

## Impact of Cultivation Areas and Analysis Site on the Nutritional Quality of Cashew Apples (*Anacardium Occidentale L.*) Grown in Côte d'Ivoire

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**ABSTRACT:** The main objective of this study was to investigate the influence of cultivation areas and analysis sites (in situ and laboratory) on the physicochemical composition of cashew apples. To this end, cashew apples collected from three regions (Bélier, Kabadougou, and Gontougo) were analyzed: one part of the cashew apples was analyzed on site and the other part was transported to the laboratory where the extracted juice was analyzed. The biochemical analyses focused on pH, titratable acidity, soluble dry extract, and vitamin C. The results showed that all the apple juices were acidic with a pH ranging from 3.35 to 3.93. The titratable acidity varied from 59.50 to 97.67; the sugar contents varied between 09.30°Brix and 13.00°Brix. Vitamin C was also present with contents ranging from 145.57 mg/100mL to 205.50 mg/100mL. Analysis of variance showed significantly different means from one region to another and from one analysis site to another.

**KEYWORDS:** Cashew apple, nutritional quality, analysis site, cultivation area, Côte d'Ivoire.

### 1 INTRODUCTION

The cashew tree was introduced to Côte d'Ivoire in the 1960s as part of a reforestation plan for the savannah zone, due to its rapid growth and resistance [1]. The tree produces fruit consisting of two parts: the cashew nut (true fruit) and the cashew apple (false fruit), which is around 9 times the weight of the nut. When the cashew nut reaches maximum size (30 to 35 days), the stalk, which until then had been normal, begins to grow considerably, becomes fleshy and is transformed into a cashew apple [2].

The cashew nut quickly attracted so much interest that the country became the world's leading producer, ahead of India. Its production is expected to reach 1,028,000 tones of cashew nuts in 2022. According to the apple/nut weight ratio, this tonnage of nuts corresponds to 9 million tones of cashew apples.

Almost all cashew apple production is lost at the point of harvest, because the Ivorian public is unfamiliar with cashew apples, which are not used industrially because of their astringency and certain taboos [2]. However, a number of studies have shown the fruit to be rich in nutrients. In fact, 85% of the cashew apple's juice is sweet and acidic, rich in vitamin C (6 times richer than sweet oranges), minerals, tannin and polyphenols [3], giving it antioxidant properties [4]. It has many uses in human health [5]. In addition to its nutritional qualities, the cashew apple is of technological interest because the edible part of the fruit is between 85% and 100% and the flesh is seed- and stone-free [6].

The industrial processing of cashew apples presents an economic challenge, as it would not only enable the creation of new income-generating activities and jobs, but would also and above all constitute an additional source of financial income for cashew nut producers [7].

The main way of using it is to convert it into juice, given its high water (80-90%) and sugar (10-12%) content. A number of studies have been carried out in this area [8], [9]. Factors such as varieties, growing regions, climate, stage of maturity at harvest and storage conditions are known to affect the composition of cashew apple juice [3].

The aim of the present study is therefore to assess the impact of the place of analysis (in situ and in the laboratory) on the composition of cashew apples. Specifically, certain physicochemical characteristics of cashew apples from three production regions in Côte d'Ivoire will be analyzed with a view to studying the variability of these characteristics as a function of production area and analysis location.

## 2 MATERIALS AND METHODS

### 2.1 MATERIALS

In addition to the usual laboratory equipment, the apparatus used in the laboratory is listed in Table 1 below.

Table 1. Technical laboratory equipment

Designation	Use	Model
pH meter	Determination of pH and temperature	CYBERSCAN PH 11
Refractometer	Determination of soluble dry extract	ATAGO pocket PAL- $\alpha$ , Japon
Balance	samples weighing	Sartorius, max : 210 g, resolution : 0,001g

### 2.2 METHODS

#### 2.2.1 SAMPLING

Cashew apples were harvested by picking under the trees in three regions of Côte d'Ivoire, namely the Béliér, Kabadougou, and Gontougo regions. In each of these regions, a locality was selected: Kabadougou (locality of Odienné: 9°32'803" North; 7°34'792" West), Béliér (localities of Toumodi: 2°97'528" North; 7°29'033" West), and Gontougo (locality of Bondoukou 5°24'581" North; 8°87'994" West). In each of these localities, 25 ripe cashew apples weighing approximately 5 kg in total were harvested and constituted the sample. After the apple collection, a portion (10 apples) was used to produce juice on the collection site (in situ). The juice from each sample was analyzed in situ. The remaining fruits were stored at 0 °C in coolers using dry ice, then transported to the laboratory in Yamoussoukro. Once at the laboratory, juice was prepared from the remaining apples after thawing. The same physicochemical analyses conducted in situ were performed on these juices. The sampling zones are presented in the figure below.

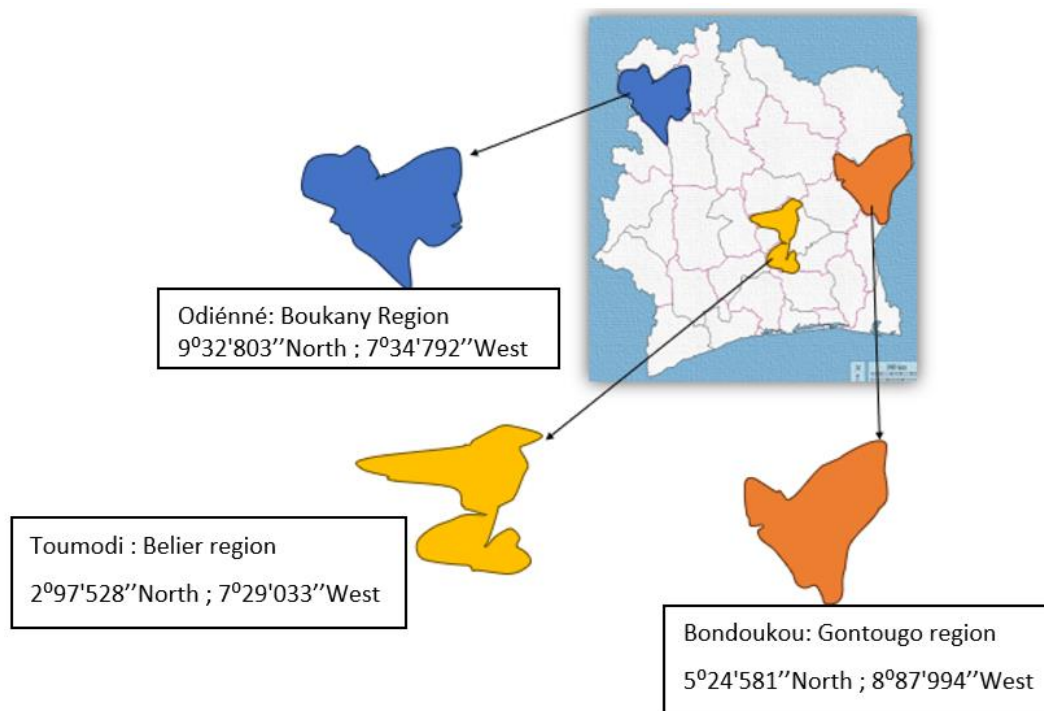


Fig. 1. Sampling zones

#### 2.2.2 JUICE EXTRACTION

The cashew apples are removed from the nuts and rinsed with distilled water. They are then cut and pressed manually under aseptic conditions. The juice obtained by manual pressing using a white cotton cloth was used for the various analyses.

2.2.3 PHYSICOCHEMICAL ANALYZES

2.2.3.1 DETERMINATION OF HYDROGEN POTENTIAL (PH)

The pH was determined using a pH meter according to the method described [10]. The calibration of the pH meter is carried out by using two buffer solutions at pH 4 and pH 7 at the reading temperature, before determining the pH of our cashew apple juice. The measurement is made by immersing the electrode in 20 mL of cashew apple juice sample contained in a 50 mL beaker. The pH value of the juice is displayed after 5 seconds.

2.2.3.2 DETERMINATION OF TITRATABLE ACIDITY (TA)

The total titratable acidity of the raw juices of cashew apple was determined by potentiometric titration using a solution of sodium hydroxide (NF V 05-101) at 0.1 N, in the presence of phenolphthalein as a colored indicator according to the AFNOR (1982) method [11].

2.2.3.3 DETERMINATION OF REFRACTOMETRIC SOLUBLE SOLIDS

The measurement of refractometric soluble solids (RSS) was conducted following the method described by AFNOR (1982) [11]. After cleaning and calibrating the refractometer with distilled water, a drop of juice was placed on the prism of the refractometer (ATAGO pocket PAL- $\alpha$  type, Japan). The device was then closed, and the reading was taken from a digital graduation scale within the device.

2.2.3.4 DETERMINATION OF ASCORBIC ACID CONTENT

Vitamin C (ascorbic acid) is an antiscorbutic and an antibiotic that plays a crucial role in collagen synthesis. The determination of vitamin C in raw cashew apple juice was carried out using a back titration method in the presence of diode and sodium thiosulfate, following standardized methods AFNOR (1982) [11].

2.2.4 STATISTICAL ANALYSES

All analyses were performed in triplicate, and the results were processed using Excel software. These data were then subjected to analysis of variance (ANOVA) using STATISTICA version 7.1 software to detect significant differences between samples. Additionally, the Newman-Keuls comparison test was used to determine homogeneous groups at a probability threshold of 5%.

3 RESULTS AND DISCUSSION

3.1 PH VALUES OF CASHEW APPLE JUICES

Figure 2 presents the pH values of cashew apple juices from three regions of Côte d'Ivoire.

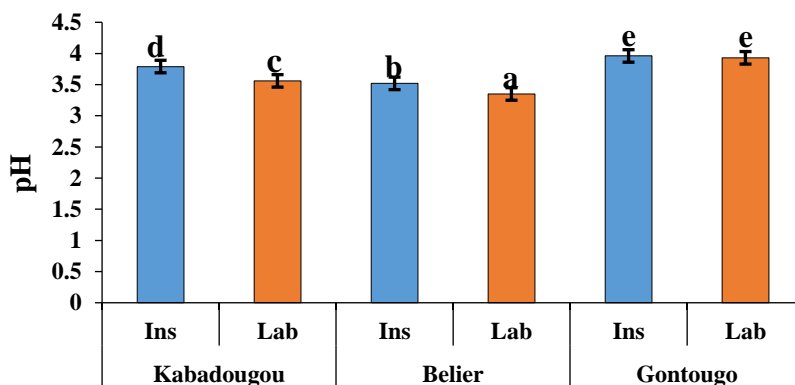


Fig. 2. Cashew apple juice pH

Histograms with different exponents are significantly different (at the 5% threshold) according to the Newman-Keuls test. Ins: analysis performed in situ; Lab: analysis performed in the laboratory in Yamoussoukro

The results obtained show that the pH of cashew apple juices varies between 3.35 and 3.93 for all three (03) regions. These values reflect the acidic nature of cashew apple juice regardless of the region and the analysis location. According to the production zone, the Gontougo region has the highest pH values (3.93-3.96), whether determined in situ or in the laboratory, while the juices from the Belier region have the lowest pH values (3.35 -3.52).

The analysis also shows that regardless of the production zone, the pH determined in situ is higher than the pH determined in the laboratory. These values obtained are lower than those reported by Dedehou et al. (2015) [9] in Benin, which ranged between 3.9 and 4.

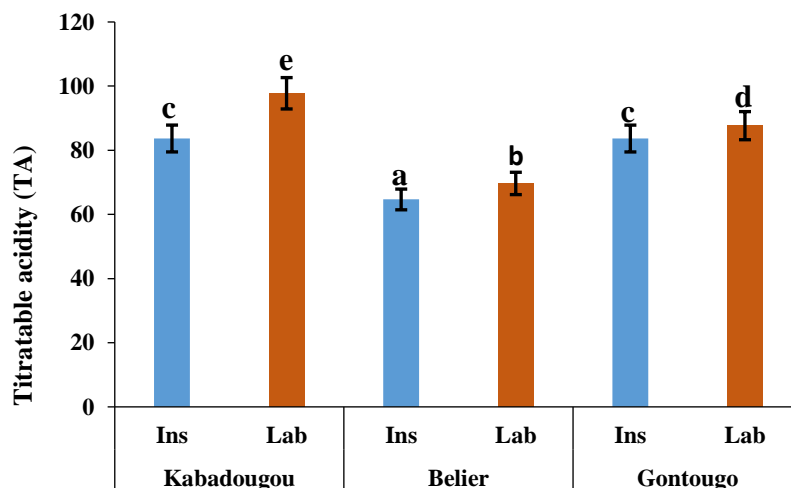
Additionally, variance analysis showed that cashew apples from the three (3) studied regions have statistically different pH values ( $p < 0.05$ ), indicating that those from the Béliér region (3.35 - 3.52) could potentially have a more stable juice than those from Kabadougou and Gontougo, given their more acidic pH. Indeed, the acidity of juices can inhibit the action of microorganisms [3], [12].

The observed pH differences between cashew apple juices from the three regions may be related to climatic conditions and soil types specific to each area. Light, well-drained, and clay-sandy soils would allow cashew trees to easily mobilize chemical compounds and synthesize compounds that promote the acidic pH of the extracted fruit juice [13].

Therefore, we can say that the cultivation zone and the duration before analysis influence the pH of cashew apple juices.

### 3.2 TITRATABLE ACIDITY VALUES OF CASHEW APPLE JUICES

Similar to pH, the acidic nature of cashew apple juices is also confirmed by the obtained titratable acidity values (Figure 3)



**Fig. 3.** Titratable acidity of cashew apple juice

Histograms with different exponents are significantly different (at the 5% threshold) according to the Newman-Keuls test. Ins: analysis performed in situ; Lab: analysis performed in the laboratory in Yamoussoukro

Regarding the different regions, titratable acidity varies significantly ( $p < 0.05$ ) from one region to another. Thus, Belier presents a more acidic juice (97.67%), followed by Gontougo (87.67%) and Kabadougou (61.33%). These differences between these zones could be explained by climatic and pedological conditions. The obtained values are higher than those of Adou et al. (2012) [3], which ranged between 56% and 57%.

The titratable acidity of cashew apple juice increases during the transport of samples in all regions. The juice analyzed in situ has the smallest value (59.5%), while the highest value (61.33%) is obtained for the juice whose analysis was performed in the laboratory. The same trend is observed for the other two regions (Belier and Gontougo). Statistical analysis revealed a statistically significant difference ( $p < 0.05$ ) between juices analyzed in situ and in the laboratory. Additionally, it is noticeable that for the regions farthest from the laboratory (Yamoussoukro, Belier region), the difference between titratable acidity in situ and that obtained in the laboratory is larger. Thus, the time associated with transporting the juices could have significantly influenced the titratable acidity of the juices. These results are in line with those reported by Costa et al. 2003 [14] in Brazil. These authors obtained values ranging between 45% and 76%, which are indeed different from those of the present study, but nevertheless, all these results show a correlation between the pH value and the titratable acidity of cashew apples.

### 3.3 SOLUBLE SOLIDS CONTENT (RSS) OF CASHEW APPLE JUICES

The sugar composition of cashew apples represented by soluble solids content is summarized in Figure 4.

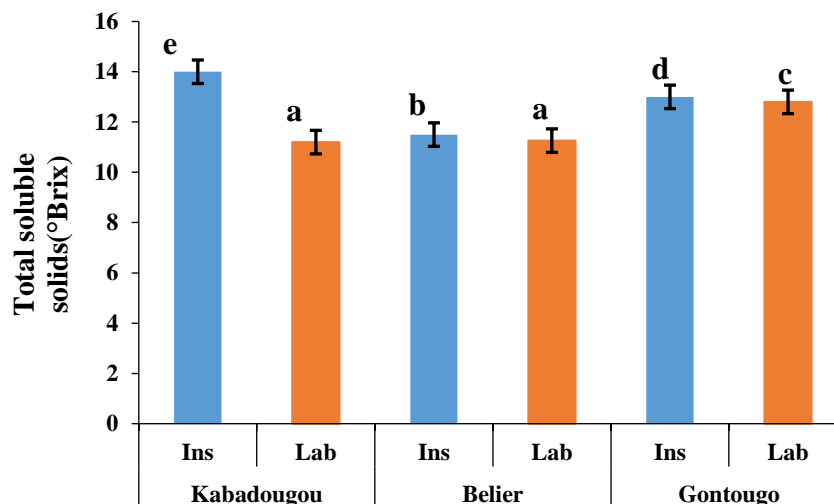


Fig. 4. Soluble solids content (RSS) of cashew apple juice

Histograms with different exponents are significantly different (at the 5% threshold) according to the Newman-Keuls test. *Ins*: analysis performed in situ; *Lab*: analysis performed in the laboratory in Yamoussoukro

Statistical analysis of the obtained results shows a significant difference ( $p < 0.05$ ) between soluble solids content values. Indeed, soluble solids content (RSS) varies from one analysis location to another for each region. It is noted that according to in situ values, the soluble solids content of juices in Kabadougou is higher with a Brix degree of 14, while the soluble solids content of juices from Belier apples has the lowest Brix degree of 11.5. This difference could be explained by the fact that in the northern regions of Côte d'Ivoire, where the climate is drier and warmer with more sandy soils, there is slower growth and a higher concentration of sugars and acids in cashew apple juices [8], [15].

Most of the obtained values are above 10 °Brix, which is the minimum value required by the Codex Alimentarius (FAO, 2022) [16]. This indicates a high sugar content of cashew apples from these three regions, which is a criterion for the valorization of this fruit in juices and alcoholic beverages.

However, these results are partly comparable to those of Gbohaïda et al. (2015) [17] ranging from 8.27 to 12.63 °Brix. Furthermore, Hédiblé et al. (2017) [18] found a content of 9.25 °Brix during their work, which is lower than those of the present study. The difference could be explained by climatic and pedological conditions specific to each region [19].

It is also observed that depending on the analysis location, the Brix degree content in Gontougo shows a small variation between the Brix degree value obtained in situ and that obtained in the laboratory. However, in the regions of Kabadougou and Belier, the Brix degree content is higher when determined in situ than when determined in the laboratory.

This decrease in sugar content in cashew apple juice observed between the juice analyzed in situ and that analyzed in the laboratory could be explained by the fact that some apples were injured during sampling, and due to these injuries, these apples were attacked by yeasts that initiated fermentation. This would decrease the sugar quantity from the apple collection site to the laboratory [2]. Also, the farther the cashew apple collection site is from Yamoussoukro, which is the laboratory analysis site, the longer it takes for the apples to reach the laboratory. This would have increased the risks of apple fermentation as it is known that fermentation is one of the pathways for sugar degradation [20].

### 3.4 VITAMIN C CONTENT OF CASHEW APPLE JUICES

Figure 5 summarizes the vitamin C content of cashew apple juices from the study regions.

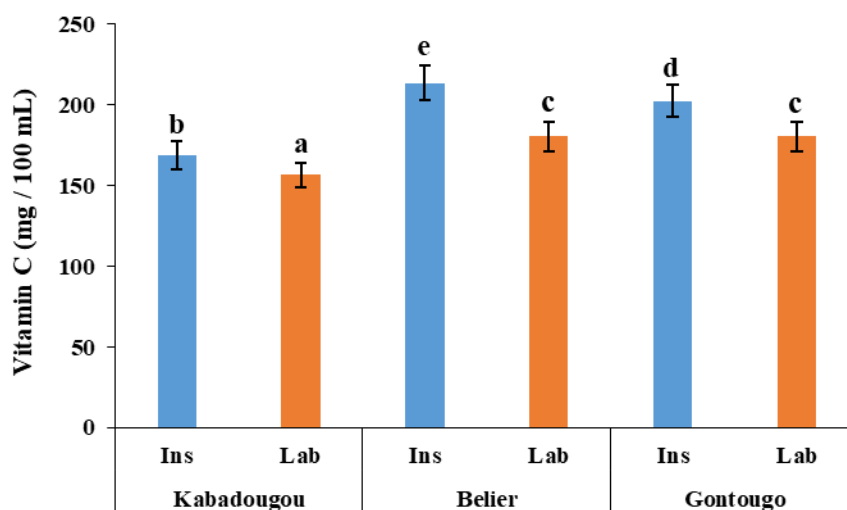


Fig. 5. Vitamin C content of cashew apple juice

Histograms with different exponents are significantly different (at the 5% threshold) according to the Newman-Keuls test. Ins: analysis performed in situ; Lab: analysis performed in the laboratory in Yamoussoukro

The maximum vitamin C content obtained in situ is 213.45 mg / 100 mL for cashew apple juice from the Belier region, and the minimum content is obtained in Kabadougou with a value of 168.8mg/100mL.

As for the juices analyzed in the laboratory, the one from the Kabadougou region has the lowest vitamin C content (156.57 mg / 100 mL), and the highest content is obtained in the juice from the Belier and Gontougo regions. According to Nagy (1980) [21], the variation in vitamin C content could be due to the climate of different cultivation zones. Note that all these contents are lower than those obtained by Gnoumou et al. (2022) [22], who obtained an average vitamin C content of 290.84 mg/100 mL in cashew apple juice, but they are higher than the vitamin C content of mango, Lippens variety (149.15 mg / 100 mL) obtained by Belem et al. (2017) [23], showing the richness of cashew apple in vitamin C.

The study showed that the vitamin C values obtained in situ were significantly higher than those of juices from apples obtained in the laboratory. This difference could be due to the fact that during collection, the apples were exposed to open air at room temperature before being stored at 0 °C. Thus, during this time, there would have been partial degradation of vitamin C. Indeed, according to studies, high room temperature is one of the favorable factors for the deterioration of vitamin C, which is a thermosensitive compound [24].

## 4 CONCLUSION

This study determined the biochemical composition, such as pH, acidity, soluble solids content, and vitamin C of cashew apples from the producing regions of Côte d'Ivoire. Cashew apple juice is characterized by its acidity and rich sugar composition; it is also an excellent source of vitamin C. However, the results obtained highlight the influence of the cultivation zone and the location (in situ and in the laboratory) where different analyses were performed. "This demonstrates that the composition of cashew apple juice can be significantly influenced by the region of cashew origin and the time elapsed between cashew apple harvest and juice analysis.

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