



Impact of Harvest Stage on Some Physicochemical and Biochemical Parameters of Ripe Cashew Apples (*Anacardium occidentale* L.) Grown in Côte d'Ivoire

Ettien Léon Hamian, Kakou Kouassi Enerst, Kadji Beugré Romuald Léonce, Soro Doudjo, Abo Kouabenan, Elleingand Fattoh Eric

► To cite this version:

Ettien Léon Hamian, Kakou Kouassi Enerst, Kadji Beugré Romuald Léonce, Soro Doudjo, Abo Kouabenan, et al.. Impact of Harvest Stage on Some Physicochemical and Biochemical Parameters of Ripe Cashew Apples (*Anacardium occidentale* L.) Grown in Côte d'Ivoire. *European Journal of Nutrition and Food Safety*, 2025, 17 (3), pp.299-311. <10.9734/ejnfs/2025/v17i31668>. <hal-04987383>

HAL Id: hal-04987383

<https://hal.science/hal-04987383v1>

Submitted on 12 Mar 2025

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons CC BY 4.0 - Attribution - International License



Impact of Harvest Stage on Some Physicochemical and Biochemical Parameters of Ripe Cashew Apples (*Anacardium occidentale* L.) Grown in Côte d'Ivoire

**HAMIAN Ettien Léon ^{a,b*}, KAKOU Kouassi Enerst ^a,
KADJI Beugré Romuald Léonce ^a, SORO Doudjo ^a,
ABO Kouabenan ^b and ELLEINGAND Fattoh Eric ^a**

^a Nutrition and Food Technology Laboratory, Institut National Polytechnique Félix Houphouët-Boigny (INP-HB), BP 1093 Yamoussoukro, Côte d'Ivoire.

^b Laboratory of Phytopathology and Plant Biology, Institut National Polytechnique Félix Houphouët-Boigny (INP-HB), BP 1093 Yamoussoukro, Côte d'Ivoire.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: <https://doi.org/10.9734/ejnf/2025/v17i31668>

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://pr.sdiarticle5.com/review-history/132048>

Original Research Article

Received: 01/01/2025

Accepted: 03/03/2025

Published: 07/03/2025

ABSTRACT

Aims: Harvest stage of mature cashew apples is of the significant factors that determines their physicochemical and biochemical properties, those properties have an impact on the quality, the processing potential, and the overall valorization of cashew apples.

*Corresponding author: Email: ettien.hamian21@inphb.ci;

Cite as: Léon, HAMIAN Ettien, KAKOU Kouassi Enerst, KADJI Beugré Romuald Léonce, SORO Doudjo, ABO Kouabenan, and ELLEINGAND Fattoh Eric. 2025. "Impact of Harvest Stage on Some Physicochemical and Biochemical Parameters of Ripe Cashew Apples (*Anacardium Occidentale* L.) Grown in Côte d'Ivoire". *European Journal of Nutrition & Food Safety* 17 (3):299-311. <https://doi.org/10.9734/ejnf/2025/v17i31668>.

Objectives: This study aims at identifying an optimal harvest stage for a rational valorization of the cashew apple.

Materials and Methods: In terms of methodological approach, 18 samples of 1 to 2 kg cashew apples (red and yellow) at ripening stages 1, 2 and 3 were collected from Yamoussoukro, Katiola and Korhogo. A combined analysis of physicochemical and biochemical parameters was used to determine the contents of pH, titratable acidity, refractometric dry extract, polyphenols, flavonoids, total tannins, reducing and total sugars in the extracted juices.

Results: The red and yellow stage 2 juices presented the best PH (3.7 to 5; 3.8 to 3.9) the highest levels of dry extract refractometry (9.6 to 11.34; 9.30 to 10.94) as well as the dry matter (12.464 to 13.907; 12.361 to 14) content in the three localities. This same observation was revealed with total sugars 130.66 to 152.23 g/L and 94.01 to 165.24 g/L respectively for cashew apples from the three localities. Furthermore, the contents of flavonoids (986.66 mg/L; 1933.33 mg/L), polyphenols (2156.66 mg/L; 1933.33 mg/L) for the locality of Korhogo, polyphenols (1546.66 mg/L; 1633.33 mg/L) for the locality of Katiola and flavonoids (1800 mg/L; 2280 mg/L) for the locality of Yamoussoukro successively for red and yellow apples.

Conclusion: In view of the results obtained, the cashew apples of stage 2 give off the best physicochemical and biochemical profile. The choice of harvest stage 2 for ripe cashew apples therefore appears to be a key factor in optimising their physico-chemical and biochemical characteristics. This could directly influence their quality, nutritional value and economic potential.

Keywords: Cashew apple; physicochemical; biochemical; Côte d'Ivoire.

1. INTRODUCTION

Cashew tree is a tropical crop native to Brazil, belonging to the Angiospermae Phylum and the Dicotyledons Class (Abalokoka et al., 2018). For the last decade, Ivory Coast is far ahead cashew apple leader in the world. From 1.028 million tonnes in 2022, cashew apple production in ivory coast increased to 1.225 million tonnes in 2023 almost 40% of the world supply. In addition, the coveted cashew nut is attached to the fleshy part of the fruit called the cashew apple (Dedehou et al., 2015). This represents 9 to 10 times the mass of the nut and is mainly rich in sugars, minerals, amino acids, carotenoids, organic acids, dietary fiber but also in antioxidant compounds (Akyereko et al., 2023b; Emelike & Obinna-Echem, 2020; Ghag et al., 2024). It is recognized as a real source of energy, contains vitamins (thiamine, riboflavin and niacin) (Yisa, 2020) but it remains perishable because of the large quantity of water it contains. Like any fruit, the quality of the cashew apple is linked to pedoclimatic factors, the genotype of the cashew tree, the time of harvest, the rate of maturation, the positioning of the apple on the cashew tree, the sunshine (Shi et al., 2023). Furthermore, the flavor and palatability of the cashew apple itself and derived products are highly dependent on the stage of maturity (Kumar et al., 2024; Ravi et al., 2020). Previous work has shown that the level of maturity has an impact on the biochemical compounds of several fruits as well as their derivatives (Zou et al., 2022). Moreover,

several studies on fruits have shown that premature or late harvesting would limit the value to the extent that Early harvested fruits contain fewer nutrients and late harvested fruits are degraded (Sharma et al., 2025). Faced with the challenges of increasing the quantity of processed cashew apples coupled with quality derivative products that meet nutritional standards, it is then essential to know the harvest period when all the nutrients are available in the cashew apple for its use in processing. It is in this context that this study is taking place, which aims to identify the optimal stage of harvesting with a view to rational valorization of the cashew apple.

2. MATERIALS AND METHODS

2.1 Sampling

The biological matrix of this work are cashew apples collected from village's fields in the localities of Yamoussoukro, Katiola, Korhogo from February to March 2023 and 2024. During this study, two types of apples were used based on the color of the peel: red apples and yellow apples made up of ripe apples harvested directly from the cashew tree (stage 1), those fallen from the tree and then picked up the meday (stage 2), ripe apples dropped after two days (stage 3). A total of 18 samples were collected, weighing 1 to 2 kg. Each fruit was separated from its nut and then packaged in thermoses with added dry ice and then transported to the school factory for

juice extraction followed by various laboratory analyses.

3. METHODS

3.1 Extraction of Apple Juice

At the school factory, cashew apples were soaked in 4% chlorinated water for 15 min to remove sand, dead leaves and eliminate microorganisms present. They were rinsed three times with tap water. 1 to 2 kg of rinsed cashew apples were placed in the bags and then pressed using a mechanical press at 150 bars. The different types of juice were subjected to physicochemical and biochemical analyses.

3.2 Measuring the pH of Juices

pH of juices from the different samples of cashew apples according to the method described by AOAC (1995). To do this, the pH meter probe was introduced into 50 mL of fresh apple juice and the value is displayed on the screen after a few seconds

3.3 Determination of Titratable Acidity

Titrate acidity expressed in percentage was determined by titration with 0.1 N sodium hydroxide (NaOH) solution. 10 mL of each juice was taken and placed in an Erlenmeyer flask. Each test sample was previously calibrated with two drops of phenolphthalein and then titrated with NaOH solution until a pink color (Cunnith, 1995).

3.4 Determination of Dry Extract Refractometry

Dry extract refractometry known as Brix Degree was determined using an ATAGO type refractometer according to the method described by the AOAC 1995 method. A few drops of extracted cashew juice were placed on the glass of the refractometer and the reading was made by light at the eyepiece of the device. It is expressed in Brix degree (°Brix) (Cunnith, 1995).

3.5 Determination of Humidity and Dry Matter

Dry matter content was determined by oven method, based on the dehydration of a quantity of product until a constant mass of the sample is obtained at 105°C (Kennith, 1990).

3.6 Determination of Total Polyphenols

Total polyphenol content of cashew apple juices was performed according to the method described by Wood et al., (2002) using Folin-Ciocalteu. 2.5 mL of diluted Folin-Ciocalteu (1/10) was added to 30 µL of juice. The mixture obtained was placed in the dark in a cabinet at room temperature for 2 min then 2 mL of sodium carbonate solution was added. The whole was incubated for 15 min in a sea bath at 50°C, then removed and cooled to room temperature. The absorbance was performed with a UV-visible spectrophotometer at 760 nm against a blank.

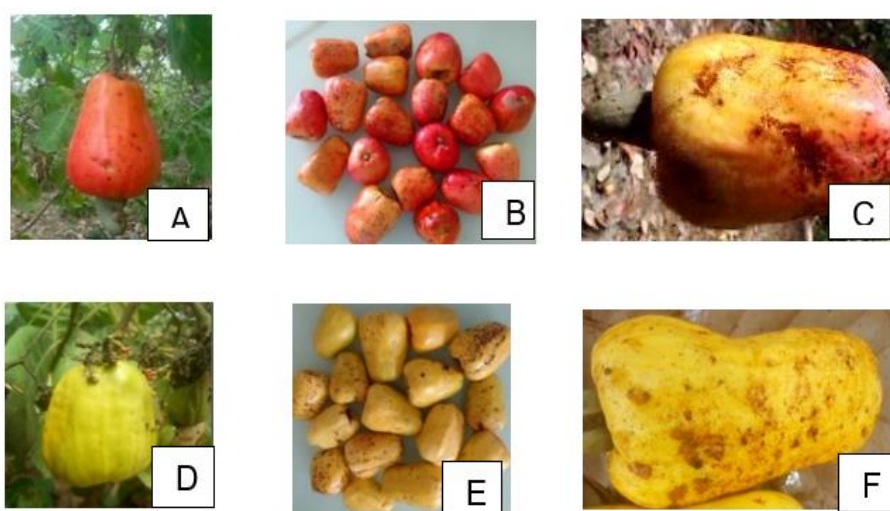


Fig. 1. Cashew apples at different stages

A: Red apple at stage 1 B: Red apple at stage 2 C: Red apple at stage 3, D: Yellow ripe apple at stage 1 E: Yellow apple at stage 2; F: Yellow apple at stage 3.

3.7 Dosage of Flavonoids

Flavonoid assay was performed according to the method described by Marinova et al., (2005). To do this, 0.75 mL of 5% sodium nitrite (NaNO_2) was added to 2.5 mL of cashew apple juice in a 25 mL graduated flask. The mixture was then supplemented with 0.75 mL of 10% (m/v) aluminum chloride (AlCl_3), then incubated for 6 min in the dark. 5 mL of 1 N sodium hydroxide solution was added and the volume was brought to the mark with distilled water. The mixture obtained was homogenized and left to stand for 15 min. The optical density (OD) was measured using a spectrophotometer at 510 nm against a blank.

3.8 Determination of Total Tannins

The determination of total tannins was carried out by the method described by Ci & Indira., (2016). 100 μL of cashew apple juice was added to a test tube containing demineralized water and 0.5 mL of Folin Ciocalteu reagent. To this mixture, 1 mL of CaCO_3 was added and then the volume was made up to 10 mL with distilled water. Subsequently, the solution was homogenized and left to react at room temperature for 30 min. The optical density is determined by spectrophotometer at 700 nm.

3.9 Dosage of Reducing Sugars

The determination of the concentration of reducing sugars in cashew apple juice was carried out by the colorimetric method of Bernfeld (1955) using 3,5-dinitro-salicylic acid (DNS). For this, 0.1 mL of cashew apple juice was introduced into a test tube and supplemented with 1 mL of DNS. The mixture was heated in a boiling water bath for 15 min. After 15 minutes, the solution was removed and 10 mL of demineralized water was added. The absorbance of each sample was measured at 540 nm against a blank using a spectrophotometer.

3.10 Determination of Total Sugars

The determination of total sugars was carried out according to the method of Dubois et al. (1956). 0.1 mL of apple juice was introduced into a test tube with the addition of 0.9 mL of distilled water. The mixture obtained was then treated with 1 mL of 5% (m/v) phenol and 5 mL of acid sulfuric. The optical density was determined by spectrophotometer at 490 nm against a blank consisting of glucose solution of concentration 1 g/L.

3.11 Statistical Analysis

The statistical processing of the data obtained consisted firstly in calculating the means and standard deviations of each parameter using Excel software version 2016. Secondly, the physicochemical and biochemical parameters of cashew apples at different stages were compared by a one-way analysis of variances (ANOVA) and the level of significant difference determined by the Duncan test. XLSAT software version 2016 was used to carry out these analyses.

4. RESULTS

4.1 Physicochemical Characteristics of Three Maturity Levels of Cashew Apple

The average values of pH, titratable acidity, Brix degree, dry matter and humidity rate of cashew apple juices (red and yellow) from the locality of Yamoussoukro, Katiola, Korhogo are recorded respectively in Tables 1, 2 and 3. The pH values of the different juices from Yamoussoukro are generally between 3.6 ± 0.01 to 4.0 ± 0.06 for red apples while the values for yellow cashew apple juices ranged from 3.6 ± 0.01 and 3.9 ± 0.07 . Maturity stages 1 and 3 (red) as well as stages 1 and 2 (yellow) do not show no statistical difference. At the locality of Katiola, the results indicated in Table 2 show acidic cashew apple juices (red and yellow) with a significant difference ($P < 0.05$) regardless of the level of maturity. The juice S2RKA reflects a less acidic pH compared to the pH of the samples S1RKA and S3RKA. In the locality of Korhogo, The pH of raw cashew apple juice from the highest red variety was 3.8 ± 0.02 while that of the yellow variety was 4.1 ± 0.06 (Table 3). Furthermore, the pH of juices from different maturity levels is statistically different ($P < 0.05$) depending on the variety.

Regarding the titratable acidity contents, the Yamoussoukro juices ranged from 0.45 to 0.52% for the red variety and 0.46 to 0.49% for the yellow variety. The juices of the yellow variety have no significant difference ($P < 0.05$) On the other hand, those of the red variety showed variability. However, the Katiola samples showed a significant difference regardless of the variety for titratable acidity. The low contents in this locality were obtained at stage 2 for the juices of the red variety and at stage 1 for the yellow variety. Approximately 0.65 and 0.51% were the

highest contents of titratable acidity of the respective red and yellow varieties from the locality of Korhogo. The samples from each variety showed a significant difference.

As for the dry extract refractometry, the values vary from 9.17 to 9.60° Brix and 9.04 to 9.30° Brix respectively for the juices of the red and yellow varieties from the locality of Yamoussoukro. However, the juice of stage 2 (9.60 ± 0.10° Brix) is sweeter than that of stage 1 (9.17 ± 0.02) and 3 (9.35 ± 0.05). However, a significant difference at the 5% threshold was noted for each variety. For yellow apples, stages 1 and 3 appear to have no statistical difference but reveal a difference at the 5% threshold with stage 2 apple juice (Table 1). The raw juices of red apples of stage 1 and 2 of Katiola do not show any difference. In addition, the two levels (1 and 2) show a difference with the maturity stage 3. Regarding the raw juices of yellow apple, the highest (9.85 ± 0.02° Brix) was obtained at maturity stage 2. In the locality of Korhogo, the dry extract refractometry of the raw juices (red) varied from 10.51 ± 0.58 to 11.34 ± 0.03° Brix with an intermediate value of 10.94 ± 0.01° Brix. As for the juices of the yellow variety, they all presented variable average values. A point of honor goes to the red cashew apple juice (S2RKO) which records the refractometry dry extract of 11.34 ± 0.03° Brix.

The analysis of juices from the Yamoussoukro locality in dry matter and humidity rates revealed variability between different samples of the same variety. The juices of the red variety varied from 8.92 to 13.74% and 86.26 to 91.26% respectively for dry matter and moisture content. As for the yellow variety from the same locality, low contents were recorded at stage 1 for dry matter and at stage 2 for moisture content. The Katiola samples show a significant difference regardless of the variety for titratable acidity. The low contents were obtained at stage 2 for the juices of the red variety and at stage 1 for the yellow variety. The juices of the red variety of stages 2 and 3 recorded the highest contents respectively for dry matter and moisture content of the locality of Katiola. In addition, the yellow variety of the said locality had contents that varied from 10.65 to 12.84% and from 88.49 to 89.49% successively for dry matter and moisture content. As for juices from stage 2 (12.46%) and stage 1 (90.63%), they had the highest contents of the red variety respectively for dry matter and

humidity rate of Korhogo. In the same locality the yellow variety revealed the low contents at stage 1 (9,361%) (dry matter) and at stage 2 (87,639%) (humidity level) with variability.

4.2 Biochemical Characteristics of Three Maturity Levels of Cashew Apple

Tables 4, 5 and 6 show the biochemical composition of cashew apple in the locality of Yamoussoukro, Katiola, Korhogo. In the locality of Yamoussoukro, the polyphenol contents of juice varied from 3813.33 ± 5.77 to 770 ± 45 mg/L with a high content for cashew apples of maturity 1. Statistical analysis indicates a significant difference between stages 1 and the other two stages of maturity (2, 3) which do not seem to have any difference. In addition, the juices of the yellow variety of Yamoussoukro, the highest content (4260 ± 120 mg/L) was obtained at stage 1 (Table 4). In terms of the concentration of raw red and yellow juices, the contents vary from 1276.66 ± 11.55 to 1546.66 ± 5.77 mg/L for red cashew apples versus 1270 ± 10 to 1633.33 ± 5.77 mg/L for yellow apples in Katiola. The levels 1766.66 ± 5.77; 2156.66 ± 11.55; 1813.33 ± 11.55 mg/L are respectively the raw juice samples of maturity level 1, 2 and 3 of red cashew apples from Korhogo. In addition, the juices (yellow) had concentrations of 1503.33 ± 5.77 (stage 1); 1933.33 ± 5.77 (stage 2); 1933.33 ± 5.77 (stage 3) in the same locality. These different concentrations are significantly different ($P < 0.05$) from one maturity level to another.

In the locality of Yamoussoukro, the highest flavonoid contents were recorded at stage 2 (1800 ± 100 and 2280 ± 10 mg/L) for cashew apples of red and yellow varieties respectively. The flavonoid content of the juices of the red cashew apples of Katiola analyzed ranged from 770 ± 10 to 1646.66 ± 35.12 mg/L with the highest content observed at stage 2. As for yellow apples, the highest concentration was revealed at stage 2. The different samples from the locality of Katiola show a significant difference ($P < 0.05$). In addition, the flavonoid concentrations of cashew apples from the locality of Korhogo indicate a significant difference between the juices according to the variety. Furthermore, the maturity levels 2 of cashew apples (red, yellow) had the highest contents in the locality of Korhogo. The juices of yellow apples revealed flavonoid concentrations between 966.66 ± 20.82 at 780 ± 10 mg/L.

Table 1. Physicochemical parameters of three maturity levels of cashew apples from Yamoussoukro

Codes	Ph	Titratable acidity (%)	Dry Extract Refractometry (°Brix)	Dry matter (%)	Humidity rate (%)
S2RYA	4.0 ± 0.06 ^a	0.45±0.2 ^b	9.60 ±0.10 ^a	13.74 ± 0.57 ^a	86.26±0.57 ^c
S1RYA	3.7 ± 0.01 ^b	0.52 ± 0.1 ^a	9.17 ± 0.02 ^c	8.92±0.85 ^c	91.08±0.85 ^a
S3RYA	3.6 ± 0.01 ^b	0.45± 0.05 ^b	9.35 ±0.05 ^b	11.32±0.54 ^b	88.68±0.54 ^b
S2JYA	3.9 ± 0.07 ^a	0.49 ±0.04 ^a	9.30 ±0.1 ^a	14.00±0.97 ^a	85.99±0.97 ^b
S1JYA	3.8 ± 0.01 ^a	0.46±0.20 ^a	9.04 ±0.03 ^b	10.27±0.20 ^b	89.73±0.20 ^a
S3JYA	3.6 ± 0.01 ^b	0.46± 0.01 ^a	9.19 ±0.01 ^{ab}	10.30±0.37 ^b	89.70±0.37 ^a

Values in the table are means ± standard deviation of three trials for each parameter. Values with identical superscript letters are not statistically different at $P > 0.05$. S1RYA: Stage 1 red Yamoussoukro; S2RYA: Stage 2 red Yamoussoukro; S3RYA: Stage 3 red Yamoussoukro; S1JYA: Stage 1 yellow Yamoussoukro; S2JYA: Stage 2 yellow Yamoussoukro; S3JYA: Stage 3 yellow Yamoussoukro

Table 2. Physicochemical parameters of three maturity levels of Katiola cashew apples

Codes	Ph	Titratable acidity (%)	Dry Extract Refractometry (°Brix)	Dry matter (%)	Humidity level (%)
S2RKA	3.7 ±0.01 ^a	0.44± 0.1 ^c	10.25 ±0.01 ^a	13,907±0.74 ^a	86.09±0.74 ^b
S1RKA	3.2 ±0.01 ^c	0.68± 0.01 ^a	10.19 ±0.01 ^a	12,453±0.49 ^{ab}	87,547±0.49 ^{ab}
S3RKA	3.6 ±0.02 ^b	0.53±0.01 ^b	9.93 ±0.03 ^b	10,990±0.74 ^b	89,010±0.74 ^a
S2JKA	3.9 ± 0.02 ^a	0.37±0.01 ^c	9.85 ± 0.02 ^a	12,849±0.26 ^a	87,151±0.26 ^b
S3JKA	3.3 ± 0.02 ^c	0.65± 0.05 ^a	9.74 ± 0.01 ^b	11,508±0.54 ^b	88,492±0.54 ^a
S1JKA	3.7 ±0.03 ^b	0.50± 0.05 ^b	9.61 ±0.03 ^c	10,652±0.61 ^b	89,348±0.61 ^a

Values in the table are means ± standard deviation of three trials for each parameter. Values with identical superscript letters are not statistically different at $P > 0.05$. S1RKA: Katiola Red Stage 1; S2RKA: Katiola Red Stage 2; S3RKA: Katiola Red Stage 3; S1JKA: Katiola Yellow Stage 1; S2JKA: Katiola Yellow Stage 2; S3JKA: Katiola Yellow Stage 3

Table 3. Physicochemical parameters of three maturity levels of Korhogo cashew apples

Codes	pH	Titratable acidity (%)	Dry Extract Refractometry (°Brix)	Dry matter (%)	Humidity rate (%)
S2RKO	3.8 ±0.02 ^a	0.57± 0.1 ^c	11.34 ±0.03 ^a	12,464±0.44 ^a	87,536±0.44 ^b
S3RKO	3.4 ± 0.03 ^c	0.61± 0.01 ^b	10.51 ±0.58 ^b	11,840±0.38 ^a	88,160±0.38 ^b
S1RKO	3.5 ±0.02 ^b	0.65± 0.14 ^a	10.94 ±0.01 ^{ab}	9,473±0.29 ^b	90,527±0.29 ^a
S2JKO	4.1 ± 0.06 ^a	0.44± 0.1 ^b	11.22 ± 0.02 ^a	12,361±0.41 ^a	87,639±0.41 ^b
S1JKO	3.2 ±0.021 ^b	0.51± 0.1 ^a	10.80 ±0.01 ^c	9,361±0.52 ^b	90,639±0.52 ^a
S3JKO	3.3 ± 0.02 ^b	0.50±0.01 ^a	10.97 ± 0.01 ^b	10,163±0.46 ^b	89,837± 0.46 ^a

Values in the table are means ± standard deviation of three trials for each parameter. Values with identical superscript letters are not statistically different at $P > 0.05$. S1RKO: Stage 1 red Korhogo; S2R KO: Stage 2 red Korhogo; S3R KO: Stage 3 red Korhogo; S1J KO: Stage 1 yellow Korhogo; S2JKO: Stage 2 yellow Korhogo; S3J KO: Stage 3 yellow Korhogo

Examination of the total tannin contents of the different juices (red and yellow) indicates statistically different results ($P < 0.05$). The highest content (3855.79 ± 25.71 mg/L) was recorded at ripening stage 2 (red) regardless of the apple phenotype in the locality of Yamoussoukro. As for the different tannin concentrations in Katiola juices, the contents of red cashew apple juices from stages 1, 2 and 3

were respectively 2613.86 ± 3.17; 1552.8 ± 2.2 and 787.03 ± 579.57 mg/L. In yellow cashew apple juice, the concentrations were 1061.133 ± 3.2525 mg/L (stage 1); 1704.96 ± 3.25 mg/L (stage 2) and 1471.96 ± 6.30 25 mg/L (stage 3). These mean values of the different concentrations are significantly different ($P < 0.05$). The total tannin contents of the different samples revealed a significant

difference at the threshold of 5% for red and yellow cashew apples from Korhogo. Total tannin concentrations 2460.63 ± 0.23 ; 2931.833 ± 4.35 mg/L are respectively the highest contents of the red and yellow juices of ripening stage 2.

The highest reducing sugar contents of cashew apple juices were 25.80 ± 0.129 g/L and 22.8 ± 0.1 g/L respectively for red and yellow colour varieties. The analysis also indicates a significant difference ($P < 0.05$) between samples of the same variety. This trend is also observed with total sugars from the same locality whose concentrations range from 102.56 ± 0.28 to 152.23 ± 0.43 g/L and 75.21 ± 0.28 to 165.24 ± 0.99 g/L respectively for red and yellow cashew apple juices. Stage 2 juices had high concentrations of 152.23 ± 0.43 g/L (red apple) and 165.24 ± 0.99 g/L (yellow apple) (Table 4).

At the locality of Katiola, the reducing sugar contents were statistically different ($P < 0.05$) between the different levels of maturity within each variety of cashew apple. The high contents were observed during stage 2 of ripening with $38,427 \pm 0.28$ g/L (red cashew apple) and 44.79 ± 0.53 g/L (yellow cashew apples). Still in the same locality of Katiola, the concentrations of total sugars oscillated from $121,064 \pm 0.51$ to $130,118 \pm 0.82$ g/L for the red variety. Statistical analysis of juices from maturity stages 1 and 2 does not show any significant difference ($P < 0.05$). On the other hand, they present a difference in concentration of total sugars with the juice of stage 3. The examination of cashew apple juices of the yellow variety reveals a difference within the variety. The highest concentration was reported at maturity stage 2 of the yellow variety (94.01 ± 1.74 g/L). In addition, reducing and total sugars follow the same distribution in the locality of Korhogo. Except for the samples of red cashew apple of maturity level 1 and 3 where the contents are identical, all the concentrations present a significant difference ($P > 0.05$). In the yellow variety apples, the contents are between 20.172 ± 0.85 to 33.456 ± 0.85 g/L and 59.829 ± 7.12 to 141.026 ± 0.06 g/L respectively for the reducing and total sugars. The highest contents raised from the red variety of cashew apple were $39,907 \pm 0.72$ g/L (reducing sugars) and $148,623 \pm 5.01$ g/L (total sugars).

5. DISCUSSION

The pH of the raw juice samples of the three maturity levels at harvest differed and an acidic

character was recorded regardless of the locality. On the other hand, the pH of the less acidic juices was observed at stage 2 regardless of the locality. Indeed, the cashew apple being a climacteric fruit once fallen (stage 2) continues to ripen and respire. This respiration process consumes organic acids, which generally reduces the pH of the juices extracted from stage 2. Similar pH results have been reported (Deli et al., 2022; Luengo Ferreira & Hernández-Varela, 2021; kamble et al., 2024) Furthermore, the acidic character of cashew apples during ripening is an asset for processing operators because a pH acid can inhibit the growth of many pathogenic microorganisms. The acidic character of cashew apple has been described in several works (Cai et al., 2020; Souleymane et al., 2024). Moreover, the raw juices extracted from cashew apples of the red and yellow varieties from the three localities reveal a slightly acidic character at stages 1 and 3 compared to stage 2. The results of titratable acidity confirm the acidic character of cashew apple regardless of the level of maturity. However, the variability of apple acidity could be explained by the composition of the fruits itself influenced by the physiological state of the cashew apple. Our results are comparable to those obtained in the province of Kompong Thom in Cambodia (Chim, 2022). Dry extract refractometry is an important parameter of fruit quality, reflects the taste of the food. It serves as an indicator of sugar and organic acid content during fruit ripening at harvest (Simkova et al., 2024). The juices from cashew apples dropped and collected at 0 days (stage 2) have slightly higher contents than those from stages 2 and 3 overall. This result could justify that when the cashew apples fall, they are completely ripe so the fruits have all the sugars accumulated during ripening (Simkova et al., 2024). In addition to maturity, the high content of dry extract refractometry of stage 2 juices is related to hydrolysis through enzymes (hydrolases) breaking down complex sugars (polysaccharides) into simple sugars by increasing the level. Furthermore, during this work, it was found that the ESR of cashew apple juices drops after stage 2. Similar behavior was observed during the development of cashew apple (Hédiblé et al., 2017; Luengo Ferreira & Hernández-Varela, 2021). A similar decline in sugars during ripening has been reported in work in plantain (Assemmand et al., 2012). However, the variation in ESR expressed between stages 1, 2 and 3 is related to the degree of maturity of the different cashew apple variants harvested which is in agreement with other previous studies

(Bouali et al., 2023). Thus, the ESR contents of stages 1 and 2 overall were slightly lower compared to the contents of stage 2. The dry extract refractometry (ESR) obtained during this work was comparable to those obtained by Ouattara et al., (2017) in Côte d'Ivoire. However, several investigations on fresh cashew apple juice have obtained higher contents than those observed in our study (Adou et al., 2021; Dedehou et al., 2015; Ndiaye et al., 2022). The portions dry matter content found in this study range from 8.92 to 14% for juices from stages 1, 2 and 3 of red and yellow cashew apples. These portions constitute the mineral and organic fraction after evaporation of the water but reflect the richness of the juices in nutritive substance. In Côte d'Ivoire and Benin, research on cashew apples has shown almost similar trends. Indeed, during the work of Naka et al., (2015), they found a dry matter content of 8.94 to 11.45% while that of Adou, 2012 was 7.07 to 10.20% in Ivory Coast. However, low (7.68 to 8.43%) portions of dry matter were found in Hédiblé et al., (2017) in Benin. The portions of dry matter and moisture content are correlated. The moisture content indicates that the cashew apple contains a large amount of water. This high content is an advantage for manufacturers who want to make juice and liqueur from it (Singh et al., 2019; Souleymane et al., 2024). High polyphenol content was observed at maturity stage 2 regardless of cultivar. The high polyphenol contents of the juices of unripened Yamoussoukro apples compared to the other two stages of maturity could be explained by the fact that the cashew apple on the tree produces polyphenols for its defense (Saini et al., 2024). Beyond that, investigations have noted that fruits are an important source of total polyphenols, particularly at the growth stages. These high levels of total polyphenols could have potential industrial and cosmetic applications (Pontesegger et al., 2023). Our results are superior to those obtained by Cruz Reina et al., (2022) and Msoko et al., (2017) which vary respectively from 1110 to 1900 g/L and from 1066.55 to 2886.67 g/L. Thus, Ghate et al., (2021) showed that a diet rich in polyphenols in Asia and Africa led to less prevalence and mortality from covid-19 than in developed countries, because these bioactives strengthen immunity. In fact, polyphenols are composed of natural bioactives found mainly in fruits and vegetables. They are synthesized as secondary metabolites in plants, primarily in response to pathogens and other environmental stressors. The flavonoid contents of stage 1 juices of the

yellow variety (Katiola) and those of the red variety (Korhogo) recorded high values than the juices of stages 2 and 3 of the same color. An upward trend in total flavonoid contents was mentioned during fruit ripening (Adegbanke et al., 2024; Jia et al., 2024). The increase in flavonoids would be linked to age, the health of the cashew tree feet as well as the quality of the soil (Mangalassery et al., 2024). Our results are far superior to those of apples from Benin (1.68 g/L) (Pascal et al., 2018). However, the juices of the yellow (Korhogo), red (Katiola) varieties of stage 2 were also concentrated in flavonoids. The same trends were observed in Yamoussoukro with the red cashew apples as well as that of the yellow variety. Indeed, when the cashew apple falls, it undergoes mechanical stress thus increasing the content of total flavonoids. Conversely, low levels were found in the cashew apple juices of stage 3. A similar downward trend in total flavonoids was obtained in apples during advanced maturation (Bizjak et al., 2013; Konsue et al., 2023). High total tannin contents were obtained in cashew apples at stage 2. However, the observed contents are relatively high for the three levels of maturity in the three localities. Our results are consistent with those of Cameroon, ranging from 3465.9 to 3388.9 g/L (Ngoko et al., 2021). Similar levels (3889.6 mg/L) in cashew apples have been observed in other regions of Africa (Dimoso et al., 2020). On the other hand, low levels (49 to 148 mg/L) were reported in work carried out in Benin (Dedehou et al., 2015). The reducing sugars obtained in cashew apple juices from the localities of Yamoussoukro, Katiola, Korhogo are relatively rich. The results of our investigations are favorably comparable to those obtained by N'guessan et al. (2023) in the production of bioethanol by using cashew apples rejected in Ivorian plantations. Other research on the cashew apple from Senegal has reported quanquasi-similar reducing sugar properties (Ndiaye et al., 2022). In the same vein, low concentrations of 9.174 g/L were obtained by Adou et al., (2021) in Côte d'Ivoire in addition Hanh et al. (2024) obtained higher concentrations (54.8 to 61.20 g/L). Our work also revealed that the reducing sugar contents of stage 1 juices are lower than those of stage 2. Also, the contents of stage 2 are higher than those of stage 3 of maturity. This phenomenon is based on the active metabolism of the fruit which leads to the production and accumulation of reducing sugars. Conversely, the drop in reducing sugar contents after stage 2 results in two phenomena, namely enzymatic degradation

Table 4. Biochemical parameters of three maturity levels of cashew apples from Yamoussoukro

Codes	Polyphenols (mg/L)	Flavonoids (mg/L)	Total tannins (mg/L)	Reducing sugars (g/L)	Total Sugars (g/L)
S2RYA	4213.33 ±15.27 ^{ab}	1800 ±100 ^a	3855.79 ±25.71 ^a	25.80 ±0.1 ^a	152.23 ±0.43 ^a
S1RYA	4770 ±45.00 ^a	1660 ±34.64 ^a	3364.89 ±56.91 ^b	21.00 ±0.1 ^b	102.56 ±0.28 ^c
S3RYA	3813.33 ±5.77 ^b	1080 ±10 ^b	2837.7 ±213.9 ^c	18.00 ±0.1 ^c	135.04 ±0.28 ^b
S2JYA	3913.33 ±66.58 ^b	2280 ±10 ^a	2753.96 ±142.83 ^a	22.8 ±0.1 ^a	165.24 ±0.99 ^a
S1JYA	4260 ±120.00 ^a	1020 ±10 ^b	2070.15 ±191.97 ^b	18.00 ±0.1 ^b	75.21 ±0.28 ^c
S3JYA	3946.66 ±5.77 ^b	980 ±34.64 ^b	2641.55 ±0.32 ^a	17.4 ±0.1 ^c	111.11 ±0.28 ^b

Values in the table are means ± standard deviation of three trials for each parameter. Values with identical superscript letters are not statistically different at $P > 0.05$ S1RYA: Stage 1 red Yamoussoukro; S2RYA: Stage 2 red Yamoussoukro; S3RYA: Stage 3 red Yamoussoukro; S1JYA: Stage 1 yellow Yamoussoukro; S2JYA: Stage 2 yellow Yamoussoukro; S3JYA: Stage 3 yellow Yamoussoukro

Table 5. Biochemical parameters of three maturity levels of Katiola cashew apples

Codes	Polyphenols (mg/L)	Flavonoids (mg/L)	Total tannins (mg/L)	Reducing sugars (g/L)	Total Sugars (g/L)
S2RKA	1546.66 ±5.77 ^a	1646.66 ±35.12 ^a	1552.8 ±2.2 ^b	38.42 ±0.28 ^a	130.11 ±0.82 ^a
S1RKA	1393.33 ±5.77 ^b	770 ±10 ^b	2613.86 ±3.17 ^a	36.96 ±0.31 ^b	129.62 ±0.04 ^a
S3RKA	1276.66 ±11.55 ^c	1660 ±17.32 ^a	787.03 ±57.57 ^b	32.69 ±0.42 ^c	121.06 ±0.51 ^b
S2JKA	1633.33 ± 5.77 ^a	1550 ± 26.46 ^b	1471.96 ± 6.30 ^b	44.79 ± 0.53 ^a	94.01 ± 1.74 ^a
S3JKA	1570 ± 10 ^b	1000 ± 26.46 ^c	1704.96 ± 3.25 ^a	25.09 ± 0.01 ^b	66.95 ± 0.45 ^b
S1JKA	1270 ±10 ^c	1843.33 ±15.27 ^a	1061.13 ± 3.25 ^c	25.52 ±0.53 ^b	54.13 ±7.12 ^c

Values in the table are means ± standard deviation of three trials for each parameter. Values with identical superscript letters are not statistically different at $P > 0.05$. S1RKA: Katiola Red Stage 1; S2RKA: Katiola Red Stage 2; S3RKA: Katiola Red Stage 3; S1JKA: Katiola Yellow Stage 1; S2JKA: Katiola Yellow Stage 2; S3JKA: Katiola Yellow Stage 3

Table 6. Biochemical parameters of three maturity levels of Korhogo cashew apples

Codes	Polyphenols (mg/L)	Flavonoids (mg/L)	Total tannins (mg/L)	Reducing sugars (g/L)	Total Sugars (g/L)
S2RKO	2156.66 ±11.55 ^a	986.66 ±20.82 ^a	2460.63 ±0.23 ^a	39.90 ±0.72 ^a	148.62 ±5.01 ^a
S3RKO	1813.33 ±11.55 ^b	820 ±10 ^b	1899.46 ±4.35 ^c	30.57 ±0.56 ^b	101.14 ±0.82 ^b
S1RKO	1766.66 ±5.77 ^c	780 ±30 ^b	2018.3 ±1.1 ^b	30.78 ±0.56 ^b	96.39 ±0.82 ^b
S2JKO	1933.33 ± 5.77 ^a	1933.33 ±15.27 ^a	2931.83 ± 4.35 ^a	33.45 ±0.85 ^a	141.02 ±0.06 ^a
S1JKO	1503.33 ±5.77 ^c	276.66 ± 5.77 ^c	2227.6 ±4.4 ^b	26.56 ± 4.35 ^b	83.57 ± 0.82 ^b
S3JKO	1736.66 ± 15.27 ^b	680 ± 3.60 ^b	2102.56 ± 1.68 ^c	20.17 ± 0.85 ^c	59.82 ± 7.12 ^c

Values in the table are means ± standard deviation of three trials for each parameter. Values with identical superscript letters are not statistically different at $P > 0.05$ S1RKO: Stage 1 red Korhogo; S2R KO: Stage 2 red Korhogo; S3R KO: Stage 3 red Korhogo; S1J KO: Stage 1 yellow Korhogo; S2JKO: Stage 2 yellow Korhogo; S3J KO: Stage 3 yellow Korhogo

followed by respiration and fermentation. During fermentation, the yeasts which contaminate the cashew apple after it has fallen will use the sugar, leading to a drop in the reducing sugar content Zahan et al., (2024) have shown that the concentrations of reducing sugars gradually decrease under the effect of selective preservatives during the shelf life of guava juice extracted using the enzyme pectinase. The total sugars of cashew apple are mainly composed of glucose, fructose and sucrose as indicated by several authors (Adou et al., 2012; Naka et al., 2015). From Yamoussoukro to Korhogo through Katiola, the different samples of cashew apple juice are concentrated in total sugars in general at all levels of maturity. In addition, in the three localities, the juices of apples dropped and collected revealed the best concentrations regardless of the variety. This observation has already been described in several similar studies on fruits whose work from Assemmand et al., (2012) As for the work of Hédible et al., (2017), they also pointed out that during the maturation of the cashew apple the total sugar contents increase. In general, the results of our investigations are higher than those obtained by some authors in their regions. Thus, Hanh et al., (2024) reported a maximum content of 86.7 g/L while Cai et al., (2020) obtained 50.7g/L in cashew apple samples. Humidity, sunshine, agro-ecological zone and climate are factors that influence the composition of the cashew apple, especially the sugar content (Almeida et al., 2022; Cruz Reina et al., 2022; N'guessan et al., 2023).

6. CONCLUSION

This study highlighted the influence of the physicochemical and biochemical composition of cashew apples from stages 1, 2 and 3 from different locations. The different results indicate that the level of maturity has a significant effect on the composition of cashew apples by increasing the pH level, dry extract refractometry, dry matter content, sugars, polyphenols and flavonoids. These different parameters determine the organoleptic and nutritional quality as well as the ability to transform the apple. In addition, the best concentrations were obtained from the juices from cashew apples from stage 2. Cashew apples from stage 2 have the best physicochemical and biochemical profile.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models

(ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- Abalokoka, E.-Y., Tchaou, N. M., Adi, K., & Osseyi, E. (2018). Nutritional value of the almond and apple of *Anacardium occidentale* from three localities in Northern Togo.
- Adegbanke, O. R., Oyeleye, F. O., & Dada, T. A. (2024). Production and Storage Stability of Composite Juice from Watermelon, Grape, Soursop, and Cashew Apple. *IPS Journal of Nutrition and Food Science*, 3(3), Article 3. <https://doi.org/10.54117/ijnfs.v3i3.51>
- Adou, M., Adjouman, Y. D., Kouadio, K. O., Tetchi, A. F., & Amani, N. G. (2021). Improvement of Cashew Apple Juice (*Anacardium occidentale*) by Association with Passion Fruit Juice (*Passiflora edulis*). *Food and Nutrition Sciences*, 12(07), 787-804. <https://doi.org/10.4236/fns.2021.127059>
- Adou, M., Tetchi, F. A., Gbané, M., Kouassi, K. N., & Amani, N. G. (2012). physico-chemical characterization of cashew apple juice (*anacardium occidentale*, L.) from yamoussoukro (côte d'ivoire).
- Akyereko, Y. G., Yeboah, G. B., Wireko-Manu, F. D., Alemawor, F., Mills-Robertson, F. C., & Odoom, W. (2023a). Nutritional value and health benefits of cashew apple. *JSFA Reports*, 3(3), 110-118. <https://doi.org/10.1002/jsf2.107>
- Akyereko, Y. G., Yeboah, G. B., Wireko-Manu, F. D., Alemawor, F., Mills-Robertson, F. C., & Odoom, W. (2023b). Nutritional value and health benefits of cashew apple. *JSFA Reports*, 3(3), 110-118. <https://doi.org/10.1002/jsf2.107>
- Almeida, M. L. B., Moura, C. F. H., Innecco, R., Silveira, M. R. S. da, & Brito, E. S. D. (2022). Could the production region influence the quality and antioxidant activity of cashew apple? *Revista Colombiana de Ciencias Hortícolas*, 16(3), Article 3. <https://doi.org/10.17584/rcch.2022v16i3.15108>
- Assemmand, E., Camara, F., Kouamé, F., Konan, V., & Kouamé, L. P. (2012). Biochemical

- characterization of plantain fruits (*Musa paradisiaca* L.) variety "Agnrin" from Ivory Coast and sensory evaluation of its derived products.
- Bernfeld, P. (1955). [17] Amylases, α and β . *Methods in Enzymology*, 1, 149-158. [https://doi.org/10.1016/0076-6879\(55\)01021-5](https://doi.org/10.1016/0076-6879(55)01021-5)
- Bizjak, J., Mikulic-Petkovsek, M., Stampar, F., & Veberic, R. (2013). Changes in Primary Metabolites and Polyphenols in the Peel of "Braeburn" Apples (*Malus domestica* Borkh.) during Advanced Maturation. *Journal of Agricultural and Food Chemistry*, 61(43), 10283-10292. <https://doi.org/10.1021/jf403064p>
- Bouali, I., Tsafouros, A., Ntanos, E., Albouchi, A., Boukhchina, S., & Roussos, P. A. (2023). Influence of Ripening Process on Pecan Nut (*Carya illinoensis*) Kernel Quality: Phenolic Profile, Antioxidant Activity, and Carbohydrate Composition. *Horticulturae*, 9(10), Article 10. <https://doi.org/10.3390/horticulturae9101093>
- Cai, M., Xie, C., Lv, Y., Yang, K., & Sun, P. (2020). Changes in physicochemical profiles and quality of apple juice treated by ultrafiltration and during its storage. *Food Science & Nutrition*, 8(6), 2913-2919. <https://doi.org/10.1002/fsn3.1593>
- Chim, C. (2022). Physicochemical and Antioxidant Properties in Varieties of Cashew Apple (*Aacardium Occidetale* L.). *Advances in Food Technology & Public health*, 1-4. <https://doi.org/10.46715/aftph2022.04.1000110>
- Ci & Indira, K. C. (2016). Quantitative estimation of total phenolic, flavonoids, tannin and chlorophyll content of leaves of *Strobilanthes Kunthiana* (Neelakurinji). *Journal of Medicinal Plants Studies*.
- Cruz Reina, L. J., Durán-Aranguren, D. D., Forero-Rojas, L. F., Tarapuez-Viveros, L. F., Durán-Sequeda, D., Carazzone, C., & Sierra, R. (2022). Chemical composition and bioactive compounds of cashew (*Anacardium occidentale*) apple juice and bagasse from Colombian varieties. *Heliyon*, 8(5), e09528. <https://doi.org/10.1016/j.heliyon.2022.e09528>
- Cunniff, P. (1995). Official methods of analysis of AOAC international (16th ed). Association of Official Analytical Chemists.
- Dedehou, E., Dossou, J., & Soumanou, M. (2015). Diagnostic study of cashew apple juice processing technologies in Benin. *International Journal of Biological and Chemical Sciences*, 9(1), 371. <https://doi.org/10.4314/ijbcs.v9i1.32>
- Deli, M. G. E. P., Kirit, B. D., Ağçam, E., Cinkir, N. I., & Akyildiz, A. (2022). Changes in cashew apple juice treated with optimum thermosonication during storage. *Food Chemistry Advances*, 1, 100120. <https://doi.org/10.1016/j.focha.2022.100120>
- Dimoso, N., Makule, E., & Kassim, N. (2020). Quality Assessment of Formulated Osmotically Dehydrated Cashew Apple (*Anacardium occidentale* L.) Slices Dried using Hot air and Solar Driers.
- DuBois, Michel., Gilles, K. A., Hamilton, J. K., Rebers, P. A., & Smith, Fred. (1956). Colorimetric Method for Determination of Sugars and Related Substances. *Analytical Chemistry*, 28(3), 350-356. <https://doi.org/10.1021/ac60111a017>
- Emelike, N. J., & Obinna-Echem, P. C. (2020). Physicochemical and microbiological properties Quality of cashew apple juice.
- Ghag, S. S., Gokhale, J. S., & Lele, S. S. (2024). Shelf-life extension of cashew apples (*Anacardium occidentale*) by chemical pretreatment using dip and dry method. *Journal of Food Measurement and Characterization*, 18(3), 2306-2317. <https://doi.org/10.1007/s11694-024-02356-6>
- Ghate, U., Kulkarni, H., Ghate, U., & Kulkarni, H. (2021). Polyphenols, Spices and Vegetarian Diet for Immunity and Anti-Inflammatory Drug Design. In *Bioactive Compounds Biosynthesis, Characterization and Applications*. IntechOpen. <https://doi.org/10.5772/intechopen.97661>
- Hanh, N. T., Trang, N. T., Anh, N. T. M., Huong, N. T., Hung, N. V., Trang, V. T., Long, N. V., & Huda, N. (2024). Effect of Pretreatment Methods on Juice Extraction Yield and Nutritional Composition of Cashew Apple (*Anacardium Occidentale* L.) Harvested from Binh Phuoc (Vietnam). *Current Research in Nutrition and Food Science Journal*, 12(1), 115-124. <https://doi.org/10.12944/CRNFSJ.12.1.09>
- Hêdiblê, L. G., Adjou, E. S., Tchobo, F. P., Agbangnan, P., & Soumanou, M. M. (2017). Physicochemical and morphological characterization of three morphotypes of cashew apples

- (*Anacardium Occidental* L.) for their use in the production of edible alcohol and spirits.
- Jia, D., Liao, G., Ye, B., Zhong, M., Huang, C., & Xu, X. (2024). Changes in fruit quality, phenolic compounds and antioxidant activity of kiwifruit (*Actinidia eriantha*) during on-vine ripening. *LWT*, 206, 116564. <https://doi.org/10.1016/j.lwt.2024.116564>
- Kamble, A. B., Pawar, C. D., Khanvilkar, M. H., Kadam, J. J., & Kasture, M. C. (2024). Effect of Blending Cashew Apple (*Anacardium occidentale* L.) and Aonla (*Emblica officinalis* Gaertn.) Juice on Quality of Wine During Storage. *European Journal of Nutrition & Food Safety*, 16(10), 151-159. <https://doi.org/10.9734/ejnfs/2024/v16i101565>
- Kenneth, H. (1990). Official Method of Analysis of the Association of official analytical chemists: Vol. Volume 1 (Fifteenth Edition).
- Konsue, N., Bunyameen, N., & Donlao, N. (2023). Use of young jackfruit (*Artocarpus heterophyllus* Lam.) as a plant-based food ingredient: Influence of maturity on chemical properties and changes during in vitro digestion. *LWT*, 180, 114721. <https://doi.org/10.1016/j.lwt.2023.114721>
- Kumar, H., Kimta, N., Guleria, S., Cimler, R., Sethi, N., Dhanjal, D. S., Singh, R., Duggal, S., Verma, R., Prerna, P., Pathera, A. K., Alomar, S. Y., & Kuca, K. (2024). Valorization of non-edible fruit seeds into valuable products: A sustainable approach towards circular bioeconomy. *Science of The Total Environment*, 922, 171142. <https://doi.org/10.1016/j.scitotenv.2024.171142>
- Luengo Ferreira, A. J., & Hernández-Varela, J. D. (2021). Relationship between color and physico-chemical properties of cashew apple (*Anacardium occidentale* L.) at different days of storage. *Revista Facultad Nacional de Agronomía Medellín*, 74(2). <https://doi.org/10.15446/rfnam.v74n2.90073>
- Mangalassery, S., Adiga, J. D., Veena, G. L., Binitha, N. K., & Anil Kumar, K. S. (2024). Cashew (*Anacardium occidentale* L.). In G. V. Thomas & V. Krishnakumar (Éds.), *Soil Health Management for Plantation Crops: Recent Advances and New Paradigms* (p. 253-279). Springer Nature. https://doi.org/10.1007/978-981-97-0092-9_6
- Marinova, D., Ribarova, F., & Atanasova, M. (2005). Total phenolics and total flavonoids in bulgarian fruits and vegetables.
- Monteiro, F., Romeiras, M. M., Barnabé, J., Catarino, S., Batista, D., & Sebastiana, M. (2022). Disease-Causing Agents in Cashew: A Review in a Tropical Cash Crop. *Agronomy*, 12(10), 2553. <https://doi.org/10.3390/agronomy12102553>
- N'guessan, D., Bedikou, M., Abouo, V., Samagaci, L., Ehon, C., Yacouba, C., & Akpa, E. (2023). Waste Cashew Apple (*Anacardium occidentale*) as Feedstock for Simultaneous Production of Two Main Ecofriendly Fuels. *Journal of Power and Energy Engineering*, 11(8), Article 8. <https://doi.org/10.4236/jpee.2023.118002>
- Naka, T., Martin, D. K., & Soumaila, D. (2015). Cashew varieties affected by three regions of Côte d'Ivoire.
- Ndiaye, L., Charahabil, M. M., Niang, L., & Diouf, A. (2022). Nutritional and energy value of cashew apples (*Anacardium occidentale* L.) from Casamance, Senegal.
- Ngoko, J. T., Ngatchic, J., & Saïdou, C. (2021). Improvement of the traditional production process for cashew juice (*Anacardium occidentale* L.).
- Ouattara, G. S., Soro, D., Chatigre, K. O., & Koffi, E. K. (2017). Physicochemical and sensory characterization of various cashew apple and pineapple juice formulations. *International Journal of Biological and Chemical Sciences*, 10(6), 2447. <https://doi.org/10.4314/ijbcs.v10i6.4>
- Pascal, A. D. C., Virginie, G., Diane, B. F. T., Estelle, K. R., Félicien, A., Valentin, W. D., & Dominique, S. K. C. (2018). Nutritional Profile and Chemical Composition of Juices of Two Cashew Apple's Varieties of Benin. 4(4).
- Pontesegger, N., Rühmer, T., & Siegmund, B. (2023). Physicochemical Attributes, Volatile Profile and Sensory Quality of Organic Crimson Crisp Apples during On-Tree Maturation. *Foods*, 12(7), Article 7. <https://doi.org/10.3390/foods12071425>
- Ravi, H. K., Degrou, A., Costil, J., Trespeuch, C., Chemat, F., & Vian, M. A. (2020). Larvae Mediated Valorization of Industrial, Agriculture and Food Wastes: Biorefinery Concept through Bioconversion, Processes, Procedures, and Products. *Processes*, 8(7), 857. <https://doi.org/10.3390/pr8070857>
- Saini, N., Anmol, A., Kumar, S., Wani, A. W., Bakshi, M., & Dhiman, Z. (2024). Exploring

- phenolic compounds as natural stress alleviators in plants- a comprehensive review. *Physiological and Molecular Plant Pathology*, 133, 102383.
<https://doi.org/10.1016/j.pmpp.2024.102383>
- Sharma, A., Thakur, A., Sharma, A., Thakur, M., Sharma, S., Sharma, H., Thakur, R., Thakur, D., & Suhag, R. (2025). Nano-edible coatings for quality enhancement and shelf-life extension of fruits and vegetables. *Journal of Food Science and Technology*, 62(3), 397-412.
<https://doi.org/10.1007/s13197-024-06146-2>
- Shi, J., Xiao, Y., Jia, C., Zhang, H., Gan, Z., Li, X., Yang, M., Yin, Y., Zhang, G., Hao, J., Wei, Y., Jia, G., Sun, A., & Wang, Q. (2023). Physiological and biochemical changes during ripening and fruit ripening of highbush blueberry (*Vaccinium corymbosum* L.). *Food Chemistry*, 410, 135299.
<https://doi.org/10.1016/j.foodchem.2022.135299>
- Simkova, K., Veberic, R., Hudina, M., Grohar, M. C., Pelacci, M., Smrke, T., Ivancic, T., Cvelbar Weber, N., & Jakopic, J. (2024). Non-destructive and destructive physical measurements as indicators of sugar and organic acid contents in strawberry fruit during ripening. *Scientia Horticulturae*, 327, 112843.
<https://doi.org/10.1016/j.scienta.2024.112843>
- Singh, S. S., Abdullah, S., Pradhan, R. C., & Mishra, S. (2019). Physical, chemical, textural, and thermal properties of cashew apple fruit. *Journal of Food Process Engineering*, 42(5), e13094.
<https://doi.org/10.1111/jfpe.13094>
- Souleymane Soumahoro, Maimouna L Kouame, Wilfried K Yao, Abdoulaye Toure, & Yadé R Soro. (2024). Cashew apples: Physico-chemical analysis and occurrence of yeasts in plantations north of Côte d'Ivoire for processing into bioethanol and fermented beverages. *GSC Biological and Pharmaceutical Sciences*, 29(1), 124-133.
<https://doi.org/10.30574/gscbps.2024.29.1.0362>
- Wood, J. E., Senthilmohan, S. T., & Peskin, A. V. (2002). Antioxidant activity of procyanidin-containing plant extracts at different pHs. *Food chemistry*, 77(2), 155-161.
- Yangomoudou, O. D., Ayo, O. S., Uthman, Y. O., & Okolosi, J. E. (2020). 1Department of Home Science and Hospitality Management, College of Agricultural Sciences, Olabisi Onabanjo University, Yewa Campus, Ayetoro, Nigeria. 7(1).
- Yisa, I. K. (2020). utilisation of cashew (*anacardium occidentale* L.) apple pomace as a source of energy by broiler chicken.
- Zahan, I., Khan, M. M., Rana, M. S., Sahabuddin, M., Rasik, M. R., & Uddin, M. B. (2024). Effect of selective preservatives on shelf-life of guava juice extracted using pectinase enzyme. *Heliyon*, 10(18), e37596.
<https://doi.org/10.1016/j.heliyon.2024.e37596>
- Zou, S., Gao, P., Jia, T., & Huang, H. (2022). Physicochemical Characteristics and Nutritional Composition during Fruit Ripening of *Akebia trifoliata* (Lardizabalaceae). *Horticulturae*, 8(4), Article 4.
<https://doi.org/10.3390/horticulturae8040326>

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the publisher and/or the editor(s). This publisher and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

© Copyright (2025): Author(s). The licensee is the journal publisher. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<https://pr.sdiarticle5.com/review-history/132048>