkinson's. (Fernandes et al., 2017)

Certain flavonoids exhibit antimicrobial properties, which can help in fighting against various bacteria, viruses, and fungi. This property contributes to their role in traditional medicine (Singh, et al., 2014) and their potential application in developing novel antimicrobial agents. Flavonoids have been studied for their potential antiviral activity. They may inhibit the replication of certain viruses and modulate the host immune response to viral infections. (Badshah et al., 2021)

Triterpenes, naturally occurring compounds widely distributed in plants, fungi, and some animals, exhibit diverse biological activities. Their potential health benefits, particularly anti-inflammatory effects, have garnered interest. Found in medicinal herbs and plants, triterpenes modulate inflammatory pathways, inhibiting inflammatory mediator production, and beneficial in conditions linked to chronic inflammation. Possessing antioxidant properties, they neutralize reactive oxygen species (ROS), protecting cells from oxidative stress. This antioxidant activity is associated with potential overall health benefits and contributes to its anti-ageing properties. (Han & Bakovic, 2015)

Some triterpenes have shown promising anticancer properties in laboratory studies. They may inhibit the growth of cancer cells, induce apoptosis (programmed cell death), and interfere with the formation of blood vessels that support tumour growth (Ghante &

Jamkhande, 2019; Yadav et al., 2010). They have been investigated for their antimicrobial activity against bacteria, viruses, and fungi. They may have potential in the development of novel antimicrobial agents or as complementary treatments for infectious diseases.

Some triterpenes have been studied for their potential benefits in cardiovascular health. They may help lower cholesterol levels, reduce blood pressure, and have positive effects on lipid metabolism. (Han & Bakovic, 2015)

Triterpenes can modulate the immune system, potentially enhancing immune responses. This immunomodulatory activity may have implications for supporting the body's defence mechanisms against infections and diseases. (Ud Dim et al., 2023)

Anthocyanins, flavonoid pigments in fruits and vegetables, act as potent antioxidants, neutralizing free radicals to reduce oxidative stress and potential cell damage (He & Giusti, 2010). Associated with anti-inflammatory properties, they modulate various pathways, potentially managing inflammatory conditions. (Khoo et al., 2017)

Studies suggest anthocyanins may offer cardiovascular benefits, obesity control, and alleviate diabetes, potentially improving blood pressure, cholesterol levels, and overall heart health (Mozos et al., 2021; Cerletti et al., 2016; Li et al., 2015; Alvarez-Suarez et al., 2014; Wu et al., 2013). Additionally, they show neuroprotective effects, supporting cognitive function and reducing neurodegenerative disease risk. (Za et al., 2023) In vitro and animal studies reveal anthocyanins' anti-cancer properties by inhibiting cancer cell growth and inducing apoptosis (programmed cell death). (Lin et al., 2017; Jiang et al., 2014)

Anthocyanins, implicated in blood sugar regulation and enhanced insulin sensitivity, show potential benefits for diabetes management. Investigated for their role in managing obesity, they influence pathways in fat metabolism. (Belwal et al., 2017)

Steroids are a class of organic compounds with a characteristic structure consisting of four rings. They play essential roles in various physiological processes and exhibit diverse biological activities.

Corticosteroids, a class of steroid hormones, possess potent anti-inflammatory properties, commonly employed to mitigate inflammation and immune responses in allergies, asthma, and autoimmune disorders. Steroids modulate immune system activity, with corticosteroids suppressing responses and certain others enhancing immune function. Additionally, steroids influence bone metabolism, with glucocorticoids contributing to bone loss and sex hormones supporting bone health. (Buttgereit et al., 2016; Dhabhar, 2009)

### **3.2. Macronutrient content analysis results**

The macronutrient content analysis outcomes are presented in Table 2, which specifically outlines the moisture content of pumpkin and watermelon samples.

**Table 2.** Results of moisture content in pumpkin and watermelon samples

Sample	Moisture (%)	Raw ash (%)	Lipids (%)	Proteins before fermentation (%)	Carbohydrates (%)	Proteins from fermentation residue (%)
Pumpkin	10.07	6.09	5.80	2.457	75.58	6.916
Watermelon	22.29	7.82	7.60	3.458	58.83	-

Pumpkin, characterized by optimal moisture content, represents a distinctive carbohydrate source vital for wine fermentation. Despite its relatively low protein and fat levels, the raw ash content introduces essential minerals, enriching the fermentation process and imparting a qualitative enhancement to the resultant wine.

Watermelon, distinguished by elevated moisture and minimal protein and fat, serves as a carbohydrate-rich source, ideal for fermentable sugars in winemaking. Its raw ash content imparts essential minerals, augmenting the fermentation process and elevating the overall quality of the resultant wine.

### 3.3. Elemental analysis results for K, Na, Ca, and Mg

Detailed results of the elemental analysis for potassium (K), sodium (Na), calcium (Ca), and magnesium (Mg) before and after fermentation are succinctly summarized in Table 3.

**Table 3.** Results of elemental analysis for K, Na, Ca, and Mg

Plant material	K (ppm)	Na (ppm)	Ca (ppm)	Mg (ppm)
Pumpkin sample	17800	120	1291.8	8242.0
Watermelon sample	17400	220	1351.2	993.0
Pumpkin residues	11000	200	2020.8	756.6
Watermelon residues	6200	100	1001.4	565.8
Pumpkin wine	-	3600	1143.8	574.6
Watermelon wine	-	-	-	-

Upon comparison of the potassium (K), sodium (Na), calcium (Ca), and magnesium (Mg) contents in watermelon before and after fermentation, it is apparent that these elements are present in the resulting wines. The determination of the elemental concentration in the wines was made possible by calculating the difference in their concentrations before and after fermentation.

Notably, it should be acknowledged that the production of watermelon wine proved challenging due to the limited quantity of the sample, rendering a conclusive determination of its elemental composition unattainable. Nevertheless, based on the available results, it is reasonable to infer that watermelon wine would contain K, Na, Ca, and Mg, potentially at varying levels comparable to those found in pumpkin wine.

### 3.4. Micronutrient analysis results

The outcomes of the micronutrient determination for both pumpkin and watermelon are outlined in Table 4.

**Table 4.** Micronutrient determination results for pumpkin and watermelon

Elements	Average content	The average	Average content	The average
----------	-----------------	-------------	-----------------	-------------

	of pumpkin pulp	content of pumpkin wine	of watermelon pulp	content of watermelon wine
K (%)	5,11	1,17	1,99	1,17
Ca (%)	0,00	1,82	2,26	1,82
Sc (%)	0,00	0,69	0,00	0,69
Ti (%)	0,00	0,09	0,13	0,09
V (%)	0,00	0,00	0,00	0,00
Cr (%)	0,00	0,00	2,44	0,00
Mn (%)	0,33	0,00	0,00	0,00
Fe (%)	0,31	0,12	0,12	0,12
Ni (%)	0,00	0,00	0,00	0,00
Cu (%)	0,00	0,01	0,04	0,01
Zn (%)	0,00	0,00	0,00	0,00
Y (%)	0,10	0,38	0,38	0,38
Mo (%)	0,00	0,00	0,00	0,00
Sn (%)	1,51	0,03	0,04	0,03
Ba (%)	0,00	0,01	0,01	0,01
W (%)	0,00	0,00	0,01	0,00
Pb (%)	0,00	0,01	0,01	0,01
La (%)	0,00	0,00	0,00	0,00
Ce (%)	0,00	0,00	0,00	0,00
Nd (%)	0,00	0,00	0,00	0,00
Pr (%)	0,00	0,01	0,02	0,01
Pm (%)	0,00	0,00	0,00	0,00
Sm (%)	0,00	0,05	0,06	0,05
Eu (%)	0,00	0,01	0,04	0,01
Gd (%)	0,00	0,03	0,05	0,03
Tb (%)	0,00	0,02	0,03	0,02
Dy (%)	0,02	0,04	0,05	0,04
Ho (%)	0,00	0,00	0,00	0,00
Er (%)	0,00	0,00	0,00	0,00
Tm (%)	0,00	0,00	0,00	0,00
Yb (%)	0,00	0,00	0,00	0,00
Lu (%)	0,00	0,00	0,00	0,00

### Potassium

Potassium plays several important roles in winemaking, contributing to both the fermentation process and the characteristics of the final wine.

Potassium modulates wine acidity by acting as a counterion to tartaric acid, forming potassium bitartrate. This interaction reduces acidity, preventing tartaric acid crystal precipitation during storage, and maintaining taste, balance, and stability.

Essential for yeast metabolism, potassium supports growth and activity in converting sugars to alcohol and CO<sub>2</sub>. Adequate levels prevent sluggish fermentations, ensuring desired wine characteristics development. Proper potassium concentration in the must is crucial for efficient fermentation. (Walker & Blackmore, 2012)

Potassium ions impact wine sensory attributes, influencing flavour, mouthfeel, and texture by interacting with other compounds. Proper potassium levels enhance the overall sensory experience, providing a balanced and harmonious taste. (Payan et al., 2023; Paissoni et al., 2023)

Winemakers need to monitor and manage potassium levels throughout the winemaking process to achieve the desired sensory attributes and ensure the stability of the final product. The role of potassium in wine is multifaceted, impacting both the chemical and sensory aspects of the wine.

### Calcium

Critical for tartrate crystal development and stability in wine, calcium plays a pivotal role in vinification. Its intricate interactions mitigate the risk of crystal precipitation, contributing to overall wine stability. This mineral's influence highlights the complex chemical processes in vinification.

### Sodium

Despite its low concentration in wine, sodium subtly influences taste and acidity perception. Sodium ions interact with sensory receptors, modulating the overall flavour profile. Understanding the intricate interplay of trace elements enhances our appreciation of nuanced factors shaping wine taste, underscoring the importance of even minor components in palate impression.

### Magnesium

Magnesium plays a pivotal role in winemaking, contributing to the stability of wine colour and influencing the fermentation process. Its impact on colour stability involves interactions with pigments, ensuring vibrancy. In fermentation, magnesium participates in enzymatic reactions, underscoring its multifaceted influence on overall wine quality (Jackson, 2008; König & Uden, 2008)

### Phosphorus

Phosphorus assumes a vital role in winemaking, intricately woven into diverse biochemical processes during fermentation. It influences energy transfer, nucleic acid synthesis, and cellular signalling, orchestrating transformations that define the fermentation process. Acknowledging its nuanced contributions enhances understanding of the dynamic biochemical interplay in winemaking. (Bisson, 2019; Fleet, 2003)

Phosphorus assumes a pivotal role in the intricate ballet of fermentation, intricately engaged in diverse biochemical processes. It influences energy transduction, nucleic acid synthesis, and cellular signalling, emerging as a linchpin in the dynamic biochemical symphony underlying the transformative process of grape juice into wine. (Fleet, 2008; Bisson & Butzke, 2000)

### Iron

Iron, often present at low levels in wine, assumes dual significance in vinification. Its involvement in colour stability includes complex interactions with pigments, contributing vibrancy. Simultaneously, iron participates in oxidation reactions, enhancing the wine's resilience against undesirable alterations. Recognizing this delicate balance underscores iron's

impact on both aesthetic and chemical facets of wine quality. (Waterhouse et al., 2016; Rombaldi et al., 20002)

#### Zinc

Zinc, a trace element in winemaking, assumes a pivotal role in enzymatic reactions during fermentation. Functioning as a cofactor, zinc facilitates crucial biochemical transformations, influencing the efficiency and specificity of the process. Acknowledging zinc's nuanced involvement unveils its significance in orchestrating the cascade of reactions that transform grape must into wine, emphasizing its indispensable contribution to the complex biochemistry underlying vinification. (Mendoza & Farias, 2006; Bisson & Butzke, 2000)

#### Copper

Present in trace amounts, copper subtly influences wine, impacting colour preservation through interactions with pigments. Simultaneously, its presence catalyzes oxidation reactions, enhancing the wine's resilience against undesirable alterations. Recognizing this delicate equilibrium underscores the nuanced impact of copper on both aesthetic and chemical attributes of wine quality.

#### Manganese

Manganese, a trace element in winemaking, plays a key role in enzymatic reactions, intricately influencing the biochemical landscape during fermentation. Its catalytic role as a cofactor for various enzymes contributes to crucial biochemical transformations, and it fosters the stability of wine. Recognizing manganese's nuanced contributions enhances our understanding of the intricate interplay of elements shaping both the biochemistry and stability of the final wine product. (Frérot & Duteurtre, 1997; Henschke & Jiranek, 1993)

#### Sulfur

While not a mineral, sulfur plays a pivotal role in winemaking. Sulfur compounds, notably sulfites, are prevalent tools for preservation and antioxidative purposes, mitigating oxidation and microbial spoilage. Recognizing the strategic use of sulfur underscores its indispensable contribution to preserving the sensory integrity and overall quality of the final wine product.

### 3.5. Fermentation monitoring

The fermentation progress was meticulously monitored by employing a pH meter for pH measurements and an alcoholometer for alcohol content assessments at the controlled room temperature of the Laboratory of Chemistry and Microbiology (LCM) Nanisana, under the Ministry of Commerce.

#### a. Fermentation tests and winemaking parameters

Fermentation was initiated after the filtration or pressing stage, following the white winemaking process. The detailed trials and parameters for the vinification of pumpkin and watermelon are tabulated in Table 5.

**Table 5.** Trials and parameters of pumpkin and watermelon vinification

Parameters Tests	Pulp obtained (g)	Sugar (g)	Water (mL)	Yeast (g)	Potassium metabisulfite (g)	Fermentation time (day)
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Pumpkin	450	250	1200	1.00	0.047	21
Watermelon	500	500	1000	6.00	0.070	14

The alcoholic strength of the pumpkin test is registered at 10°, whereas the alcohol content for watermelon attains a level of 14°.

b. Results of physicochemical analyses

The physicochemical analysis results are systematically presented in Table 6.

**Table 6.** Results of direct reading of %Brix and pH, total acidity of wines

Physico-chemical characteristics	Pumpkin wine	Watermelon wine	Regulation: EU no. 1308/2013 of February 2013/ NOR: AGRT1733576A	AFNOR standards: Decree no. 2009-1306 of 27 October 2009 / NOR: AGRT0912391D
Alcoholic strength (%vol)	11.0	14.0	<15	- 7 to 11 (dry wine) - 11.5 to 13.5 (sweet wine) - 12 to 16 (sweet or sweet wine)
pH	3.9	4.3	<5	-
Degré de Brix (%)	5	9	<15	-
Acidité totale (g d'H <sub>2</sub> SO <sub>4</sub> /l du vin)	4.508	5.786	3 à 6	-

The total acidity of the wines falls within the range of 3 to 6 g/l of sulfuric acid, indicating compliance with regulatory norms.

Notably, the physicochemical attributes classify Pumpkin wine as dry, while Watermelon wine is characterized as sweet, mellow, or sweet.

In concordance with European regulations, these wines manifest conformity to stipulated physicochemical benchmarks, affirming their alignment with established standards

### 3.6 Sensory test results

The outcomes of the descriptive analyses for each wine have been documented, as presented in Table 7.

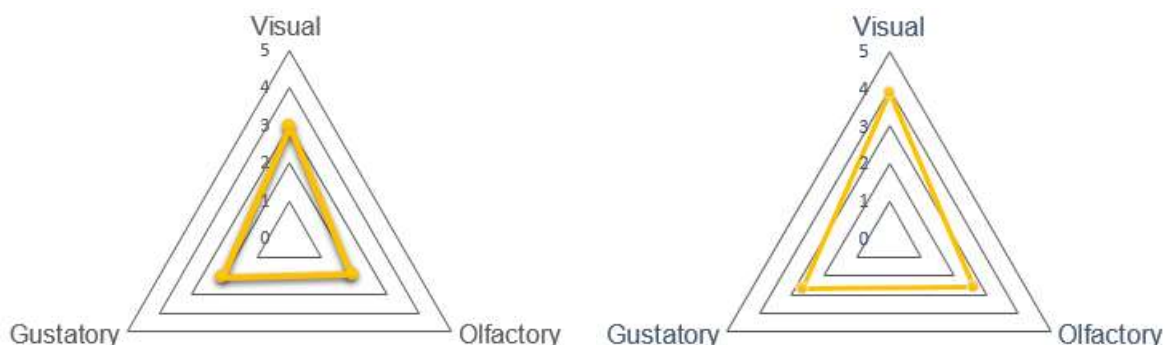
**Table 7.** Results of descriptive analyses of pumpkin and watermelon wine

REVIEW	Panel 1	Panel 2	Panel 3	Panel 4	Panel 5	Panel 6	Panel 7	Average
<b>PUMPKIN WINE</b>								
Visual	2.2	2.8	3	3.4	2.8	3.6	3	3.0
Olfactory	2	2.7	2	0.6	1	4.3	0.7	1.9
Gustative	1.8	2.5	2	1.8	1.7	2.8	1.8	2.0
<b>WATERMELON WINE</b>								
Visual	3.2	4	4.2	3.6	3.8	3.4	5	3.9
Olfactory	2.3	2.7	1.7	2.7	4	2.3	2.5	2.6
Gustative	2.7	1.8	2.5	2.8	3.7	2.33	3	2.7

The tabulated data indicates that pumpkin wine exhibits an exceptional visual quality, although its olfactory and gustatory attributes are somewhat subdued.

In contrast, watermelon wine showcases commendable visual quality, with an average rating of 3.9, closely approaching the maximum appreciation value of 5.

Furthermore, its olfactory and gustatory qualities surpass the average rating on the appreciation scale (2.5), rendering this wine moderately commendable in these two aspects



**Figure 1.** Sensory profile of pumpkin wine

**Figure 2.** Sensory profile of watermelon wine

The sensory profile of both pumpkin wine and watermelon wine is depicted through a graphical representation employing the metaphor of a spider web.

The tabulated data reveals that pumpkin wine demonstrates exceptional visual quality, notwithstanding somewhat subdued olfactory and gustatory attributes. In contrast, watermelon wine exhibits commendable visual quality, nearing the maximum appreciation value of 5 at 3.9. Additionally, its olfactory and gustatory qualities exceed the average rating on the appreciation scale (2.5), classifying this wine as moderately commendable in these aspects. The nuanced analysis underscores the complex interplay of sensory elements, providing valuable insights into the distinctive characteristics of each wine variant, thus contributing to a comprehensive understanding of their overall quality and sensory profile

### 3.7 Composting results

Considering the notable similarities and commonalities in the results of various analyses for both pumpkin and watermelon, a decision was made to collect all waste and recycle it collectively through a composting process.

The compost acquired after a decadal interval exhibited a desiccated state, a pigmentation characterized by darkness, and an absence of discernible odours.

Table 8 presents the chemical characteristics of the compost after 20 days of composting.

**Table 8.** The chemical characteristics of compost

Chemical elements	Compost of all waste from handling	Commercial compost	Reference synthesis
MS	57,570 %	68 %	50 – 60 %
pH	7,22	6,51	7 - 8
C	21,620 %	37,98%	20 - 22 %

MO	37,186 %	65,327%	23 - 63%
N	1,110 %	1,51%	1,5 - 3%
C/N	19,477	25,15	10 - 20
P	1,148 %	0,269%	-
K	8,866 %	1,36 %	-
Ca	5,833 %	0,245%	-
Mg	1,698 %	0,55%	-
Na	1,210%	-	-

The analysis indicates that the compost derived from all manipulation waste contains essential nutrients for plant growth (N, P, K, Ca, Mg, Na). Primary elements (N, P, K) play a pivotal role in the initial development of plants, influencing their growth, quality, and overall health.

Secondary elements (Ca, Mg, Na) contribute to plant nutrition. A comparison with the chemical compositions of green waste composts from previous studies reveals the highly beneficial nature of our compost. Despite having a slightly lower organic content than commercial compost, the results remain satisfactory.

The high dry matter (DM) content of 57.570% falls within the reference range of 50 to 60%, signifying that the vinasse compost is more concentrated and rich in fertilizing elements. The pH of 7.22 indicates a slightly acidic product with satisfactory stability. The C/N ratio of 19.477 adheres to the recommended standard of 10 to 20. Phosphorus content at 1.148% is notably higher than in commercial compost. The elevated potassium content of 8.866% is particularly noteworthy.

The significant presence of calcium, magnesium, and sodium further enhances the compost's potential. This comprehensive evaluation underscores the compost's richness, providing valuable insights for its potential agricultural applications.

#### IV. Conclusion

In essence, this research was focused on the valorization of pumpkins and watermelons, primarily aiming to produce dry wine from pumpkins and sweet wine from watermelons. Simultaneously, the goal was to establish composts, contributing to the promotion of a zero-waste environment within the framework of a green circular economy.

Throughout the study, an extensive array of analyses and tests were systematically conducted. The outcomes revealed that watermelon wine displayed superior characteristics, boasting an alcohol content of 14°, while the alcohol content of pumpkin wine ranged at 11°. The physico-chemical and organoleptic attributes of both wines were meticulously preserved. Micronutrient analyses, encompassing the initial fruits and vegetables as well as the resultant wines, indicated minimal alterations in nutritional content. Crucial nutrients such as Mg, Fe, P, etc., were notably conserved following the processing stages.

Concerning the compost generated, it was observed that all handling waste contained essential nutrients for plant growth, including N, P, K, Ca, Mg, and Na.

Some molecules like flavonoids represent a prominent category of polyphenolic compounds intricately linked to the organoleptic attributes and health-enhancing characteristics inherent in red wine. Comparative analysis concerning green waste composts

emphasized the highly advantageous nature of our compost. Although its organic content marginally trailed that of commercial compost, the overall results were considered satisfactory.

This research serves as an inaugural exploration into the valorization of tropical fruits and vegetables in Madagascar. While the journey toward the complete industrialization of these fruits is ongoing, the promising findings from this study instil optimism for the future of lesser-known tropical fruits and vegetables.

This study aspires to illuminate the untapped potential of watermelon and pumpkin as sources for wine production within the framework of a zero-waste circular economy. By challenging the conventions of traditional viticulture and embracing a holistic approach to sustainability, an endeavour is made to contribute to the evolving discourse on environmentally conscious winemaking practices, fostering a paradigm shift towards a more ecologically harmonious, future in the agro-industrial sector.

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