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Production of Cashew Apple Wine Enriched with *Hibiscus sabdariffa* Extracts

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Abstract

This study focuses on enhancing the value of agricultural products by developing a process to produce wine from cashew apples enriched with extracts from *Hibiscus sabdariffa*. The formulation consisted of a blend of cashew apple juice and Hibiscus calyxes in a ratio of 90:10 (w/w). The Hibiscus calyxes were added at three different stages: before, during, and after fermentation. The physico-chemical analysis of the resulting wines revealed a pH range of 3.073 ± 0.005 to 3.583 ± 0.015 and acidity levels ranging from 4.018 ± 0.028 to 5.628 ± 0.059 g/L. The alcoholic strength ranged from 13.54% ± 0.036% to 13.86% ± 0.04%, with a soluble dry extract of 7.2 ± 0.25 to 8.1 ± 0.28 °B. Regardless of the stage of Hibiscus calyx addition, the fermentation kinetics and physico-chemical parameters met the standards set for wines.

Keywords

Vinification, Cashew Apple, *Hibiscus sabdariffa*, Fermentation

1. Introduction

In Côte d'Ivoire, fruit production has been steadily increasing due to improved cultivation techniques [1]. Among these fruits, the cashew apple stands out as a nutrient-rich fruit, containing polyphenols, sugars, and vitamin C [2]. Since 2015, Côte d'Ivoire, being the world's leading cashew nut producer and exporter [3], has aimed to establish itself as a major player in cashew processing globally. The country is expected to produce over 1,040,000 tonnes by 2022, according to the Conseil du coton et de l'anacarde.

The cashew apple, which weighs 9 to 10 times more than the nut [2] [4] represents approximately 10 million tonnes of production for the year 2022. Unfortunately, a significant portion of this production goes to waste at harvest due to the lack of marketing opportunities compared to other fruits [5]. The underutilization of cashew apples is attributed to their astringency and certain cultural beliefs that discourage their consumption, such as the belief that eating cashew apples with milk is incompatible in several African countries [2]. However, processing the apples into juice is a primary method to eliminate astringency. Cashew apples are highly juicy (85% to 90% water), sweet (9% to 13% carbohydrate), slightly fragrant, and acidic [1], similar to grape.

Guinea sorrel, scientifically known as *Hibiscus sabdariffa L*, is a plant native to India and Malaysia that is widely grown in West Africa [6] [7]. *Hibiscus sabdariffa*, variety sabdariffa also known as bissap in Wolof [6] is widely used in beverage production in tropical Africa [8]. The calyxes of *Hibiscus sabdariffa* contain anthocyanin pigments, giving them a red color, which is desirable for producing refreshing beverages highly appreciated by local communities. Additionally, *Hibiscus sabdariffa* calyxes offer nutritional and therapeutic benefits [9] [10] [11].

Since cashew apples lack anthocyanins necessary for red wine production, the appropriate approach is to use a coloring agent to enhance their color. In this study, we propose using *Hibiscus sabdariffa* as a natural coloring agent, rich in anthocyanins and possessing similar coloring characteristics to grapes.

2. Material and Methods

2.1. Material

The materials used in this study included cashew apples (**Figure 1**) and *Hibiscus* calyxes (**Figure 2**). The cashew apples were sourced from Yamoussoukro, located in the Bélier region of Côte d'Ivoire, between the forest and savannah zones. The *Hibiscus sabdariffa* calyxes were obtained from the local market in Yamoussoukro.

Figure 1. Cashew apples.

2.2. Methodology

2.2.1. Extraction of Cashew Apple Juice

After collecting the cashew apples, they were carefully sorted to separate the good apples from the bad ones and remove any small pieces of wood or dead leaves that could affect the juice quality. The apples were then washed by spraying them with running water. Subsequently, a disinfection step was carried out using 100 ppm active chlorine for 5 minutes, followed by two rinses to eliminate all traces of chlorine. Once the rinsing process was complete, the apples were taken to a hydraulic press and pressed at a pressure of 200 Bar to obtain raw cashew apple juice. After extraction, a gelatine clarification step was performed by diluting 10 g of gelatine in 90 ml of warm water. The gelatine clarification was carried out using 12 ml of gelatine for every 1 litre of juice, followed by filtration and pasteurisation (Figure 3).

Figure 2. *Hibiscus sabdariffa* calyxes.

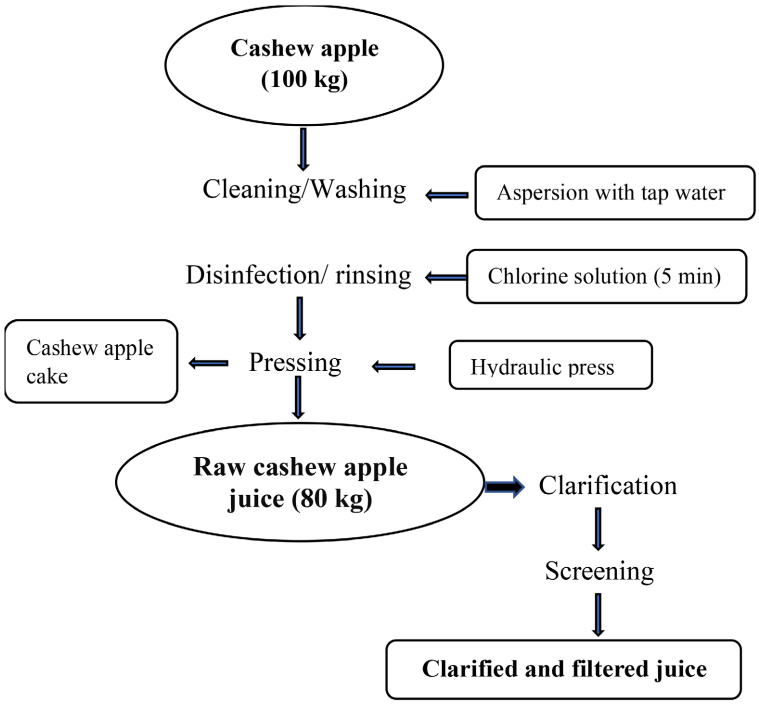

Figure 3. Process for the extraction and clarification of cashew apple juice.

2.2.2. Production of Cashew Apple Wine Enriched with *Hibiscus sabdariffa* Extracts

- Preparations of our different batches

The cashew apple juice was divided into three batches, and the *Hibiscus sabdariffa* extract (calyxes) was added at a rate of 10% based on the quantity of juice used. The dried and sorted *Hibiscus sabdariffa* extracts were weighed and washed with tap water.

- Fermentation of the must

Chaptalisation was performed at this stage to adjust the sugar content (˚B) of the cashew apple juice to achieve the desired alcohol content. Chaptalisation was carried out based on the principle that 17 g/L of sugar would yield 1% alcohol.

Dehydrated *Saccharomyces cerevisiae cerevisiae* yeast was used as a fermenting agent at a concentration of 1% of the final soluble dry extract (24˚B). The yeast was rehydrated for 15 minutes in approximately 1/3 of the must at a temperature of 40˚C to 45˚C to obtain a live and highly active culture. The rehydrated yeast was then added to the entire must. The fermentation process was monitored for 14 days at room temperature (30˚C ± 2˚C), with fermentation kinetics assessed every 24 hours. The end of fermentation was determined by the cessation of CO_2 production and the stability of the soluble dry extract after four days. Finally, the wines obtained after 14 days of fermentation were stabilized using the method described by Gnoumou *et al.* (2022) which involved stabilization at 65˚C for 5 to 10 minutes. The production diagram for cashew apple wine enriched with Hibiscus extracts is shown in **Figure 4**.

2.2.3. pH

The pH of the samples was measured using a pH meter (HANNA HI98240, China) after calibration with pH 4.01 and pH 6.87 buffers (AOAC, 2010). Ten milliliters (10 mL) of the sample were pipetted into a beaker, and the pH was determined by immersing the electrodes into the sample. The pH value was read from the meter's screen.

2.2.4. Soluble Dry Extract

The soluble dry extract (SDE) or refractometry was determined using the AOAC method (1995). A drop of each sample was placed on the refractometer's glass to assess the quantity of suspended solids. The refractometric dry extract value was read through the eyepiece of the apparatus.

2.2.5. Titratable Acidity

Titratable acidity was determined following the method described by Amoa-Awua *et al.* (2007) which involves an acid-base assay. In the presence of 2 to 3 drops of 1% phenolphthalein, 10 mL of each sample contained in an Erlenmeyer flask were titrated using a 0.1 N sodium hydroxide solution. The volume of sodium hydroxide required to neutralize the titratable acidity of the different samples was determined based on the pink color change of the solution.

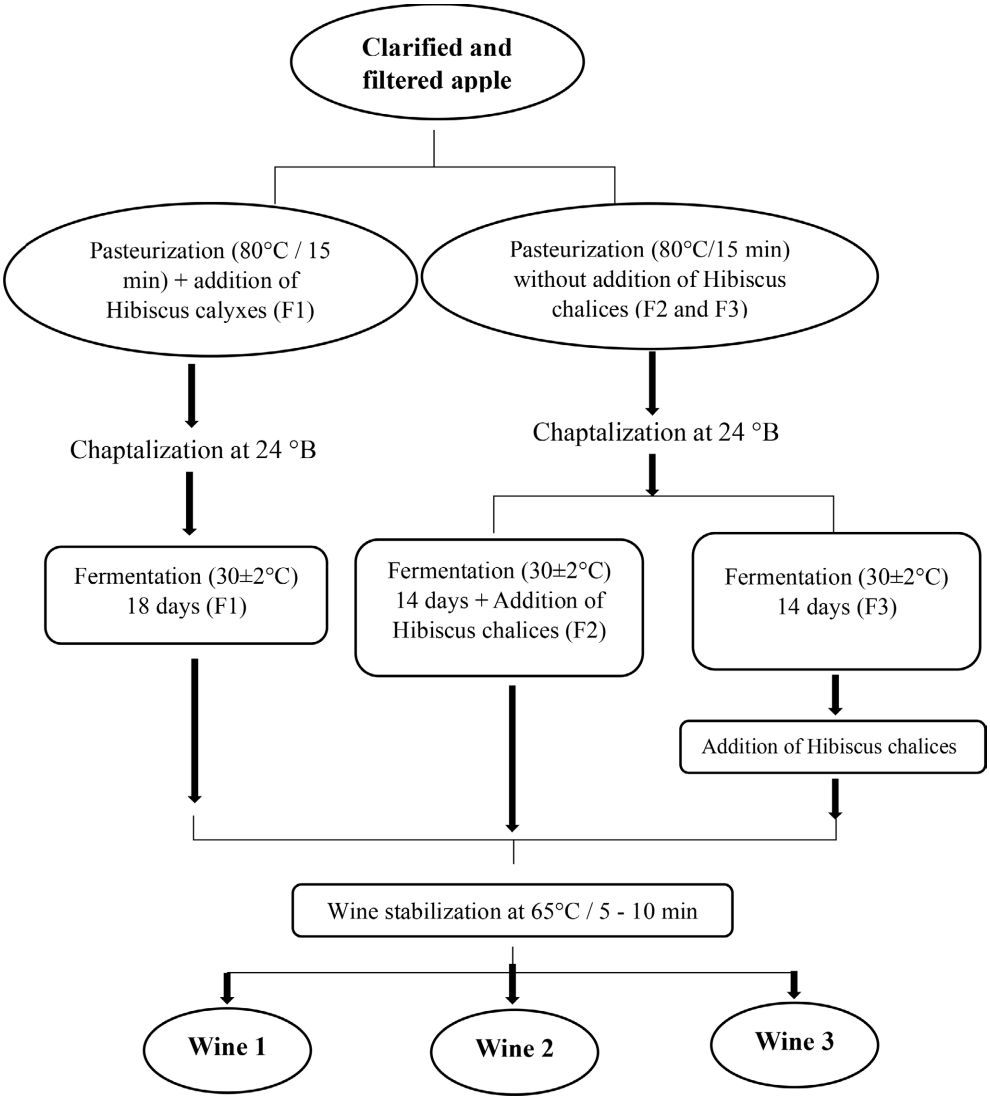

Figure 4. Production of cashew apple wine enriched with *Hibiscus sabdariffa* extracts.

2.2.6. Determination of the Alcoholic Degree

The alcoholic strength was determined using the Gay-Lussac alcoholometer or alcohol scale, which utilizes the conversion of the density of a water-alcohol mixture. Since wine contains compounds other than water and alcohol, such as sugar, direct measurement with an alcoholmeter is not accurate. Therefore, the alcoholic strength was determined in three stages. First, a sample of 250 mL was taken for analysis. Next, distillation was performed to separate the water from the alcohol. The alcoholic strength was measured every twenty minutes at a temperature of around 95˚C, and distillation was stopped when the alcoholometer reading reached zero. Finally, the alcoholic strength was calculated.

2.2.7. Statistical Analysis

Statistical analysis of the obtained results was conducted using STATISTICA version 7.1 software. One-factor analysis of variance (ANOVA) was performed, and statistically significant differences were identified using Duncan's test at a

significance level of 5%.

3. Results

3.1. Fermentation Kinetics

The changes in soluble dry extract (SDE), pH, and yeast activity during fermentation are depicted in Figures 5-7, respectively. Initially at 24˚B, the SDE gradually decreased until it stabilized on day 10 for wines 2 and 3, and on day 13 for wine 1 (Figure 5). Wine 1 had a longer fermentation time of 18 days compared to wines 2 and 3, which fermented for 14 days. The pH values exhibited a downward trend over time, ranging from 5 to (3.16; 3.57). Yeast activity closely

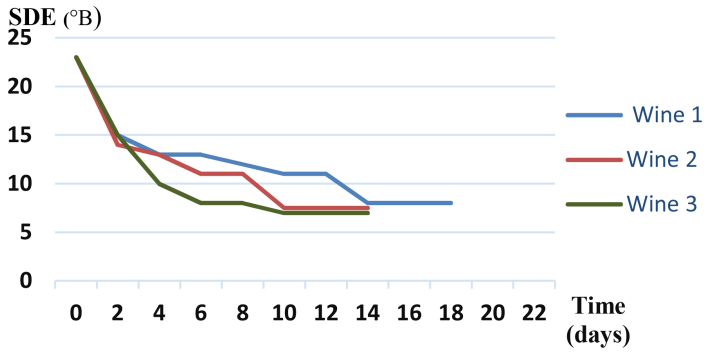

Figure 5. Evolution of the soluble dry extract of the fermentation.

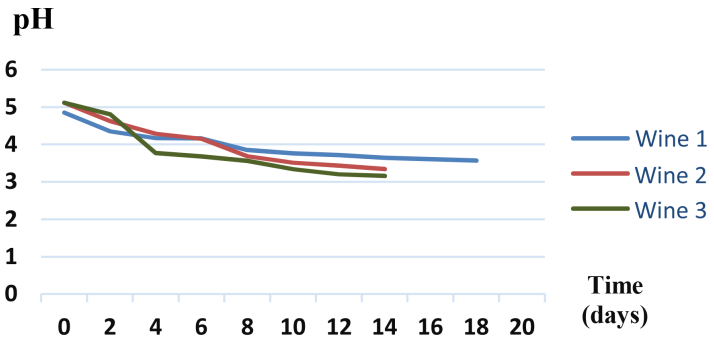

Figure 6. Evolution of pH during fermentation.

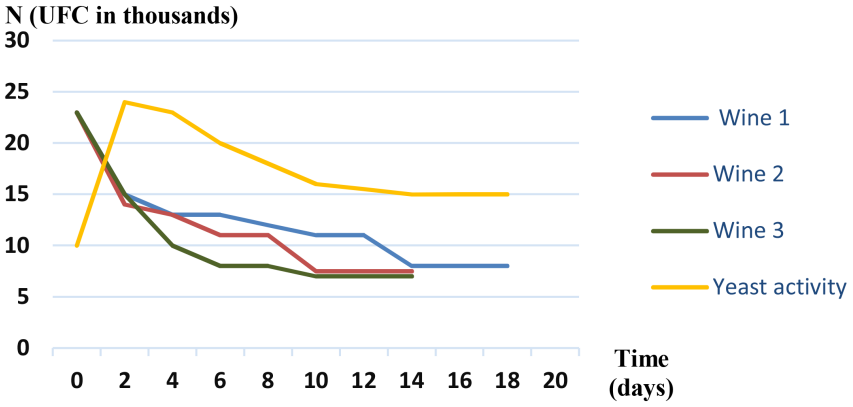

Figure 7. Evolution of yeast activity during fermentation.

correlated with changes in the concentration of soluble dry extract during fermentation. The first 4 days showed high yeast activity, followed by a sudden drop in soluble dry extract. Subsequently, a gradual decrease was observed from day 6 onwards, and yeast activity ceased almost entirely by the 11th day.

3.2. Physico-Chemical Analyses

Table 1 presents the results for soluble dry extract (SDE), pH, titratable acidity, and alcoholic strength. The SDE content of the wines varied between 7.2 and 8.1˚B. The pH values for wines 1, 2, and 3 were 3.073, 3.553, and 3.583, respectively. Regarding acidity, the concentrations were 4.127 ± 0.002 for wine 1, 5.628 ± 0.059 for wine 2, and 4.018 ± 0.028 for wine 3. The alcoholic strength was determined as 13.86, 13.85, and 13.54 for wines 1, 2, and 3, respectively.

4. Discussion

During the fermentation process, sugar in the must under the action of yeast will produce alcohol and release CO_2 in anaerobic environment. The quality of the wine is determined by certain physico-chemical parameters during fermentation. *Hibiscus sabdariffa* extracts (calyxes) have the particularity of being used as a natural colorant in industry, due to their anthocyanin content [12]. In addition to their coloring properties, *Hibiscus* calyxes give off a floral and fruity aroma that could add a refreshingly exotic note to our wine.

Chaptalization is a very important characteristic because it acts as an indicator of the alcohol content of the wine. The significant decrease in soluble dry extract of different wines could be due to the activity of yeasts by the activity of yeasts [13] [14]. Indeed, during fermentation yeasts consume the sugar present in the must to produce alcohol.

The chemical and biological stability could depend largely on pH. More acidic pH is known to have a favourable effect on the stability of wine and is favourable to the inhibition of bacterial proliferation, to the balance of the fermentation of sugars. A wine with low pH is also more visually appealing [15] [16].

When their pH is lower, red and white wines retain a more intense color. Red wines have a more pleasant color and smell. On the other hand, when the pH of a wine is high, bacteria proliferate rapidly and the undesirable problem of bacterial fermentation becomes more of a concern. This condition decreases the biological and chemical stability of the wine and depletes its color [17].

Table 1. Physico-chemical characteristics of the wines obtained.

	Wine 1	Wine 2	Wine 3
SDE (˚B)	8.1 ± 0.28	7.2 ± 0.25	7.4 ± 0.15
pH	3.073 ± 0.005	3.553 ± 0.005	3.583 ± 0.015
Acidity (g/L)	4.127 ± 0.002	5.628 ± 0.059	4.018 ± 0.028
Alcoholic degree (%)	13.86 ± 0.04	13.85 ± 0.035	13.54 ± 0.036

The total acidity is related to all the acids present in the wine. It reflects the gustatory characteristics of the wine [18]. It facilitates the conservation in case of precarious hygiene. The total acidity of the different wines respects the international standard that requires a content of 3.5 g/L of tartaric acid at least [19] [20] [21].

One of the essential characteristics of wines is the alcoholic degree [22]. The alcohol contributes to the balance of the wine by the sugar which attenuates the tannins. This makes the wine more supple and pleasant in the mouth. Alcohol is also a taste and flavor enhancer. The increase of the degree of alcohol makes the wines more complex and better tasting.

5. Conclusions

This study demonstrates that the wine obtained from cashew apples, despite being derived from a non-grape fruit, exhibits characteristics comparable to standard wines in terms of fermentation kinetics and physico-chemical analysis. For countries that do not produce grapes, but cashew nuts, this presents an opportunity to reduce wine imports.

The production of wine from cashew apples adds value to this fruit, considering the growing importance of wine as a meal accompaniment in Africa. It also provides an additional source of income for cashew growers, complementing their existing nut production. Ultimately, this can contribute to reducing unemployment rates in developing countries that produce cashew nuts.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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