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The Fruits of the Myrtle Syzygium Cumini, a Botanical, Phytochemical and Emblematic Treasure from the Bible

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Abstract: *This study on the valorization of Syzygium cumini fruit pulp was carried out in Antananarivo-Madagascar. The aim was to find a substitute for grape wine at Christian feasts. What drew our attention to the jamuns was their resemblance to grapes in bunches during fruiting and their identical color when ripe. Research undertaken through physico-chemical analyses of these fruits and the products derived from their fermentation has led to the conclusion that ordinary chemical families, such as anthocyanins (0.012 mg/g), produce a wine that is similar to grape wine in taste, slightly astringent, and color, however low its alcoholic strength. So, it would be possible to offer this type of wine that would not make anyone drunk.*
Keywords: *Syzygium cumini; fruit; pulp; anthocyanin; fermentation; wine*

I. Introduction

Wine has long been associated with grapes. Many countries have produced different grape varieties. Grapes grow in specific edaphic conditions and climates. The grapes are very dark purple to almost black and come in bunches. As Myrtle fruit, including Syzygium cumini, bears a close morphological resemblance to grapes, this prompted our curiosity to carry out in-depth studies on this fruit. Not only were we interested in seeing the transformation of this fruit into wine, and why not into the wine of the Holy Communion in Christian churches, which also marked the Passover that Jesus recalled before his crucifixion, but Syzygium cumini, a myrtle, is also one of the trees that the Creator gave after restoration as a blessing according to Isaiah 41: 18-19 and Isaiah 55:12-13 translating that "There should be rich and abundant blessings attending their return to God, and universal rejoicing from their embracing the religion of the Redeemer, and becoming interested in his mercy and salvation. This tree of blessings deserves in-depth study to uncover its treasures truly. After researching the literature, we conducted our wine, bioethanol and vinegar valorization studies in Antananarivo-Madagascar, during the Syzygium cumini fruit harvesting season.

II. Materials and Method

2.1 Myrtle in the Jewish Religion

According to Elie Munk, myrtle is one of the four types of plant that Jews use to make Loulav during the festival of Sucot (the festival of booths around September, following the Jewish New Year celebrations). The Loulav consists of a palm branch, a citron, myrtle branches and willow branches. The branches are tied together (myrtle and willow around the palm branch) with palm leaves, and the citron is held in the hand. The Loulav is shaken every holiday in the four directions of the compass, upwards and downwards.

Each species has a particular meaning, often interpreted as representing a population category. If a species is missing, the Loulav is unfit for use since it represents the unity of the Jewish people.

In Hebrew הדס hadas or the common noun Hadassah, a word found in the Jewish name Hadassah is also the name of Esther. It is used as a condiment because of its bitterness, no longer for celebrations, but instead to express sadness, penitence, and regret.

Another characteristic of the myrtle is the way its leaves grow: from a single point, three leaves can emerge (as can be seen in the photo above: "Common myrtle"). These three leaves represent the three patriarchs Abraham (right), Isaac (left) and Jacob (the bud in the center), each of whom comes from the same source, God (the point on the branch from which the three leaves sprout). The meaning of this parable is that a single source, God, gave birth to three men who embody radically different notions. Abraham embodies goodness, Isaac rigor and Jacob the harmony between the two, beautifully represented by the bud.

2.2 Myrtle in the Bible

In the Book of Zechariah, chapter 1, verse 8, we read of the Angel of the Lord standing among the myrtle trees "which have their roots in the depths" (Jerusalem et al., 1973). According to the commentators of the Jerusalem Bible, this vision has a mythological origin, according to which the myrtle is rooted in the depths of the abyss.

In the Bible, the word "myrtle" is repeated several times in the Old Testament: וְהֲדַס = the myrtle. According to New King James Version Isaiah 41:19 "I will plant in the wilderness the cedar and the acacia tree, the myrtle and the oil tree; I will set in the desert the cypress tree and the pine and the box tree together" because the Creator has already promised in verse 18 that "I will open rivers in desolate heights, and fountains amid the valleys; I will make the wilderness a pool of water, And the dry land springs of water." So it is a blessing to have myrtles and confirmed by Isaiah 55:13: "Instead of the thorn shall come up the fir tree, and instead of the brier shall come up the myrtle tree: and it shall be to the LORD for a name, for an everlasting sign that shall not be cut off.", for thorns and brambles were the signs of curses.

2.3 Myrtle Syzygium Cumini for the Phytochemical Treasures of Its Flowers and Leaves

The flowers are fragrant and small, about 5 mm in diameter. Flowers are white and grouped in branched axillary clusters. Calyx campanulate, very short, 4-lobed. Corolla with white, leafy petals and several protruding stamens (Ramya et al., 2012). Flowers contain oleanolic acid, ellagic acids, isoquercetin, quercetin, kampferol and myricetin (Sagrawat et al. 2006).

The jamblon plant is known for its phytochemical compounds, most of which are considered beneficial to health. The leaves contain β-sitosterol, betulinic acid, mycaminose, crategolic (maslinic) acid, n-hepatcosan, n-noncosan, n-hentriacontan, noctacosanol, n-triacontanol, n-dotricontanol, quercetin, myricetin, myricitrin and the flavonol glycoside myricetin 3-O-(4″-acetyl)-α-L-rhamnopyranosides, acylated flavonol glycosides. (Mahmoud et al. 2001; Sagrawat et al. 2006)

While branches, leaves and flowers were used, we researched the fruit pulp of Syzygium cumini of the MYRTACEAE family in Antananarivo-Madagascar.

2.4 Description of the Syzygium Cumini Fruit

The fruit is a small, olive-shaped berry called a "jamblon". It is oblong, ovoid, green at first, turning pink, then black and brilliant purple as it ripens. A variant of the tree produces white fruit.

The fruit, sometimes called Java plum, combines sweet, slightly acidic and astringent tastes. At the center of the fruit is a single, oval, brown-skinned, bony seed, constituting the reproductive seed, with greenish elements. Each fruit contains a single, large, oblong seed surrounded by a thin layer of yellowish paste. The fruit, in clusters, is round or oblong.

2.5 Choice of Study Environment

Following the bibliographical data below, the study used fruit collected in Antananarivo. Research undertaken in 2009 by a team of researchers at Institut Malgache de Recherches Appliquées on the fruit of Syzygium cumini, which grows in its botanical garden, made it possible to choose the collection season and the fruit to be collected. The fruits were harvested in Antananarivo at a ripening time when chlorophyll levels decreased, unlike anthocyanin levels. (Rasamimanana, 2009).

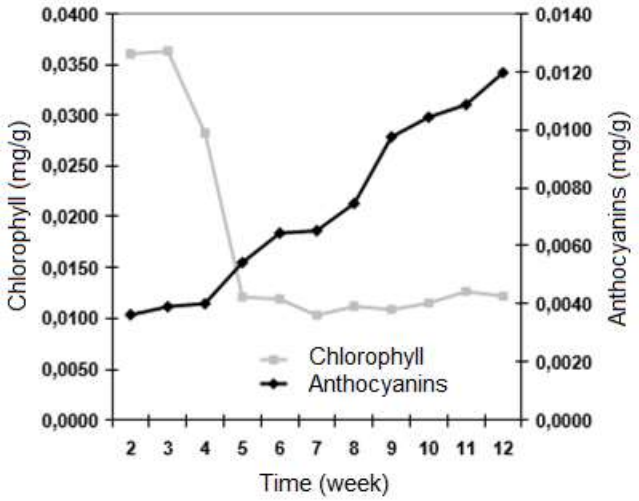

***Figure 1**. Variation in total chlorophyll and anthocyanin content of Syzygium cumini pulp during ripening (**Rasamimanana, 2009**)*

Chlorophyll content drops sharply from 0.0363 to 0.0121 mg/g between weeks 3 and 5, then remains unchanged until the end of ripening. On the other hand, anthocyanin concentration increases progressively from 0.003 to 0.012 mg/g from week 4 to the end of ripening.

According to Lee et *al.* (2008), pelargonidin, cyanidin, peonidin, delphinidin, petunidin and malvidin are the six common anthocyanidins found in nature. However, *Syzygium cumini* fruits owe their purple color to the three anthocyanin pigments delphinidin, petunidin and malvidin. Malvidin is the major anthocyanin at the end of ripening. (Veigas et *al.*, 2008)

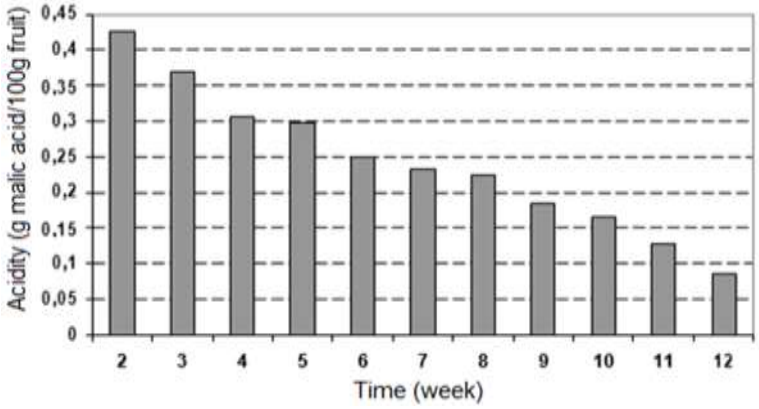

***Figure 2**. Variation in Syzygium cumini pulp acidity during fruit ripening (**Rasamimanana, 2009**)*

Pulp acidity gradually decreases from 0.42 to 0.08 g malic acid/100g fruit during ripening (Figure 2).

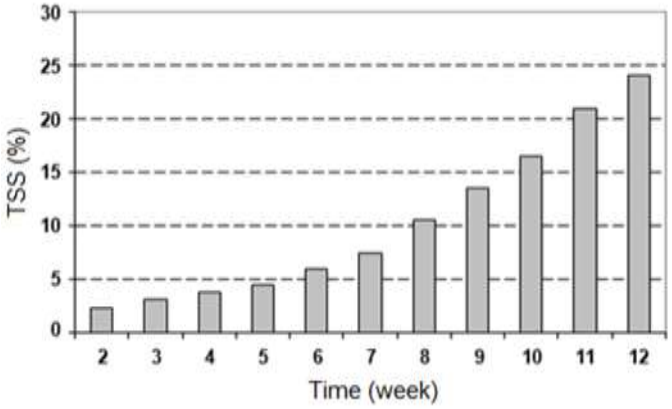

***Figure 3**. Variation in total soluble solids (TSS) of Syzygium cumini pulp during fruit ripening (**Rasamimanana, 2009**)*

TSS (total soluble solids) increases progressively from 2.25 to 24% at the end of ripening in *Syzygium cumini* fruits (Figure 21). The increase in TSS is caused by the rapid conversion of polysaccharides into simple sugars and their accumulation in the pulp vacuoles.

2.6 Previous Research Work on Pulp

Rasamimanana, as part of his master's thesis, extracted the essential oil from jamblon pulp. Each week, around 500-1000g of fresh pulp is hydrodistilled for 4 hours in a Clevenger-type extractor. The evolution of *Syzygium cumini* pulp essential oil composition during the ripening process is shown in Table 3. Monoterpene content rises sharply between week 1 (0.99%) and week 3 (90.13%), then stabilizes before dropping at the end of ripening (2.31%). The major monoterpene constituents are cis-ß-ocimene, trans-ß-ocimene, α-pinene and β-myrcene. On the other hand, the sesquiterpene content is high (43.02%) at the start of ripening, then falls sharply from the third week (3.03%) before rising significantly at the end of ripening (29.32%). These fluctuations in sesquiterpene levels are mainly due to germacrene-D, nβ-cadinene, δ-cadinene, caryophyllene oxide, β-caryophyllene and α-humulene. The level of oxygenates drops sharply between week 1 (36.08%) and week 3 (0.08%), then rises again slightly by week 12 (5.51%). The main components of oxygenated products are linalool, geranyl acetate, benzyl benzoate and eugenol. Similarly, the rate of unidentified compounds decreased between week 1 (19.9%)

and week 3 (5.91%), then stabilized before increasing considerably at the end of ripening (62.85%). Using the Weende method, Rakotonirina (2005) reported that the fiber content of *Syzygium cumini* fruit from Antananarivo contains 1.8-1.94% fiber.

2.7 Fruit Selection

This study aimed to convert *Syzygium cumini* fruit pulp into wine, bioethanol and vinegar in a zero-waste green circular economy. It was carried out in 2022 in Antananarivo. It is more ingenious to harvest fruit towards the end of its ripening period (March-April) when anthocyanin levels (one of the components ensuring wine's biological activity) are at their highest, acidity is at its lowest and total soluble solids are at their highest to support proper fermentation.

Figure 4. *Syzygium cumini fruits picked in Antananarivo*

Here is our fruit, ready to be analyzed for optimal use in a green, zero-waste circular economy.

III. Research Method

3.1 Micronutrients in *Syzygium Cumini* Fruit Pulp

Micronutrient determination was performed at the Office des Mines Nationales et des Industries Stratégiques laboratory. This is a chemical analysis technique based on the physical property of X-ray fluorescence. (Robijaona Rahelivololoniaina, 2023a; Robijaona Rahelivololoniaina, 2023b)

3.2 Macronutrients in *Syzygium Cumini* Fruit Pulp

Macronutrient determination was carried out at the Laboratoire d'Analyse et de Contrôle des Aliments et des Eaux Tsimbazaza.

Moisture content is determined by weighing the samples before and after placing them in the oven using the gravimetric method.

5g of samples were placed in clean, vacuum-weighed capsules. The oven was heated to 103°C, and the capsules containing the samples were inserted and left for 4 hours. Before weighing the capsules after drying, they are cooled for 1 hour. (Robijaona Rahelivololoniaina, 2023a ; Robijaona Rahelivololoniaina, 2023b)0 When the weights are taken, the following formula is used to calculate the moisture content:

$$\%\,\text{Moisture} = \frac{m1 - m2}{m1 - m0} \times 100 \qquad \textbf{F.01}$$

With m_0 : mass of the empty capsule
m_1 : mass of capsule + test sample before steaming
m_2 : mass of capsule + test sample after steaming

Determination of lipid content involves percolation by soxhlet using hexane. After evaporating the hexane, the percentage by mass of lipid remaining is calculated.

5 g of sample is introduced into an extraction cartridge, wrapped in Joseph paper. The extraction cartridge is placed in the soxhlet, above which is a ball cooler. At the base of this assembly is a flask containing 150 ml of hexane. The balloon heater is ignited at a temperature of 70°C (the boiling point of hexane) and the operation runs for 6 hours.

After 6 hours, the flask is removed and mounted on the rotavapor to separate the lipid from the hexane. To ensure all the hexane has been evaporated, the condensate must be baked at 103°C and then cooled.

The flask containing the lipid is then weighed, and the formula used to calculate the lipid content is as follows:

$$\% \text{ Lipid} = \frac{m2 - m0}{m1} \times 100 \qquad \textbf{F.02}$$

m_0 = mass of empty flat-bottomed flask
m_1 = mass of test sample
m_2 = mass of flask + test sample after steaming

The Kjeldhal method is used to determine protein content. The method comprises three stages: mineralization, distillation and titration.

Mineralization is started by adding 15 ml of sulfuric acid per matra. The 0.5 g test sample, well wrapped in filter paper, is introduced into the digestion tube with the catalyst. The closed assembly is then placed on the mineralizer and heated to 350-400°C for 4 hours.

Next comes distillation: ammonia, freed from its ammonium sulfate $(NH_4)_2SO_4$ salt form by adding excess concentrated sodium hydroxide, takes on a volatile form and is distilled, then condensed by passing through the cooler. This liquid flows over the tube immersed in the beaker containing the boric acid trap solution. When nitrogen is added, the solution turns light green. 20 ml of distilled water is poured into the ammonium salt. 25 ml boric acid followed by a few drops of indicator solution is also added to a beaker filled with distilled water until 1 cm of the tube is immersed. The addition of 50 ml of soda (in excess) is done automatically by the instrument as soon as the operation starts. The unit is set to run for 10 min. The operation ends when all the nitrogen has been released.

Titration completes the process: sulfuric acid titrates the distilled nitrogen trapped in the acid with the indicator solution. The color of the solution changes from green to dark red, and the amount of burette drop is then read off.

The beaker containing the solution to be titrated is placed on the magnetic stirrer, set to the desired speed, and the sulfuric acid is added drop by drop.

The solution takes on a dark red hue each time it comes into contact with the acid, and after a few drops it changes color completely. The addition of drops of acid is stopped as soon as this change appears, and the volume of acid added is read through the burette chute (BC).

The protein content is then determined only after the nitrogen content of the test sample has been determined.

$$\%N = \frac{BC \times 0.1 \times 1.4}{Ts} \qquad \textbf{F.03}$$

With BC = Burette drop (in ml)
Ts = Test sample (g)

0.1 = H_2SO_4 normality
1.4 = $M_{NaoH} \times 10^{-3} \times 100$
M_{NaoH} = Molar mass of nitrogen

The formula for protein content is therefore as follows:

$$\% \text{ Protein} = \%N \times 6.25 \qquad \textbf{F.04}$$

The crude ash content, which is the total mineral content of the fresh fruit, was determined.

5g of the sample were incinerated in an oven at around 550°C for 12 hours, until white, light-gray ash was obtained, free of carbon particles.

It was then placed in a desiccator to cool. Immediately after cooling, it was weighed.

Calculating the percentage of ash in the sample:

$$\%Ash = \frac{(Capsule + Ts)_{after\ oven} - (Empty\ capsule)}{Ts} \times 100 \qquad \textbf{F.05}$$

The total amount of carbohydrates is deducted from the other nutrients. The total carbohydrate content (G%), expressed in g per 100g of fruit, is obtained by the following calculation:

$$\%Lipid + \%Protein + \%Moisture + \%Ashes + \%Carbohydrates = 100 \qquad \textbf{F.06}$$

The total energy value is the energy released by the combustion of the macronutrients: proteins, carbohydrates and lipids contained in the food, taking into account their ATWATER coefficients: 4 kcal, 4 kcal and 9 kcal respectively.

The following calculation gives the overall energy value (E) expressed in kilocalories:

$$1g\ of\ Proteins \rightarrow 4\ kcal$$
$$1g\ of\ Carbohydrates \rightarrow 4\ kcal$$
$$1g\ of\ Lipid \rightarrow 9\ kcal$$
$$1\ kcal = 4{,}19\ Kj$$

$$E = (4 \times \%Proteins) + (4 \times \%Carbohydrates) + (9 \times \%Lipid) \qquad \textbf{F.07}$$

Moisture and ash are non-calorific ingredients.

3.3 Phytochemical Families in *Syzygium Cumini* Fruit Pulp

Phytochemical Screening is an analytical method used to identify the presence of existing chemical families in a plant. It is a method for exploiting the medicinal virtues of a plant. This operation is therefore essential before carrying out any other in order to predict and explain any subsequent reactions. (Robijaona Rahelivololoniaina, 2023a ; Robijaona Rahelivololoniaina, 2023b)

It was carried out at the Laboratoire de Chimie et de Microbiologie Nanisana and the Laboratoire de Biochimie Appliquée aux Sciences de l'Alimentation et à la Nutrition in Ankatso, according to their protocols.

a. Flavonoid and Leucoanthocyanin Screening

The operation begins with maceration in 96° alcohol for 24 hours, in a tightly sealed jar, for a quantity of 1g of sample for 10ml of alcohol. Then, the maceration product is filtered to extract the alcoholic extract. A solution equivalent to 3g of plant material, including 3ml of extract, is evaporated and then cooled. After treatment with petroleum ether, a second filtration is necessary. This operation is repeated until all pigments have been removed. The residue thus obtained is dissolved in 80° alcohol and filtered a third time. Only then are 3ml of the last filtrate poured into a test tube, to which 0.5ml of concentrated HCl has been added, placed in a water bath for 30 minutes and allowed to cool. A purplish-red coloration indicates the presence of leucoanthocyanins.

For flavonoids, 3ml of the previous filtrate is poured into a test tube. 0.5ml of concentrated HCl and three turns of magnesium are added. A confirmation test is then carried out by repeating the previous operation and adding 1 ml of distilled water and 1 ml of isoamyl alcohol to the solution. A red coloration indicates the presence of flavonoids. In contrast, a red to purple coloration represents flavonols and a purplish-red coloration indicates the presence of both molecules at the same time.

b. Saponin Screening

Saponin detection is a straightforward operation. 10g of dry powdered plant material is placed in a test tube and 10ml of distilled water is added. The tube is shaken vigorously for 30 seconds and left to stand for 10 minutes. The appearance of foam on the surface indicates the presence of saponins.

c. Screening for 6-Desoxy-Hexose

Screening for the presence of 6-desoxy-hexose is also quick and easy. It involves adding 1.5 ml of acetone and 10 ml of concentrated HCl to 10 mg of dry powder in a test tube. The mixture is then heated in a boiling water bath for 10 minutes. If a red coloration appears, this indicates the presence of the 6-desoxy-hexose sugar.

d. Cardiac Glycoside Screening

1 ml of the alcoholic filtrate is mixed with 2 ml of chloroform or dichloromethane in a test tube. A few drops of H2SO4 are essential for a reddish-brown color change. If this color appears, the plant part studied does indeed contain cardiac glycosides.

e. Determination of Anthraquinone

The Borndrägen test is used to trace the presence of anthraquinones in a given sample. 0.5 ml of aqueous extract is mixed with 1 ml of benzene collected from the organic phase and 5 drops of ammonia 25%. If, after shaking, the alkaline phase turns red, then the part of the plant studied contains anthraquinone.

f. Determination of Decomposes (Glucose)

The presence of desoxyoses is verified using the Keller Kiliami test. To do this, 0.5 ml of aqueous extract is mixed with 0.5 ml of ferric chloride $FeCl_3$ 10% aqueous solution and 0.5 ml of glacial acetic acid. Stirring with the addition of 0.5 ml H_2SO_4 follows the process, and the appearance of a purple ring at the interphase corresponds to the presence of desoxyoses in the plant studied.

g. Determination of Tannins and Polyphenols

Gelatin test: 4 to 5 drops of 1% aqueous gelatin are added to 0.5 ml aqueous extract. If precipitation is observed, the test portion contains tannin. Salt gelatin test: 4 to 5 drops of 1% aqueous salt gelatin are added to 0.5 ml aqueous extract. Precipitation indicates the presence of pyrogallic tannins. $FeCl_3$ test: 1 ml of the filtrate obtained by alcoholic maceration is taken in a test tube. 1 ml of distilled water is added with two drops of 1% $FeCl_3$. A dark green color indicates the presence of catechic tannins, while a blue-green color confirms the presence of gallic tannins. If the salt gelatine test is negative but the $FeCl_3$ test is positive, a green or blue-black coloration indicates the presence of polyphenolic compounds other than tannin.

h. Alkaloid Determination

0,5 ml acid extract for three tests:

Mayer test: 3 drops of mercuric chloride II HgCl are added to the acid extract. Alkaloids are present if there is an orange-red precipitate. Wagner test: 3 drops of iodo-iodide I_2/KI are added to the acid extract. A brown precipitate confirms the presence of alkaloids in the test portion. Dragendorff test: If 3 drops of potassium tetraiodobismutate Bi (NO_3)$_3$/KI) mixed with the acid extract produce a yellowish precipitate, then the test portion contains alkaloids.

i. Determination of Steroids and Terpenoids

Liebermann-Burchard test: 1 ml of chloroform extract is mixed with 3 drops of acetic anhydride and stirred. 3 drops of 36.76 M H_2SO_4 concentrate are added. The solution separates into two phases and is left to incubate for 30 min. A blue-green shift in the upper (aqueous) phase denotes the presence of steroids and a violet-red ring on the interphase for triterpenes. Salkowski test: 1 ml of chloroformic extract is used with 1 ml of concentrated H_2SO_4 36.76 M. A red or violet coloration indicates the presence of unsaturated sterols. Kedde test: A few drops of picric acid are added to 1 ml chloroformic extract. Lactonic steroids stand out for their orange coloration.

j. Determination of Water-Extractable Substances

1 g dry powder of plant material is mixed with 20 ml distilled water in a beaker. The mixture is then decocted for 15 min on a hot plate, cooled for 20 min and filtered with filter paper.

A well-cleaned, dry glass petri dish is weighed on a precision balance. After this, the filtrate obtained is poured in, and the dish containing the filtrate is placed in the oven for 3 days for dry evaporation to obtain the residue. The following formula is used to calculate the percentage of water-extractable substances:

$$\text{Water} - \text{extractable sustances} = (n' - n) \times 100 \qquad \textbf{F.08}$$

Where

n : mass of empty petri dish

n': mass of the dish after evaporation in the oven, containing the residue

3.4 Valorisation of *Syzygium Cumini* Fruit Pulp

a. Fruit Vinification

This is the phase when yeast transforms sugars into alcohol. Red wines contain 11% to 15% alc.vol/l. Yeast contributes many compounds other than alcohol. Some yeasts

enhance the expression of fruity aromas (raspberry in Beaujolais, exotic fruit in Sauvignon, etc.). All sugars are converted into alcohol (sugars must be less than 2g/l).

Alcoholic fermentation takes place in airtight (anaerobic) tanks. These must first be cleaned with water containing sodium metabisulfite (5 g/l) and then rinsed with clean water. The quantity of yeast varies from 3 g to 20 g per 10 l of juice. It partly determines the speed of fermentation. Factors influencing fermentation time and yield are: optimum temperature 29°C (the more constant the temperature, the better the fermentation); the quantity of yeast added; the quality of the yeast added, i.e., its activity. **(Guerrini et *al.*, 2021)**

Once the fruit has been thoroughly washed, it is weighed on a tared scale before any operation begins. The fruit is then crushed using a blender, adding a small quantity of water. Filtration follows to separate the juice from the crushed flesh, and the juice is then diluted; adding water depends on the desired concentration.

The amount of sugar added depends on the desired alcoholic strength of the wine. As sugar is generally of poor bacteriological quality, it should be added as syrup at 60° Brix. To calculate the quantity of syrup to be added, we first use a refractometer to measure the quantity of sugar naturally contained in the juice at each production stage, which varies according to variety, maturity, production region, etc.

$$\text{Amount of sugar} = \frac{(\text{Brix degree of the solution x } 100) - \text{Sugar content of the juice}}{0.6 - \text{Brix degree of the final solution}} \quad \textbf{F.09}$$

On average, fermentation takes between 7 (seven) and 10 (ten) days in summer, while in winter it takes 10 (ten) to 14 (fourteen) days. Note that this duration can also vary according to the sugar content of the must: a high sugar content results in a high alcohol content with slower fermentation. In contrast, a low sugar content leads to rapid fermentation with a lower alcohol content. On the other hand, an excessive increase in sugar content will bring fermentation to a halt, while sufficient dilution will slow down the fermentation rate. Fermentation is said to be complete when no more CO_2 is released.

Temperature also plays an essential role in the fermentation process, as yeast development and activity depend on it. Yeasts live and work at around 25°C to 35°C, below which only a few can activate and start fermentation, and above which they die and cannot continue fermentation.

When fermentation ends, the dead yeast forms a veil on the surface, and the fermentation debris settles to the bottom of the tank. Filter paper is ideal for this operation. The wine is obtained and needs to be well preserved by sulfiting or adding SO_2. Sulfur dioxide reduces oxidation phenomena harmful to product quality and inhibits the growth and development of bacteria responsible for wine deterioration.

Generally speaking, SO_2 is added in the form of potassium metabisulfite at a dose of 10g/hl, which corresponds to 5g/hl of SO_2.

b. Process for Converting Pulp into Bioethanol

Like wine, alcohol is obtained by filtering the wort from alcoholic fermentation. The next stage of the process differs in that the sugar transformed into alcohol in the wort is separated by distillation.

Distillation consists of separating the alcohol obtained from fermentation from the must by boiling the latter and condensing the steam. Distillation is carried out to collect only the desired product. **(Rick Morris, 2014)**

c. Process for Turning Pulp into Vinegar

Vinegar is the product of a double fermentation: alcoholic fermentation followed by acetic fermentation. Alcoholic fermentation, already explained in the preceding paragraphs, takes place in an airtight place, while the second fermentation results from the action of bacteria (acetobacter). They use alcohol to produce acetic acid. Acetic fermentation takes place in the open air, an aerobic fermentation. Acetic fermentation is a natural phenomenon when wine is left in the open air.

After alcoholic fermentation, the mixture is inoculated with acetic bacteria and commercial vinegar in the following proportions: 1/3 vinegar at 6° and 2/3 wine at 10° alcohol. After eight days, a veil called the "mother" forms on the surface, and after 5 weeks, when acetification is complete, the vinegar is drawn off.

Care must be taken, as a mixture too rich in alcohol (>10°) kills the acetic bacteria.

Control and monitoring of fruit processing into wine, ethanol and vinegar

Brix level is measured using a refractometer: a drop of wine is poured onto the refractometer, and the Brix level is read as indicated by the refractometer Alcoholic strength is measured using an alcoholmeter: the wine is placed in a graduated cylinder and the alcoholmeter is immersed vertically. The graduation coinciding with the free surface of the wine is the alcoholic degree. Acidity titration with NaOH: 5 ml of wine are poured into a beaker, adding 10 ml of distilled water and 3 drops of phenolphthalein or φφ as a color indicator. The 0.1 M NaOH titrant solution is poured in meticulously, drop by drop, so that the fuchsia-pink color change can be noticed. The formula for calculating acidity is :

$$\text{Acidity} = V(\text{NaOH}) \times 0.98 \qquad \textbf{F.10}$$

d. Composting *Syzygium Cumini* Fruit Waste

Composting is a way of conserving and transforming organic waste into a valuable product for planting, rich in humic compounds, in order to reduce pollution. Composting reactions take place under the action of aerobic bacteria, releasing heat that eliminates pathogens contained in incoming waste.

Compost is thus the product of the degradation of organic matter by the natural action of microorganisms present in air and water.

Microorganisms, the small creatures responsible for the degradation of waste, require several conditions in order to work appropriately and thrive:

Nitrogen and carbon compounds as food sources, Air favored by carbon compounds, Moisture provided by nitrogenous matter

During the degradation phase, temperature evolves in three stages:

First, the temperature rises from 40°C to 45°C due to the respiration of aerobic mesophilic microorganisms. The most degradable compounds, such as sugars and starch, disappear first.

After this, following a short pause, there is a slight rise in temperature resulting from the endogenous respiratory activity of living cells present in the mass to be composted. This is a very short phase and can only be observed in the laboratory when a high proportion of fresh tissue appears in the mixture.

Finally, microorganism respiration gradually raises the temperature from 60°C to 70°C, and these mesophilic microorganisms become thermophilic and thermotolerant. The environment becomes anaerobic as the microorganisms breathe, consuming all the oxygen in the composting mixture. As a result, anaerobic germs develop, lowering the temperature because their metabolism is less thermogenic. Restoring aerobic conditions is necessary to eliminate this mess, and high-temperature fermentation can continue. The higher

temperature destroys pathogens and parasites, odors disappear and decomposition is accelerated. When the temperature stops rising due to aeration, degradation is considered complete.

Pathogen destruction depends on temperature and degradation time. Composting occurs either at a high temperature for a short time or at a lower temperature for a more extended period.

Composting requires certain conditions, such as the decomposition of organic matter in a continuously changing environment, with variations in temperature, pH and living conditions. At the same time, microorganisms change in number and character during the process. Product maturation also depends on several factors, including nutrient supply, particle size, water content, structural strength, aeration, mixing, acidity (pH) and pile dimensions. At this stage, humic compounds predominate, and materials degradable by microflora are scarce.

P and K content are calculated using the following formulas:

$$\%\,K = \frac{\%\,K2O}{1.2} \qquad \textbf{F.11}$$

$$\%\,P = \frac{\%\,P2O5}{2.3} \qquad \textbf{F.12}$$

IV. Results and Discussion

4.1 Results of the Physicochemical Analysis

a. Micronutrients in Syzygium Cumini Fruit

Micronutrient determination was conducted in the OMNIS (Office Malgache Nationale pour l'Industrie Stratégique) laboratory. This is a chemical analysis technique based on the physical property of X-ray fluorescence.

Table 1. Nutrient content detected during the experiment

Element	1st Trial	2nd Trial	3rd Trial	Average
Mg (%)	2,34	2,59	2,31	2,41 ± 0,12
Al (%)	0,91	1,31	1,34	1,18 ± 0,19
Si (%)	0,00	0,00	0,00	0,00 ± 0,00
P (%)	0,11	0,11	0,11	0,11 ± 0,00
S (%)	0,00	0,00	0,00	0,00 ± 0,00
K (%)	1,29	1,53	1,02	1,28 ± 0,21
Ca (%)	0,00	0,00	0,00	0,00 ± 0,00
Ti (%)	0,12	0,12	0,12	0,12 ± 0,00
V (%)	0,00	0,01	0,01	0,01 ± 0,00
Cr (%)	0,04	0,03	0,04	0,03 ± 0,00
Mn (%)	0,00	0,00	0,00	0,00 ± 0,00
Fe (%)	0,39	0,40	0,40	0,39 ± 0,00
C (%)	0,00	0,00	0,00	0,01 ± 0,00
Ni (%)	0,04	0,04	0,04	0,04 ± 0,00
Cu (%)	0,01	0,01	0,01	0,02 ± 0,00
Zn (%)	0,01	0,01	0,01	0,01 ± 0,00
As (%)	0,01	0,01	0,01	0,01 ± 0,00

Se (%)	0,01	0,00	0,01	0,01 ± 0,00
Sn (%)	0,00	0,00	0,00	0,00 ± 0,00
Sb (%)	0,00	0,00	0,00	0,00 ± 0,00
Ag (%)	0,02	0,02	0,02	0,02 ± 0,00
Mo (%)	0,00	0,00	0,00	0,00 ± 0,00
Zr (%)	0,07	0,07	0,07	0,07 ± 0,00
Rb (%)	0,04	0,04	0,04	0,04 ± 0,00
Sr (%)	0,04	0,04	0,04	0,04 ± 0,00
Ba (%)	0,05	0,03	0,03	0,04 ± 0,00
W (%)	0,05	0,05	0,05	0,05 ± 0,00
Ta (%)	0,00	0,00	0,00	0,00 ± 0,00
Au (PPM)	0,00	0,00	0,00	0,00 ± 0,00
Hg (PPM)	0,00	0,00	0,00	0,00 ± 0,00
Pb (%)	0,00	0,00	0,00	0,00 ± 0,00
Cd (%)	0,00	0,00	0,00	0,00 ± 0,00

Jamblon is rich in magnesium, potassium, aluminum and iron, but other nutrients are addressed.

b. Macronutrients in *Syzygium Cumini* Fruit

Macronutrient determination was carried out at the LACAE (Laboratoire d'Analyse et de Contrôle des Aliments et des Eaux) at Tsimbazaza. By applying **F.01**, moisture content is determined by weighing the samples before and after oven drying using the gravimetric method.

Table 2. Moisture content

Test	Ts (g)	m_0 (g)	m_1 (g)	m_2 (g)	Moisture content (%)
1st test	1.0185	2.6286	3.6471	3.3891	25.66
2nd test	1.0122	2.6566	3.6688	3.4058	

Ts = Test sample (g)

Jamblon is a juicy fruit with an average moisture content of 25, 66 %.
Percolation with a soxhlet, followed by evaporation of the hexane, gives the following results:
The lipid content was calculated according to formula F.02.

Table 3. Lipid content

Sample	m_0 (g)	m_1 (g)	m_2 (g)	Lipid content (%)
Fruit	109.05	5.63	109.07	0,24

The Kjeldhal method is used to determine protein content. Two tests were carried out.

According to formulas **F.03** and **F.04**, the nitrogen and protein contents of the two tests are summarized in the table below.

Table 4. Proteins content

Tests	Ts (g)	BC (ml)	Nitrogen content (%)	Proteins content (%)
Test 1	1.31	1.80	0.18	1.12
Test 2	1.27	1.50		

With BC = Burette drop (in ml)
Ts = Test sample (g)
The crude ash content was obtained after applying formula F.05 and gave 0.23%.
The total carbohydrate content (G%), expressed in g per 100g of fruit, is obtained by applying formula F.06, which gives 72.75%.
Applying formula F.07, the overall energy value (E) is 1247.11 KJ

c. Phytochemical Families of *Syzygium Cumini* Fruits

The results of the chemical family screening are shown in the following table:

Table 5. Phytochemical screening results

Families	Flavonoids	Leucoanthocyanes	6-desoxy-hexose	Tanin	Cardiac glycosides	Saponins	Stéroids	Triterpenes	Anthraquinones	Lactonic steroids	Unsaturated sterols	Desoxy-oses
Results	-	++	+	+++	++	++	+	-	-	-	-	-

(-) absence of the required molecule.
(+) confirms the presence of the required molecule
(++) or (+++) intense coloration during the Screening, meaning that the molecule is present in large quantities.

d. Determination of Water-Extractable Substances in *Syzygium Cumini* Fruits

Water-extractable substances are shown in the following table. The calculation formula applied was **F.08**.

Table 6. Water-extractable substances WES

n (g)	n' (g)	WES (%)
42.631	42.758	12.70

The decoction yielded 12.70% hydrophilic extract

4.2 Results of the Valorization of *Syzygium Cumini* Fruits

a. Results of *Syzygium Cumini* Fruit Fermentation

From bibliographical data and the results of our analyses, we were able to move on to the stage of valorizing the pulp of the *Syzygium cumini* fruit into wine, vinegar and alcohol.
Here is how the fermentations during 14 days were carried out.

Table 7. Summary of fermentation preparations

Jambon (g)	Sugar (g)	Water (l)	Yeast (g)
750	50	1,0	8
700	50	1,0	8
1000	50	0,5	8

After controlling and monitoring the conversion of fruit into wine, ethanol and vinegar, and applying formula **F.10**, the following table shows the results of these fermentations.

Table 8. Fermentation results

	°GL	°Brix	V_{NaoH}	Acidity	Alcohol content (%)
Wine trail	0	2	2.2	2.156	Not determined
Testing vinegar	0	2	2.9	2.842	Not determined
Test for alcohol	0	3	2.8	2.744	3.33

Not determined: very low for an alcoholmeter
°GL: Gay Lussac degree
°Brix: Brix degree
V_{NaoH}: volume of NaOH

According to Ranaivoson (1993), the standard pH for Malagasy wine is 2.7 to 3.7, and its total acidity (gH_2SO_4/l) is less than 5. Total acidity corresponds to the sum of titratable acids when the must or wine is neutralized by adding a titrated alkaline liquor. It comprises several acids: tartaric, malic, citric, lactic, succinic and acetic,

These solutions are acidic due to the low sugar content, and the alcohol yield was also low.

When tasted by a dozen young people aged between 20 and 21, this limpid, red-colored wine had the scent and taste of jamblon, even though the alcohol content was low. The acidic, alcoholic, and slightly astringent flavors of grape wine were also perceived.

b. Composting of *Syzygium Cumini* Fruit Wastes

The Berkley composting method is adopted for this study. The process can produce compost in two to three weeks **(Raabe, 2001).** All waste and fresh residues from previous manipulations are collected in a bin and mixed with fresh cattle droppings. The mixture is stirred well to accelerate decomposition time, and sealed to prevent exposure to sunlight and moisture from rain. Samples are checked every five days during the two-week incubation period. The main things to consider when making compost are the carbon/nitrogen ratio, air and water.

All handling waste was collected and mixed for the composting operation to ensure that the zero waste concept was applied to the letter. Samples were taken on days 4, 8 and 13 and were tested for nitrogen, phosphorus and potassium content. Nitrogen content was measured using the Kjeldahl method. Phosphorus and potassium are still oxides, respectively: phosphorus pentoxide P_2O_5 and potassium oxide K_2O. Nitrogen content was obtained using formula **F.03**, potassium by **F.11** and phosphorus by **F.12**.

Table 9. Results of composting

Analysis elements (%)	Day 4	Day 8	Day 13
N	0,61	0,76	0,91
P_2O_5	0,96	1,31	1,72
K_2O	1,91	1,96	2,11
P	0,42	0,57	0,77
K	1,59	1,63	1,76

The following graph shows variations in nitrogen, phosphorus, and potassium percentages:

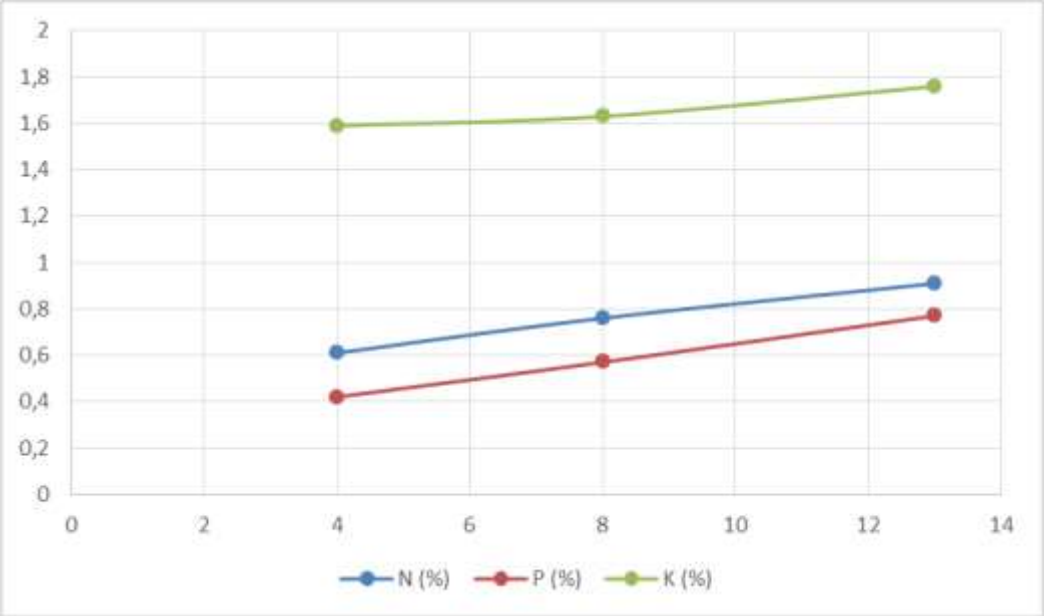

***Figure 5**. Graphical representation of N, P, and K content variations*

This figure shows that the three main elements requiring control and monitoring for the composting process have evolved upward.

4.3 Discussion

The *Syzygium cumini* tree bears dark, aubergine-colored clusters of fruit. Rich in micronutrients, macronutrients, and phytochemical families, these fruits have been used to make wine, bioethanol, and vinegar.

Alcoholic fermentation unites the process of turning *Syzygium cumini* fruit into wine, alcohol and vinegar. After filtration, however, the filtrates undergo different treatments, resulting in different products. However, despite its name, alcoholic fermentation produces alcoholic products, as the sugar added to the must is transformed into alcohol by the yeasts. It's also important to pay attention to variations in sugar and yeast, as these influence analysis results.

Trace elements essential to yeast life and growth are also present. Their proportions are meager, around 0.2%. Fruits from Antananarivo are rich in them.

As jamblon is known as a medicinal plant, phytochemical Screening is a good way of proving its biological (or pharmacological) properties through the molecules detected during the operation. Phytochemical Screening makes it possible to trace and target many molecules in the plant parts to be studied, whether leaves, flowers, fruit pulp or seeds.

Phytochemical Screening of our fruit pulp has shown the presence of anthocyanins. Previous research has found that Jamun pulp contains anthocyanins, delphinidin, petunidin, malvidin-diglucosides, and these compounds are responsible for its bright purple color. (Li et *al.*, 2009)

In India, *Syzygium cumin* seeds are widely used in traditional medicine to treat diabetes (Kumar et *al.*, 2008). The seeds, being the most studied part of the plant, contain jambosin, gallic acid, ellagic acid, corilagin, 3,6-hexahydroxydiphenoylglucose, 4,6-hexahydroxydiphenoylglucose, 1-galloylglucose, 3-galloylglucose, quercetin, β-sitoterol. (Ramya et *al.*, 2012).

During the Second World War, when Madagascar was deprived of insulin for the treatment of people with diabetes, *Syzygium cumini* powder was recommended.

V. Conclusion

So, for this tree, whose leaves, flowers and fruit are a treasure trove of micronutrients, macronutrients and phytochemical families, everything can be transformed into a green, zero-waste circular economy. Wine, bioethanol, and vinegar have been obtained by fermentation.

Syzygium cumin is a tall tree, but the grape is a climber. *Syzygium cumini* fruits are clustered and dark eggplant, almost black. Wine has been made from these fruits. The fruits of the grape are also in clusters and are dark purple, almost black. There are many similarities between these two fruits, which produce red wine with a certain astringency. Both are mentioned in the Bible and have their specific significance.

This scientific research has demonstrated their richness in micro-nutrients, macro-nutrients and phytochemical families. During the pandemic, these fruits were abundant everywhere and may have contributed to the fight against Covid-19, with its Mg content of 2.41%. The anthocyanin content of 0.012 mg/g makes it a standout for its potent antioxidant activity. For its plant-derived protein content of 1.12%, it would be even a tiny protein supplement for vegetarians and vegans.

According to this study, myrtle is a botanical treasure. These fruits are sources of micronutrients, macronutrients and phytochemical families. What is more, this tree is an emblematic treasure of the Bible.

The main objective of the study was to valorize the pulp of *Syzygium cumini* fruits. The specific objective of vinification was also achieved. A very low-alcohol wine was obtained. Would it be suitable for the holy cenacles of Christian churches, avoiding drunkenness?

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