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RESEARCH ARTICLE

Variation of Physicochemical, Nutrient, Polyphenols and Tannin Proprieties of Cashew Apple (*Anacardium occidentale* L.) Pulp During Fermentation

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ABSTRACT

Cashew tree is cultivated in northern Côte d'Ivoire primarily for its nut, but also for its fruit. The fruit also includes an edible apple, but its consumption is limited due to its astringent taste and short shelf life. This study aims to evaluate variation of physicochemical, nutritional, polyphenols and tannins of cashew apples during natural fermentation. Physicochemical tests revealed a decrease of pH for yellow and red cashew apples from 5.15 to 3.54 and from 5.12 to 3.49, respectively, alongside a corresponding reduction in dry matter content from 15.60% to 6.03% and from 15.28% to 6.12%. Meanwhile, titratable acidity increased from 0.042 g/100 g and 0.371 g/100 g and from 0.048 to 0.377 g/100 g for yellow and red apples cashew apples respectively. Nutritional analysis of red and yellow cashew apples showed a decrease in refractometric dry extract from an average of 12°Brix to 3.22°Brix (corresponding to an alcohol content of 2.24% to 5.8%), as well as a decrease in total sugars from 29.54 g/100 g to 3.68 g/100 g. However, the protein content fell from an average of 26.11 g/100 g on first day to 14.29 g/100 g on fourth day, before rising again to 22.47 g/100 g. Polyphenols and tannins analysis during fermentation revealed a drop in total polyphenol content, from 538.mgEAG/100 g to 305.14 mgEAG/100 g and from 652.66 mgEAG/100 g to 350.23 mgEAG/100 g respectively for yellow and red cashew apple. Condensed tannin content was also a decrease from 15.15 mgEAT/100 g to 3.12 mgEAT/100 g, and from 15.95 mgEAT/100 g to 3.57 mgEAT/100 g, respectively for yellow and red cashew apples. The results of these investigations allow to conclude that cashew apples could be a suitable substrate for fermentation in order to produce chemicals of interest, such as organic acids and alcohols. In addition, fermentation could be reduce astringency of cashew apples. Future studies will involve isolating and identifying microorganisms responsible for the natural fermentation of cashew apples.

Keywords: Cashew apple, fermentation, nutrient, physicochemical.

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1. Introduction

The cashew tree (*Anacardium occidentale* L.) belongs to the Anacardiaceae family and is native to South America [1]. This branched tree is cultivated to combat soil erosion and protect fragile crops because of its dense foliage [2]. It is cultivated primarily for the economic value of its nuts, the production of which was estimated to be 1,225,935 tons in Côte d'Ivoire in 2023 [3]. Despite its richness in nutritive compounds, the cashew apple, which represents 9 to 10 times the weight of nuts, has not been sufficiently exploited. The most common way to add value to cashew apples is to process them into juices. Brazil and India are the two countries that have developed a wide range of cashew-based products that are deeply rooted in the dietary habits of their populations.

In Africa, there is a widespread perception that cashew apples combined with milk can lead to fatal food poisoning [4]. This perception hold back the development of cashew apples, despite an exceptional rise in production. Several studies have shown that cashew apples are a rich source of vitamins, polyphenols, sugars, proteins, minerals, and organic acids [5], [6]. However, once detached from the cashew tree, apples degrade rapidly. Almost all of this degradation occurs during the first week after the cashew tree falls, influencing the biochemical and nutritional potential of the cashew apple during fermentation. The cashew apple browns and degrades rapidly at room temperature because of the presence of oxides and secondary molecules. Furthermore, a high concentration of condensed tannins results in a bitter taste [7]. This poses a major problem in terms of processing and preservation. Consequently, they are often left behind at harvesting sites. Monitoring the evolution of these parameters during cashew apple fermentation could be important for transforming this fruit into a desirable product. Indeed, numerous studies have shown that apples could be good substrate for producing substances of interest through fermentation, such as alcohol, wine, and vinegar [8]. With this in mind, this study aimed to evaluate the nutritional and phytochemical properties of cashew apples produced in northern Côte d'Ivoire, with a view to adding value to the production of desirable products.

2. Materials and Methods

2.1. Biological Materials

Red and yellow cashew apples were harvested in March 2024 from three orchards in Korhogo department (Côte d'Ivoire) in Tioro, Morovine, and Waraniene.

2.2. Cashew Apples Processing for Fermentation

Once harvested, apples were taken to laboratory and washed with distilled water. They were then ground using a blender (SMART model NO.: STPE1110), and grinds were transferred to a 1-liter Erlenmeyer stoppered with carded cotton for fermentation. Fermentation was carried out at room temperature for six days, with sample taken every two days for various analyses.

2.3. Determination of Physicochemical Parameters

Physicochemical parameters, such as pH, titratable acidity, dry matter content, and alcohol content, were also determined using the AOAC [9] method.

The pH was determined by dipping the previously calibrated pH meter electrode into 30 mL of fermented sample.

Titratable acidity was quantified by titrating 5 mL of fermented sample with 0.1 N sodium hydroxide solution in the presence of phenolphthalein. Titratable acidity was calculated using the following formula:

$$TA\,(\%) = N_{NaOH} \times V_{NaOH} \times 100/V_{sample}$$

where
TA – titratable acidity
N_{NaOH} – normality of NaOH
V_{NaOH} – volume of NaOH
V_{sample} – volume of sample

Alcohol consumption was measured using a digital Breathalyzer. The alcohol meter was immersed in 5 mL of the sample and the displayed value was read. Dry matter was determined by steaming 10 g of sample at 105°C until a constant weight was obtained. The following expression was used to calculate the dry matter content:

$$MS = (W_1 - W_2) \times 100/W_1$$

where
MS – dry matter content (%)
W_1 – initial sample weight (g)
W_2 – sample weight after drying

2.4. Determination of Nutrient Parameters

The dry extract content of cashew apple during fermentation was determined using the method described by Soyer *et al*. method [10]. A drop of the fermented sample was placed on the prism of a refractometer and read visually.

The total sugar content of apple was determined using the phenol-sulfuric colorimetric method [11]. One milliliter of fermented sample was successively added to one millilitre of 5% phenol and five millilitres of concentrated sulfuric acid. After cooling, optical density was measured at 490 nm against a blank. Total sugars were determined using a standard curve established with a 1 mg/mL glucose solution.

Reducing sugars were determined using the DNS colorimetric method [12]. To this end, 1 mL of DNS reagent was added to tubes containing 1 mL of fermented sample. The mixture was heated in a boiling water bath for five minutes. After cooling to room temperature, 8 mL of distilled water was added and the optical density was read at 540 nm against a blank. The amount of reducing sugars was determined using a standard curve established with 1 mg/mL glucose solution.

Total protein was extracted and assayed using the Lowry method [13]. Extraction was performed using 10% and 5% trichloroacetic acid (TCA) and 96% alcohol [14]. The extract (200 µL) was added to 850 µL of distilled water, 100 µL of Gornal reagent, and 500 µL of Folin Ciocalteu reagent (10%). After a rest period, the optical density was measured at 650 nm against a blank. The total protein content was determined using a standard curve established with 5 mg/mL bovine serum albumin solution.

2.5. Determination of Total Polyphenols and Tannins

For total polyphenols analysis of cashew apples during fermentation, the colorimetric method using the Folin-Ciocalteu reagent was employed to determine the total polyphenol content [15]. Thirty microliters of fermented sample was added to 1 mL of Folin-Ciocalteu reagent, followed by 0.8 mL of 7.5% sodium carbonate (Na_2CO_3). The mixture was incubated in the dark at room temperature for 30 min. The absorbance was measured at 765 nm against a blank sample. The polyphenol content was determined using a standard curve created with 1 mg/mL gallic acid solution.

Tannin content was determined according to the method described by Kouame *et al*. [16]. One milliliter of fermented sample was added to five milliliters of 0.001% (w/v) sulfuric vanillin reagent. After resting in the dark for 30 min, the optical density was measured at 500 nm against a blank. The tannin content was determined using a standard curve created using 1 mg/mL tannic acid solution as the standard.

2.6. *Statistical Analysis*

Trials with cashew apple samples during fermentation were carried out in triplicate, and the results are expressed as the mean ± standard deviation. Analysis of variance (ANOVA) was performed using SPSS version 2013. Duncan's test at a 95% confidence level was used to determine significant differences between the means, including principal component analysis.

3. Results

3.1. *Physicochemical Parameters*

Table I shows the evolution of the physicochemical parameters of the samples from different locations during fermentation. It can be seen that pH, titratable acidity and alcohol content varied significantly ($p > 0.05$) with the duration of fermentation. The pH of yellow apples from Tioro varied from 5.01 to 3.75, while that of yellow apples from Moroviné and Waraniéné varied from 5.06 to 3.54 and 5.15 to 3.85, respectively. For red apples, pH of red apples from Tioro decreased from 5.06 to 3.67, from Moroviné from 4.99 to 3.49 and from Waraniené from 5.12 to 3.90. The results showed that, at harvest, yellow varieties had slightly higher pH values than red varieties.

Titratable acidity and alcohol content of yellow and red apples increased significantly with the number of sampling days ($p > 0.05$). Must from yellow Tioro apples showed values ranging from 0.048 g to 0.371 g malic acid/100 g and 2.27% to 5.76% alcohol during fermentation. Those from Morovine showed values between 0.042 g and 0.279 g malic acid/100 g and between 2.2% and 5.7% alcohol, while those from Waraniene varied between 0.042 and 0.328 g malic acid/100 g and between 1.97% and 5.86% alcohol. For red apples, the acidity and alcohol content of Tioro musts varied from 0.048 to 0.377 g malic acid/100 g and 2.1% to 5.77% alcohol, respectively. The acidity and alcohol content of Morovine musts increased from 0.045 g to 0.310 g malic acid/100 g and from 2.5% to 5.87% alcohol, respectively, while those of waraniene musts increased from 0.048 g to 0.334 g malic acid/100 g and from 2.03% to 5.87% alcohol, respectively. Overall, the red varieties showed slightly higher acidity than the yellow varieties in the different samples.

Second, analyses showed that during fermentation, the dry matter content of cashew apples decreased significantly ($p > 0.05$) on different sampling days for both yellow and red apples. Dry matter content of yellow apples fell from 14.87% to 7.7% in Tioro, 15.60% to 7.96% in Morovine, and 13.97% to 6.03% in Waraniene. For red apples, dry matter content varied from 15.22% to 6.67% for Tioro, 15.28% to 7.66% for Morovine, and 13.21% to 6.12% for Waraniene. Table I shows that, in general, red apples have a higher dry matter content than yellow apples, and that the Morovine site has a lower dry matter content than the other two sites.

TABLE I: Physicochemical Parameters of Fermented Cashew Apple Grinds

Localities	Varieties of Cashew apple	Days	pH	Titratable acidity (g malic acid /100 g)	Alcohol volume (%)	Dry matter (%)
Tioro	Yellow	0	5.06 ± 0.01^a	0.048 ± 0.01^d	2.27 ± 0.05^d	14.87 ± 0.86^a
		2	4.48 ± 0.02^b	0.073 ± 0.00^c	4.06 ± 0.11^c	9.76 ± 0.99^b
		4	3.97 ± 0.01^c	0.304 ± 0.04^b	513 ± 0.11^b	8.65 ± 0.07^c
		6	3.75 ± 0.01^d	0.371 ± 0.02^a	5.76 ± 0.05^a	7.70 ± 0.67^d
	Red	0	5.01 ± 0.05^a	0.048 ± 0.00^d	2.1 ± 0.17^d	15.22 ± 0.17^a
		2	4.41 ± 0.01^b	0.079 ± 0.01^c	3.96 ± 0.05^c	9.04 ± 0.93^b
		4	3.91 ± 0.05^c	0.334 ± 0.01^b	5.37 ± 0.05^b	8.66 ± 0.23^c
		6	3.67 ± 0.02^d	0.377 ± 0.01^a	5.77 ± 0.05^a	6.66 ± 0.35^d
Moroviné	Yellow	0	5.06 ± 0.11^a	0.042 ± 0.01^d	2.2 ± 0.00^d	15.60 ± 0.88^a
		2	4.53 ± 0.05^b	0.109 ± 0.00^c	3.97 ± 0.05^c	10.42 ± 0.29^b
		4	3.80 ± 0.02^c	0.255 ± 0.01^b	5.27 ± 0.06^b	8.48 ± 0.47^c
		6	3.54 ± 0.01^d	0.279 ± 0.01^a	5.7 ± 0.01^a	7.96 ± 0.51^d
	Red	0	4.99 ± 0.01^a	0.045 ± 0.01^d	2.5 ± 0.05^d	15.28 ± 0.72^a
		2	4.23 ± 0.02^b	0.115 ± 0.01^c	4.1 ± 0.17^c	9.34 ± 0.01^b
		4	3.68 ± 0.01^c	0.267 ± 0.01^b	5.2 ± 0.01^b	8.54 ± 0.47^c
		6	3.49 ± 0.01^d	0.310 ± 0.01^a	5.87 ± 0.05^a	7.66 ± 0.30^d
Waranienne	Yellow	0	5.15 ± 0.05^a	0.042 ± 0.01^d	1.97 ± 0.05^d	13.97 ± 0.06^a
		2	4.70 ± 0.01^b	0.109 ± 0.00^c	3.93 ± 0.05^c	9.30 ± 0.67^b
		4	4.20 ± 0.01^c	0.267 ± 0.02^b	5.23 ± 0.05^b	7.68 ± 0.94^c
		6	3.85 ± 0.01^d	0.328 ± 0.01^a	5.86 ± 0.05^a	6.03 ± 0.05^d
	Red	0	5.12 ± 0.02^a	0.048 ± 0.00^d	2.03 ± 0.05^d	13.21 ± 0.58^a
		2	4.70 ± 0.01^b	0.127 ± 0.01^c	4.07 ± 0.11^c	9.02 ± 0.56^b
		4	4.30 ± 0.01^c	0.273 ± 0.01^b	5.16 ± 0.05^b	7.73 ± 0.12^c
		6	3.90 ± 0.01^d	0.334 ± 0.02^a	5.87 ± 0.05^a	6.12 ± 0.77^d

Note: The statistical differences between these mean values at 95% confidence level are indicated in the same column by different letters a, b, c, and d in superscript.

TABLE II: Nutritional Parameters of Fermenting Cashew Apple Grinds

Localities	Varieties of cashew apple	Days	Dry Extract Refracto-metry (°Brix)	Reducing sugar (g/100 g)	Total sugar (g/100 g)	Protein (g/100 g)
Tioro	Yellow	0	11.93 ± 0.00[a]	17.33 ± 1.15[a]	26.28 ± 1.09[a]	26.46 ± 1.13[b]
		2	9.50 ± 0.00[b]	6.26 ± 0.00[b]	9.59 ± 0.16[b]	23.23 ± 1.1[c]
		4	5.97 ± 0.00[c]	0.84 ± 0.00[c]	6.47 ± 0.07[c]	14.84 ± 0.31[d]
		6	4.30 ± 0.00[d]	0.56 ± 0.01[d]	3.86 ± 0.00[d]	27.30 ± 0.44[a]
	Red	0	11.50 ± 0.00[a]	16.67 ± 1.15[a]	26.33 ± 1.82[a]	31.84 ± 1.69[a]
		2	9.67 ± 0.00[b]	5.62 ± 0.34[b]	10.10 ± 0.09[b]	26.21 ± 0.44[b]
		4	6.30 ± 0.00[c]	0.79 ± 0.01[c]	6.70 ± 0.12[c]	14.09 ± 0.94[d]
		6	4.23 ± 0.00[d]	0.68 ± 0.03[d]	4.09 ± 0.04[d]	23.62 ± 0.88[c]
Morovine	Yellow	0	12.00 ± 0.00[a]	17.33 ± 1.15[a]	29.09 ± 0.78[a]	24.47 ± 0.81[a]
		2	10.0 ± 0.00[b]	5.76 ± 0.2[b]	10.34 ± 0.43[b]	21.91 ± 0.66[b]
		4	6.53 ± 0.00[c]	1.02 ± 0.00[c]	6.00 ± 0.05[c]	15.22 ± 0.57[d]
		6	5.27 ± 0.00[d]	0.65 ± 0.00[d]	3.46 ± 0.05[d]	20.32 ± 0.1[c]
	Red	0	12.00 ± 0.00[a]	16.33 ± 1.80[a]	29.54 ± 0.78[a]	28.72 ± 0.75[a]
		2	9.00 ± 0.00[b]	5.76 ± 0.00[b]	10.50 ± 0.29[b]	25.87 ± 0.66[b]
		4	6.40 ± 0.00[c]	0.93 ± 0.02[c]	6.42 ± 0.11[c]	15.88 ± 0.26[d]
		6	5.13 ± 0.00[d]	0.70 ± 0.03[d]	3.68 ± 0.03[d]	24.47 ± 0.69[c]
Waraniene	Yellow	0	12.00 ± 0.00[a]	17 ± 1.73[a]	25.9 ± 0.60[a]	21.55 ± 0.12[a]
		2	8.33 ± 0.00[b]	5.16 ± 0.3[b]	9.60 ± 0.30[b]	17.28 ± 1.10[c]
		4	5.17 ± 0.00[c]	1.36 ± 0.00[c]	5.10 ± 0.12[c]	11.25 ± 0.06[d]
		6	4.13 ± 0.00[d]	0.51 ± 0.01[d]	2.88 ± 0.03[d]	18.78 ± 0.84[b]
	Red	0	11.67 ± 0.00[a]	16.03 ± 1.81[a]	26.40 ± 1.81[a]	23.62 ± 0.88[a]
		2	8.47 ± 0.00[b]	6.10 ± 0.04[b]	10.06 ± 0.37[b]	17.94 ± 1.32[c]
		4	5.50 ± 0.00[c]	0.88 ± 0.01[c]	6.56 ± 0.11[c]	14.46 ± 0.11[d]
		6	3.77 ± 0.00[d]	0.71 ± 0.00[d]	3.98 ± 0.19[d]	20.32 ± 0.10[b]

Note: The statistical differences between these mean values at the 95% confidence level are indicated on same column by different letters a, b, c and d in superscript.

3.2. *Nutrient Parameters*

Table II shows evolution of nutrient parameters of cashew apples extracts during fermentation. It can be seen that during fermentation, refractometric dry extract content of yellow apples from Tioro decreased sharply from 11.93°Brix to 4.3°Brix, while that of yellow apples from Tioro de Morovine and Waraniene decreased from 12.00°Brix to 5.27°Brix and from 12.00°Brix to 4.33°Brix, respectively. For red apples from Tioro, refractometric dry extract content decreased from 11.50°Brix to 4.23°Brix, that from Morovine varied from 12.00°Brix to 5.13°Brix and that from Waraniene fell from 12.67°Brix to 5.77°Brix. Table II shows that red apples had lower refractometric dry extract contents than yellow apples, with a peak recorded for apples from the Morovine site. Total and reducing sugar contents varied significantly ($p > 0.05$) from 29.54 g/100 g to 2.75 g/100 g and from 17.33 g/100 g to 0.51 g/100 g, respectively, on average from the first to sixth day of fermentation. Protein content, shown in Table II, decreased from 26.11 g/100 g to 14.29 g/100 g on average from first to fourth day of fermentation. This was followed by a general increase in protein content from fourth to sixth day, with values increasing from 14.29 g/100 g to 22.47 g/100 g on average.

3.3. *Polyphenols and Tannins Contents*

Fig. 1 shows the total polyphenols content. Results generally show a sharp decrease in polyphenol content from day one to day four of fermentation, with mean values ranging from 652.66 mgEAG/100 g to 350.23 mgEAG/100 g for red apple must and from 538.76 mgEAG/100 g to 305.14mgEAG/100 g for yellow apple must. While a slight increase was observed on sixth day of fermentation, with an average value of 387.73 mgEAG/100 g for red apple musts and 357.93 mgEAG/100 g for yellow apple musts, a decrease was observed from the sixth to tenth day of fermentation, with an average value of 305.14 mgEAG/100 g for yellow apple musts and 283.33 mgEAG/100 g for red apple musts.

Tannin contents are shown in Fig. 2., analysis of results shows a significant decrease in the tannin content of all cashew apple samples during fermentation, from 15.95 mgEAT/100 g to 3.57 mgEAT/100 g for red apples and from 15.15 mgEAT/100 g to 3.12 mgEAT/100 g for yellow apples. Red apples had a slightly higher tannin content than yellow apples.

3.4. *Correlation between Various Parameters*

The Pearson correlation test revealed a strong correlation between the various parameters examined during fermentation and the different cashew varieties ($P < 0.05$). This test confirmed that significant differences between the parameters were observable at the 1% level. The correlation circle analysis in Fig. 3a shows the distribution of red and yellow cashew apples according to sampling days. Fig. 3b shows the distribution of physicochemical, nutritional and phytochemical parameters according to the same days. These parameters were oriented and correlated by PJ0, PR0, PR2, PJ2, PJ4, PR4, PJ6 and PR6. Fig. 3a and b show that cashew apples retained their nutritional properties up to the second day of fermentation.

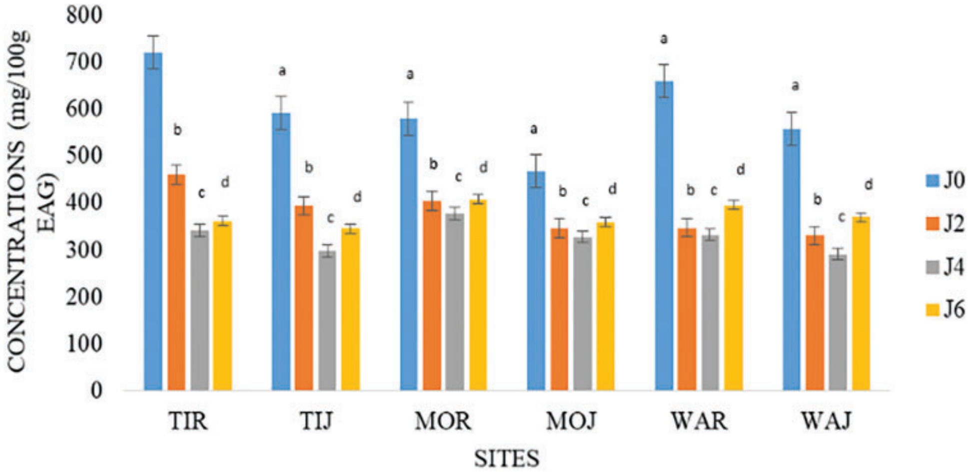


Fig. 1. Concentration of total polyphenols in fermenting cashew apple grinds. Note: Values in diagram are averages of three trials analysis of cashew apples samples during fermentation. Statistical differences between average values at 95% confidence level are indicated on same strip by different letters a, b, c, and d. Ti: Tioro; Mo: Morovine; Wa: Waraniene; J: yellow cashew apple; R: red cashew apple; J0: first sample; J2: second day of sampling; J4: fourth day of sampling; J6: sixth day of sampling.

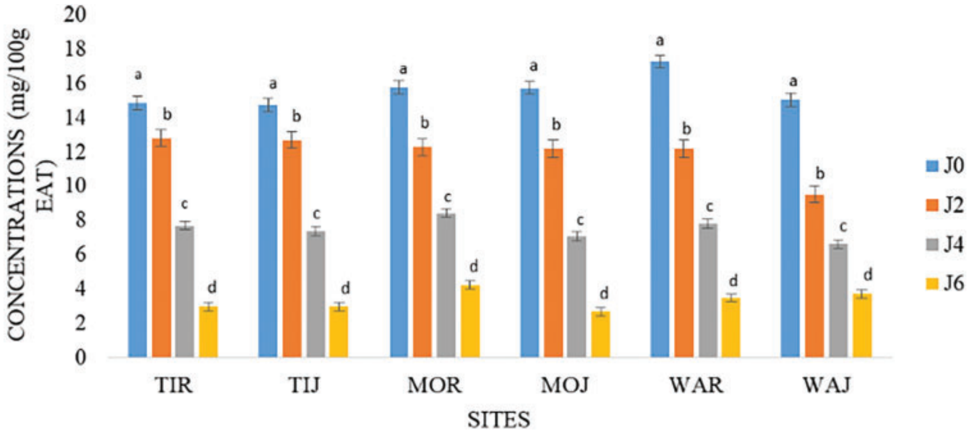


Fig. 2. Concentration of condensed tannins in fermenting cashew apple grinds. Note: Values in diagram are averages of three trials of analysis of cashew apples samples during fermentation. Statistical differences between average values at 95% confidence level are indicated on same strip by different letters a, b, c and d. Ti: Tioro; Mo: Morovine; Wa: Waraniene; J: Yellow cashew apple; R: Red cashew apple; J0: First sampling; J2: Second sampling day; J4: Fourth sampling day; J6: Sixth sampling day.

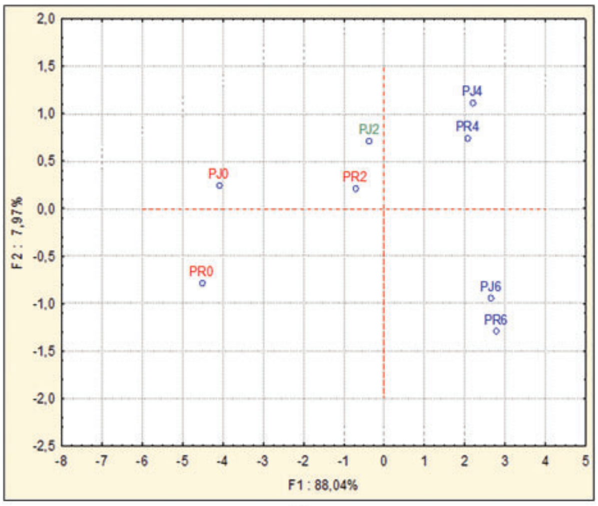
However, after two days, the cashew apples lost their nutritional properties. This loss of nutritional properties favors the production of natural substances of interest, such as organic acids and alcohol, beyond the fourth day of fermentation. At this stage, cashew apples have no nutritional value.

4. Discussion

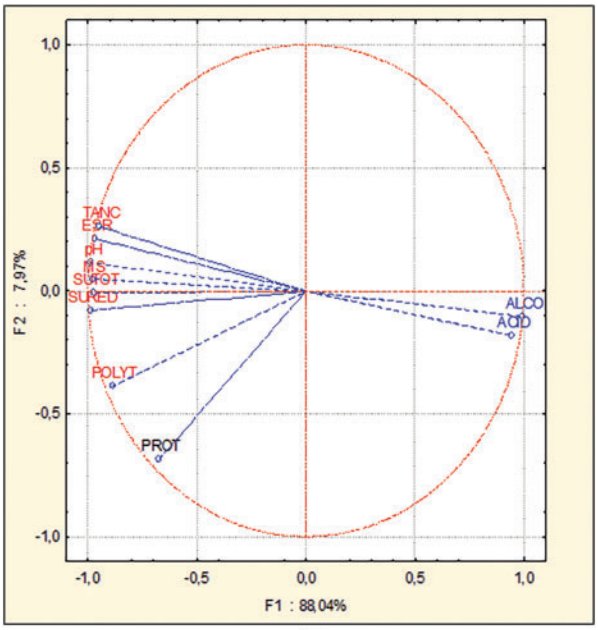
4.1. *Physicochemical Parameters*

Monitoring of fermented cashew apples showed that our recorded pH results were in line with those of Gbohaida *et al*. [17] and Gbohaida *et al*. [18]. They were obtained in cashew apple musts enriched and not enriched with urea, with values ranging from 4.5 to 4 and 4.5 to 3.8, respectively. Red apple musts showed much higher lactic acid and alcohol yields than yellow apple musts did. The drop in pH reflects the increasingly acidic nature of cashew apple musts, which may be due to the release of organic acids into the environment. This could slow down the activity of pathogenic bacteria and yeasts in apple musts, thus helping retain the compounds of interest. The increase in acidity could be due to the production of alcohol and/or acidic compounds by yeast and/or bacteria during fermentation [19]. The acidity of apples during fermentation leads to the conversion of sugars into organic acids, in particular lactic acid, tartaric acid, citric acid, ascorbic acid and amino acids, while acetic fermentation converts alcohol into acetic acid. Cashew apples initially contain a high concentration of malic acid, which is responsible for their acidification [7]. Lactic acid, citric acid and ascorbic acid are useful in food biotechnology as effective bioconservatives of perishable foods. Alcohol is also useful in the health sector and in biochemical laboratories but is less widely used in the production of liqueurs for consumption.

The results obtained before apple fermentation were in agreement with those of Charahabil *et al*. [20], who obtained values of 14.17% and 12.48%, respectively, for red and yellow apples at harvest. The low value of dry matter recorded on the sixth day could be due to the use of insoluble fiber by bacteria for energy production in the absence of macromolecules [21]. The use of insoluble fiber by bacteria during fermentation could optimize the production of interesting natural compounds in cashew apples.



(a)



(b)

Fig. 3. Principal component analysis of the physicochemical, nutrient and phytochemical parameters of the apple during fermentation: (a) Distribution of red and yellow cashew apples according to sampling days, (b) Distribution of physicochemical, nutritional and phytochemical parameters according to same days. Note: PJ: yellow cashew apple; PR: red cashew apple; 0: first day of fermentation; 2: second day of fermentation; 4: fourth day of fermentation; 6: sixth day of fermentation; pH: hydrogen potential; SU.TOT: total sugars; SU: RED: reducing sugars; MS: dry matter; ESR: refractometric dry extract; TAN: C.: condensed tannins; POLY.T.: total polyphenols; PROT.: proteins; ALCO.: alcohol; ACD.: titratable acidity.

4.2. Nutrient Parameters

Work of Gbohaida *et al*. [18] found same variations, ranging from 13°Brix to 3.67°Brix during controlled fermentation using *Saccharomyces cerevisiae* and *S. carlbergensis* for bioethanol production from cashew apple juice. Refractometric dry extract is key parameter used to control soluble sugars during alcoholic or lactic fermentation.

Our work on sugar content is in agreement with that of Kouassi *et al*. [22], who obtained a total sugar content ranging from 34.67 g/100 g to 7.86 g/100 g after controlled fermentation of cashew apples using fungus *Aspergillus niger*. Analyses showed that during fermentation, approximately 80% of the total sugars and 93% of the reducing sugars in cashew apples were consumed within two days. On average, only 10.03 g/100 g of total sugars and 5.77 g/100 g of reducing sugars remain after two days of fermentation. Four days of fermentation are sufficient to consume about 95% of total sugars and 99% of reducing sugars, corresponding to amounts of 6.25 g/100 g and 0.97 g/100 g, respectively. Bisson's work [23] on grape juice showed that during controlled fermentation, *Saccharomyces cerevisieae* consumed approximately 99.99% glucose in four days (96 h). The evolution of sugars during the natural fermentation of cashew apples provides information on the presence of alcohol and organic acids in fermented musts, which are natural substances of interest. Sugar contents are significantly higher than those obtained by Landing *et al*. [24] and Soro [25], who obtained contents of 4.9 g/kg to 5.6 g/kg and 7.8 g/kg to 9.9 g/kg, respectively, in raw cashew apple juice. Exposure of cashew apple samples to air during fermentation induces protein degradation by microorganisms [26], [27]. This increase in protein content could be due to the secretion of enzymes that break down insoluble fibers in fermented musts, allowing the appearance of interesting natural substances.

4.3. Polyphenols and Tannins Contents

Work on phenolic components follows same variations as Jean [28], who obtained total polyphenol contents ranging from 41.34 mgEAG/g to 28.33 mgEAG/g dry matter during first six days of cocoa pod fermentation (Guiana variety). The enzymes produced by microorganisms responsible for the degradation of polyphenols during fermentation are glycosidase and polyphenol oxidase [29]. Polyphenol oxidases oxidize phenolic compounds to o-quinones, which are more reactive and complex with amino acids, proteins, and other flavonoids [30]. This could explain the slight increase in protein and polyphenol content observed in cashew apple crushes on the sixth day of fermentation. Enzymes from these microorganisms can be used to remove astringency from cashew-apple juice. Variation in tannin content in the present study follows the same pattern as that of Jean [28], who fermented cocoa pods for six days at room temperature. They recorded DPPH and ORAC values ranging from 684.6 µmol to 449.6 µmolE.Trolox/g and from 1097.0 µmol to 848.4 µmolE.Trolox/g dry matter, respectively. Enzymes responsible for lowering the tannin content during apple fermentation can be extracted and used to remove the astringency of cashew apple juice. This could be a way to add value to raw cashew apple juice intended for adolescent or infant consumption.

5. Conclusion

The results of these investigations allow to conclude that cashew apples could be a suitable substrate for fermentation in order to produce chemicals of interest, such as organic acids and alcohols. In addition, fermentation could be reduce astringency of cashew apples. Future studies will involve isolating and identifying microorganisms responsible for the natural fermentation of cashew apples.

Conflict of Interest

The authors declare that they do not have any conflict of interest.

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