GSC Biological and Pharmaceutical Sciences

eISSN: 2581-3250 CODEN (USA): GBPSC2

Cross Ref DOI: 10.30574/gscbps

Journal homepage: https://gsconlinepress.com/journals/gscbps/

(RESEARCH ARTICLE)

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Study of physico-chemical parameters of mangoes produced in the departments of Korhogo and Sinématiali, North of Côte d'Ivoire.

Sara Atchoumtcho Coulibaly [1], Abdoulaye Toure [1,*], Aminata Akoubet-Ouayogode [2], Richmont Jean-Francois Kablan [3] and Ahmont Landry Claude Kablan [2]

[1] *Department of Biochemistry-Genetics, Training and Research Unit of Biological Sciences, University Peleforo GON COULIBALY, Korhogo, Côte d'Ivoire.*

[2] *Department of Mathematics-Physics-Chemistry, Training and Research Unit of Biological Sciences, University Peleforo GON COULIBALY, Korhogo, Côte d'Ivoire.*

[3] *Laboratory of Drug Sciences, Analytical Sciences and Public Health, Department of Pharmaceutical Sciences, Training and Research Unit Pharmaceutical and Biological Sciences, Félix HOUPHOUET-BOIGNY University, Abidjan, Côte d'Ivoire.*

GSC Biological and Pharmaceutical Sciences, 2026, 34(02), 332-343

Publication history: Received on 14 December 2025; revised on 21 February 2026; accepted on 24 February 2026

Article DOI: https://doi.org/10.30574/gscbps.2026.34.2.0029

Abstract

The mango is a tropical fruit from Indian origin, produce by the mango tree, which varies in shape and color. Unfortunately, the potential of its various parts, in particular those often considered as waste, remains underexplored. This study examines the physico-chemical composition of the almonds, peel and pulp of 7 varieties of mango produced in the Korhogo and Sinématiali departments in northern Côte d'Ivoire. Dry matter, titratable acidity (TA), pH, soluble dry extract (SDE), SDE/TA ratio, reducing sugars and total sugars were measured to assess the mango's physico-chemical characteristics. The results showed that the pulp of the Palmer variety (24.37 ± 0.29%) is more acidic. Kent de Torgo pulp contains the highest soluble dry extract (5.07 ± 0.21%), while Kent de Natio has the best SDE/TA ratio (44.54%). Mango pulp is the most acidic and also the sweetest part. To our knowledge, this is the first time this study has been carried out in Côte d'Ivoire.

Keywords: Physico-chemical; Mango; Sinématiali; Korhogo; Côte d'Ivoire

1. Introduction

The mango tree (*Mangifera indica* L.) is a fast-growing evergreen. Inflorescences appear at the tips of twigs on the periphery of the foliage. They are made up of male and hermaphrodite flowers [1]. Each inflorescence bears thousands of flowers which, after fertilization, will produce at best a few fruits, notably mangoes [1]. Mango is grown in tropical and subtropical regions [2], and is eaten ripe as a dessert or salad [3].

The mango is a climacteric fruit with nutritional and economic potential [4]. It is the second most important fruit in terms of surface area and production after the banana [5]. It is widely grown in subtropical and tropical regions [2], notably Côte d'Ivoire. In Côte d'Ivoire, commercial mango production is mainly concentrated in the Poro region, around 700 km from the city of Abidjan [2]. This region stands out for its favorable agroecological conditions and the quality of its mangoes, making them a key resource for local economies [2]. The mango variety most exported by Côte d'Ivoire is Kent, for its organoleptic and physico-chemical qualities, in particular its low water content, which gives it a long commercial life, with 80% of exports, followed by Keitt (7%) and Amélie (3%) [6]. Apart from these three main export varieties, several other varieties exist in Côte d'Ivoire's production zones [7]. These varieties, which are little known and therefore less valued, represent 10% of orchards in production, and are tending to disappear in favour of the Kent

* Corresponding author: Abdoulaye Toure

variety [8]. Unfortunately, in Sinématiali, only the Kent variety exists, as all other varieties have been grafted onto Kent. However, in Korhogo, precisely in Natio, apart from Kent, there are still a few plants of six other varieties, notably Cameroun, Zill, Amélie, Keitt, Mademoiselle and Palmer [7].

The cultivation of cotton, once considered the main export crop and the basis of the region's development, has now been abandoned in favor of cashew and mango crops [9]. Mango production and marketing play an important role in the region's economic development. Despite the nutritional and economic importance of mango, and the dietary interest of the local population, production is subject to enormous post-harvest losses. This loss represents between 30% and 50% of production [4]. These significant losses are often due to the lack of adequate post-harvest technologies for stabilizing the fruit in either its fresh or processed state [10]. However, a variety of mango processing technologies exist, including dried mango, juice, nectar, mango vinegar and jam [11]. To better process mango, it is necessary to know the characteristics of the varieties used. Several studies have been carried out on mango in Côte d'Ivoire, but to our knowledge, there is no statistical data on the characterization of all existing varieties in the Korhogo and Sinématiali departments.

The main objective of this study is to assess the physico-chemical parameters of the almonds, peels and pulp of mangoes grown in these departments, in order to enable efficient use of these varieties and their by-products, as well as diversification of products derived from mangoes. This analysis aims to identify opportunities for the economic and environmental valorization of mangoes and their by-products. By highlighting the physico-chemical differences between these parts, this study will offer avenues for maximizing the economic and ecological benefits of mango production in the Korhogo and Sinématiali departments.

2. Materials and methods

2.1. Materials

2.1.1. Biological materials

The biological material used consists of mature and green (unripe) mangoes of the Kent, Palmer, Keitt, Zill, Mademoiselle, Amélie and Cameroun varieties (Figure 1) harvested in the Korhogo and Sinématiali departments during March 2023.

2.1.2. Technical equipment and apparatus

The equipment used in the laboratory consisted of a Stuart magnetic stirrer for homogenizing samples in solvents. A precision balance (Ohaus) was used for weighing. The solutions were brought to the desired temperature in a Water Bath (Julabo), and the optical densities (OD) were read in a spectrophotometer (Jenway). A desiccant (Duran) was used to maintain the moisture content of the samples during cooling prior to weighing. A furnace (Nabertherm) was used to incinerate samples for ash analysis. A refractometer was used to assess soluble dry extract content. A centrifuge (Simplex) was used to filter liquid mixtures. An oven (Memmert) was used for sample dehydration.

2.2. Solvents and reagents

- Solvents: ethanol, distilled water.
- Reagents: 0.1N sodium hydroxide, phenolphthalein, sulfuric acid, phenol, 3,5- dinitrophenol-salicylic acid.

Figure 1 Mango varieties studied [7]

2.3. Methods

2.3.1. Sampling

Sampling was carried out in the Korhogo and Sinématiali departments during the 2023 mango season in Côte d'Ivoire. Samples were taken in 3 different orchards for each department using the simple random sampling method. A total of 12 samples of mango varieties at the mature green stage were collected as shown in Table 1. They were washed, wiped and peeled. The various parts of the mango, notably the almond, peel and pulp, were then sun-dried for a week on boards placed on a support about a metre high, and ground to powder separately. Analyses were carried out on the powder of the various parts.

Determination of physico-chemical parameters

Dry matter, titratable acidity (TA), pH, soluble dry extract (SDE), SDE/TA ratio, total sugars and reducing sugars were measured to assess the physico-chemical characteristics of mangoes.

Water content

Dry matter (DM) content was determined using the AOAC method [12]. Five (05) grams of powder were placed in a dish that had been cleaned, dried and weighed using an electronic balance (m0). The crucible and sample assembly (m1) was placed in an oven at 105°C until a constant mass was obtained. The assembly was removed from the oven and weighed again (m2), after cooling in a desiccator. The water content (TE) was expressed as a percentage and calculated using the following mathematical formula:

$$\mathrm{DM}\ (\%) = 100 - \left(\frac{(\mathrm{m_1} - \mathrm{m_2})}{\mathrm{m_1} - \mathrm{m_0}} \times 100 \right)$$

PH and titratable acidity

pH and titratable acidity were determined using the method of Souza et al [13]. Ten (10) grams of powder were dissolved in 100 mL of distilled water. The resulting solution was filtered through Whatman filter paper. The pH was determined by dipping the electrode of a calibrated pH meter into the filtrate obtained. Next, 10 mL of the filtrate was withdrawn and titrated with a solution of NaOH (0.1 N) in the presence of phenolphthalein. However, due to the initial color of the filtrate, the volume of NaOH (0.1N) was noted when its pH reached 8.2. Titratable acidity was calculated as a percentage according to the following formula:

Table 1 Distribution of samples in sampling zones

Departments	localities	Varieties	Number of samples
Korhogo	Klokakaha	Kent	1
	Torgo	Kent	1
	Natio	Kent	1
		Palmer	1
		Keitt	1
		Zill	1
		Mademoiselle	1
		Amélie	1
		Cameroun	1
Sinématiali	Donnonnakaha	Kent	1
	Camonnon	Kent	1
	Ouollo	Kent	1
Total			12

$$\text{citric acid} = \frac{\text{Weight of citric acid}}{\text{sample mass}} \text{ X } 100$$

192.43 g/mol: Molecular weight of citric acid

N: Normality of NaOH solution

V: Volume of NaOH solution added

2.3.2. Soluble dry extract

One gram of sample was added to 10 mL distilled water in a Falcon tube and vortexed for 10 min. The mixture was left to stand for 1 hour at room temperature. The mixture was filtered and analyzed by placing 5 microliters (5 µL) of the filtrate on the refractometer analyzer [14].

Determination of soluble dry extract/titratable acidity ratio

Carbohydrate/acid balance is a very important fruit quality factor. It expresses the ratio between soluble dry extract (SDE) and titratable acidity (TA), and can be used to determine the ripeness of fruit or the suitability of pulp for a given processing [4]. It is calculated according to the following formula:

$$\text{Ratio (R)} = \frac{\text{SDE}}{\text{TA}} \times 100$$

2.3.3. Dosage of total sugars

Total sugars were determined by the method of Dubois et al [15], using phenol and sulfuric acid: in the presence of concentrated sulfuric acid, sugars dehydrate, forming furfural-type compounds which react with phenol to give a yellow complex whose intensity is proportional to the concentration of sugars present in the medium. Starting with a 1 g/L glucose or fructose stock solution, a standard range was prepared by successively introducing 0.1 mL sample into a tube, followed by 0.9 mL distilled water, 1 mL phenol and 5 mL sulfuric acid. The blank was prepared with 1 mL distilled water, 1 mL phenol and 5 mL sulfuric acid. The optical density of the different solutions was determined at 490 nm using a spectrophotometer against the blank. To determine the total sugar concentration of the sample, 0.1 mL of the extract was taken, then 0.9 mL of distilled water, treated with 5% (w/v) phenol (1 mL) and sulfuric acid (5 mL), and the optical density read at 490 nm using a spectrophotometer. The sugar concentration of the assay was determined from the calibration curve.

Determination of reducing sugars

Reducing sugars were determined according to the method described by Bernfeld [16] using 3.5- dinitrophenol-salicylic acid (DNS). One gram of powder was added to 10 mL of ethanol (98%) in a Falcon tube and centrifuged at 330 rpm for 30 min. 150 µL of the extract obtained was collected, then 300 µL of DNS was added. The mixture was heated in a boiling water bath for 5 minutes. After 5 minutes cooling to room temperature, two milliliters of distilled water were added to the mixture. The intensity of coloration was determined at 540 nm using a spectrophotometer against a control containing all products except the extract. Reducing sugar content was determined using a calibration curve constructed from a glucose solution (1mg/mL).

2.4. Statistical analysis

All trials were carried out in triplicate. Means and standard deviations were calculated in Excel 2016. Statistically significant differences were highlighted by the Student-Newman-Keuls test at 0.05 risk using SPSS version 20.0 software. Graphs were produced using Excel 2016.

3. Results

The physico-chemical parameters analyzed included dry matter content, titratable acidity, pH, soluble dry extract, SDE / TA ratio, total and reducing sugars

The dry matter content of the almonds ranged from 82.83 ± 0.29% to 90.24 ± 0.39%. Klokakaha kernels had the highest dry matter content, while Torgo kernels had the lowest. Peel and pulp dry matter contents ranged from 84.03 ± 0.06% (Kent Klokakaha) to 89.37 ± 0.55% (Kent Natio), and from 78.18 ± 0.08% (Kent Torgo) to 89.10 ± 0.17% (Kent Natio ; Table 2). There was a significant difference between dry matter contents at $p < 0.05$ risk

Titratable acidity (TA) and pH results are shown in Table 2. Almond acidity ranged from 2.57 ± 0.29% to 14.11 ± 0.19%, with pH values ranging from 4.3 ± 0.7 to 6 ± 0.2. The lowest acidity was obtained in the Zill variety almond, and the highest in the Cameroun variety almond. This result indicates low acidity in the almonds. For peels, results ranged from 5.64 ± 0.19% to 16.93 ± 0.21%. The lowest level of acidity was observed in the peel of the Kent de Natio variety, and the highest in that of the Keitt de Natio variety. For pulp, levels varied from 8.98 ± 0.03% to 24.37 ± 0.29%, with pH values ranging from 3.0 ± 0.2 to 4.5 ± 0.5. The lowest acidity was obtained in the pulp of the Kent de Natio variety, while the highest was obtained in the pulp of the Palmer variety, which means that the Kent de Natio variety is the least acidic of the mangoes studied. The pulp is the most acidic part of the mango. However, there is no significant difference between pH values, but titratable acidity values are statistically different at $p < 0.05$ risk.

The soluble dry extract results are shown in Table 2 This table shows that soluble dry extract levels varied from 0.50 ± 00 (Zill Natio) to 3.00 ± 0.17% (Cameroun Natio); from 2.00 ± 0.26 (Zill Natio) to 4.00 ± 0.10% (Kent Camonnon) and from 3.00 ± 0.17 (Amélie Natio) to 5.07 ± 0.21% (Kent Torgo) for almonds, peel and pulp respectively.

Table 2 Physico-chemical characteristics of different mango parts

Samples	Mango parts	Dry matter (DM) %	pH	Titratable acidity (TA) %	Soluble dry extract (SDE) %
Kent Klokakaha (korhogo)	Almond	90.24 ± 0.39^{a}	5.6 ± 0.10^{a}	4.55 ± 0.09^{d}	1.00 ± 0.10^{b}
	Peel	84.03 ± 0.06^{b}	4.5 ± 0.30^{a}	10.26 ± 0.78^{c}	4.00 ± 0.30^{a}
	Pulp	81.37 ± 0.21^{c}	$4. \pm 0.00^{a}$	12.83 ± 0.76^{b}	4.67 ± 0.30^{a}
Kent Torgo (korhogo)	Almond	82.83 ± 0.29^{b}	4.7 ± 0.20^{a}	11.55 ± 0.43^{b}	2.00 ± 0.20^{b}
	Peel	84.50 ± 0.50^{b}	4.9 ± 0.10^{a}	10.26 ± 1.1^{c}	3.93 ± 0.05^{a}
	Pulp	78.18 ± 0.08^{c}	3.5 ± 0.10^{a}	12.57 ± 0.61^{b}	5.07 ± 0.21^{a}
Kent Natio (Korhogo)	Almond	89.53 ± 0.06^{a}	5.7 ± 0.10^{a}	3.34 ± 0.06^{d}	1.10 ± 0.17^{b}
	Peel	89.37 ± 0.55^{a}	4.8 ± 0.20^{a}	5.64 ± 0.19^{d}	2.03 ± 0.25^{b}
	Pulp	89.10 ± 0.17^{a}	$4.3 \pm 0{,}10^{a}$	8.98 ± 0.03^{c}	4.00 ± 0.20^{a}
Palmer Natio (Korhogo)	Almond	88.50 ± 0.50^{a}	4.5 ± 0.70^{a}	13.08 ± 0.14^{b}	2.00 ± 0.30^{b}
	Peel	85.83 ± 0.29^{b}	4.0 ± 0.20^{a}	10.52 ± 0.50^{c}	3.00 ± 0.17^{ab}
	Pulp	81.83 ± 0.29^{c}	3.0 ± 0.20^{a}	24.37 ± 0.29^{a}	4.00 ± 0.20^{a}
Keitt Natio (Korhogo)	Almond	90.00 ± 1.00^{a}	5.7 ± 0.25^{a}	3.85 ± 0.22^{d}	0.50 ± 0.17^{b}
	Peel	85.00 ± 2.00^{b}	4.3 ± 0.30^{a}	16.93 ± 0.21^{a}	4.00 ± 0.30^{a}
	Pulp	78.67 ± 0.29^{c}	3.8 ± 0.20^{a}	22.32 ± 0.16^{a}	5.00 ± 0.60^{a}
Zill Natio (Korhogo)	Almond	89.67 ± 0.58^{a}	6.0 ± 0.20^{a}	2.57 ± 0.29^{d}	0.50 ± 0.00^{b}
	Peel	87.13 ± 0.23^{a}	4.9 ± 0.10^{a}	7.44 ± 0.26^{b}	$2.00 \pm 0{,}26^{b}$
	Pulp	85.33 ± 0.29^{b}	4.5 ± 0.50^{a}	10.26 ± 0.22^{c}	$4{,}00 \pm 0.36^{a}$
Mademoiselle Natio (Korhogo)	Almond	89.83 ± 0.29^{a}	5.8 ± 0.35^{a}	3.59 ± 0.18^{d}	$0.50 \pm 0{,}10^{b}$
	Peel	88.17 ± 0.29^{b}	4.5 ± 0.30^{a}	12.06 ± 0.10^{b}	2.20 ± 0.20^{a}
	Pulp	81.03 ± 0.06^{c}	3.8 ± 0.20^{a}	11.03 ± 0.05^{b}	3.00 ± 0.20^{a}
Amélie Natio (Korhogo)	Almond	88.67 ± 0.58^{a}	4.9 ± 0.10^{a}	8.98 ± 0.07^{c}	1.00 ± 0.17^{b}
	Peel	87.33 ± 0.29^{a}	4.2 ± 0.10^{a}	7.18 ± 0.33^{c}	3.00 ± 0.20^{a}
	Pulp	83.07 ± 0.11^{b}	3.5 ± 0.50^{a}	16.68 ± 0.33^{a}	3.00 ± 0.17^{a}
Cameroun Natio (Korhogo)	Almond	88.33 ± 0.58^{a}	4.3 ± 0.75^{a}	14.11 ± 0.19^{b}	3.00 ± 0.17^{a}
	Peel	85.50 ± 0.50^{b}	4.1 ± 0.10^{a}	6.67 ± 0.16^{d}	$3.00 \pm 0.\ 00^{a}$
	Pulp	81.24 ± 0.75^{c}	$4.0 \pm 0.\ 00^{a}$	22.58 ± 0.39^{a}	3.80 ± 0.20^{a}
Kent Donnonnakaha (Sinématiali)	Almond	90.16 ± 2.75^{a}	$5.7 \pm 0{,}30^{a}$	4.87 ± 0.12^{d}	1.20 ± 0.10^{b}
	Peel	85.67 ± 0.58^{b}	4.8 ± 0.20^{a}	5.90 ± 0.17^{d}	3.00 ± 0.00^{a}

	Pulp	84.67 ± 0.58^{b}	4.2 ± 0.80^{a}	11.80 ± 0.19^{b}	4.00 ± 0.20^{a}
Kent Camonnon (Sinématiali)	Almond	83.17 ± 0.29^{b}	4.6 ± 0.40^{a}	11.80 ± 0.20^{b}	1.20 ± 0.10^{b}
	Peel	84.50 ± 0.50^{b}	3.9 ± 0.06^{a}	12,32 ± 0.07^{b}	4.00 ± 0.10^{a}
	Pulp	80.83 ± 0.76^{c}	3.5 ± 0.30^{a}	15.39 ± 0.38^{a}	4.00 ± 0.20^{a}
Kent Ouollo (Sinématiali)	Almond	90.00 ± 3.00^{a}	5.8 ± 0.40^{a}	5.64 ± 0.18^{d}	1.00 ± 0.10^{b}
	Peel	84.67 ± 0.58^{b}	4.8 ± 0.20^{a}	7.95 ± 0.04^{c}	3.10 ± 0.10^{a}
	Pulp	81.67 ± 0.58^{c}	4.0 ± 0.10^{a}	15.91 ± 0.25^{a}	4.00 ± 0.10^{a}

Values in the same column bearing the same letter show no significant difference at $p < 0.0$ risk.

Table 3 Physico-chemical characteristics of different mango parts (continued)

Samples	Mango parts	SDE /TA ratio (%)	Total sugars %	Reducing sugars %
Kent Klokakaha (korhogo)	Almond	21.98 ± 1.11^{e}	0.80 ± 0.00^{c}	0.11 ± 0.01^{b}
	Peel	38.99 ± 0.38^{b}	3.00 ± 0.00^{b}	0.43 ± 0.03^{a}
	Pulp	36.40 ± 0.39^{b}	4.40 ± 0.00	0.55 ± 0.01^{a}
Kent Torgo (korhogo)	Almond	17.32 ± 0.47^{f}	1.13 ± 0.01^{c}	0.19 ± 0.01^{a}
	Peel	38.30 ± 0.05^{b}	1.40 ± 0.00^{c}	0.21 ± 0.01^{a}
	Pulp	40.33 ± 0.34^{b}	4.60 ± 0.00^{a}	0.61 ± 0.00^{a}
Kent Natio (Korhogo)	Almond	32.93 ± 2.83^{c}	2.80 ± 0.00^{b}	0.26 ± 0.01^{a}
	Peel	35.99 ± 1.32^{b}	2.73 ± 0.01^{b}	0.27 ± 0.02^{a}
	Pulp	44.54 ± 6.67^{a}	3.20 ± 0.00^{b}	0.32 ± 0.03^{a}
Palmer Natio (Korhogo)	Almond	15.29 ± 2.14^{g}	2.80 ± 0.00^{b}	0.25 ± 0.02^{a}
	Peel	28.52 ± 0.34^{d}	3.20 ± 0.00^{b}	0.42 ± 0.03^{a}
	Pulp	16.41 ± 0.69^{f}	5.07 ± 0.01^{a}	0.48 ± 0.01^{a}
Keitt Natio (Korhogo)	Almond	12.99 ± 0.77^{g}	1.40 ± 0.01^{c}	0.09 ± 0.01^{b}
	Peel	23.63 ± 1.43^{e}	4.80 ± 0.00^{a}	0.42 ± 0.01^{a}
	Pulp	22.40 ± 3.75^{e}	4.67 ± 0.01^{a}	0.66 ± 0.02^{a}
Zill Natio (Korhogo)	Almond	19.46 ± 0.00^{f}	1.60 ± 0.00^{b}	0.10 ± 0.01^{b}
	Peel	26.88 ± 1.00^{d}	2.40 ± 0.00^{b}	0.30 ± 0.01^{a}
	Pulp	38.99 ± 1.64^{b}	3.00 ± 0.00^{b}	0.36 ± 0.04^{a}
Mademoiselle Natio (Korhogo)	Almond	13.93 ± 0.56^{g}	2.60 ± 0.00^{b}	0.14 ± 0.00^{b}
	Peel	18.24 ± 2.00^{f}	3.67 ± 0.01^{b}	0.33 ± 0.00^{a}
	Pulp	27.20 ± 4.00^{d}	4.40 ± 0.00^{a}	0.19 ± 0.01^{a}
Amélie Natio (Korhogo)	Almond	11.14 ± 2.43^{h}	2.47 ± 0.01^{b}	0.09 ± 0.01^{b}
	Peel	41.78 ± 2.43^{b}	3.00 ± 0.00^{b}	0.12 ± 0.01^{b}
	Pulp	17.99 ± 0.52^{f}	3.00 ± 0.00^{b}	0.29 ± 0.01^{a}
Cameroun Natio (Korhogo)	Almond	21.26 ± 0.89^{e}	2.53 ± 0.01^{b}	0.25 ± 0.01^{a}
	Peel	44.98 ± 0.00^{a}	2.60 ± 0.00^{b}	0.32 ± 0.04^{a}

	Pulp	16.83 ± 0.51[f]	4.27 ± 0.01[a]	0.40 ± 0.02[a]
Kent Donnonnakaha (Sinématiali)	Almond	24.64 ± 0.83[d]	1.80 ± 0.00[b]	0.21 ± 0.02[a]
	Peel	50.85 ± 0.00[a]	2.20 ± 0.00[b]	0.45 ± 0.03[a]
	Pulp	33.90 ± 1.05[c]	3.40 ± 0.00[b]	0.11 ± 0.01[b]
Kent Camonnon (Sinématiali)	Almond	10.17 ± 0.50[h]	2.60 ± 0.00[b]	0.22 ± 0.02[a]
	Peel	32.47 ± 1.43[c]	4.73 ± 0.01[a]	0.54 ± 0.05[a]
	Pulp	25.99 ± 0.53[d]	5.73 ± 0.01[a]	0.56 ± 0.02[a]
Kent Ouollo (Sinématiali)	Almond	17.73 ± 0.56[f]	0.87 ± 0.01[c]	0.05 ± 0.01[a]
	Peel	38.99 ± 2.50[b]	1.40 ± 0.00[c]	0.26 ± 0.01[a]
	Pulp	25.14 ± 0.40[d]	2.20 ± 0.00[b]	0.34 ± 0.02[a]

Values in the same column bearing the same letter show no significant difference at $p < 0.0$ risk.

Table 3 shows that pulp from the Kent de Torgo variety had the highest soluble dry extract (SDE), with an SDE / TA ratio of 40.33 ± 0.34%. The pulps of the Amélie and Mademoiselle varieties had the lowest soluble dry extract (3%), with SDE / TA ratios of 17.99 ± 0.52 and 27.20 ± 4.00% for Amélie and Mademoiselle respectively. Natio's Kent variety recorded the highest SDE /TA ratio (44.54%) despite having an SDE content of 4% (Figure 2).

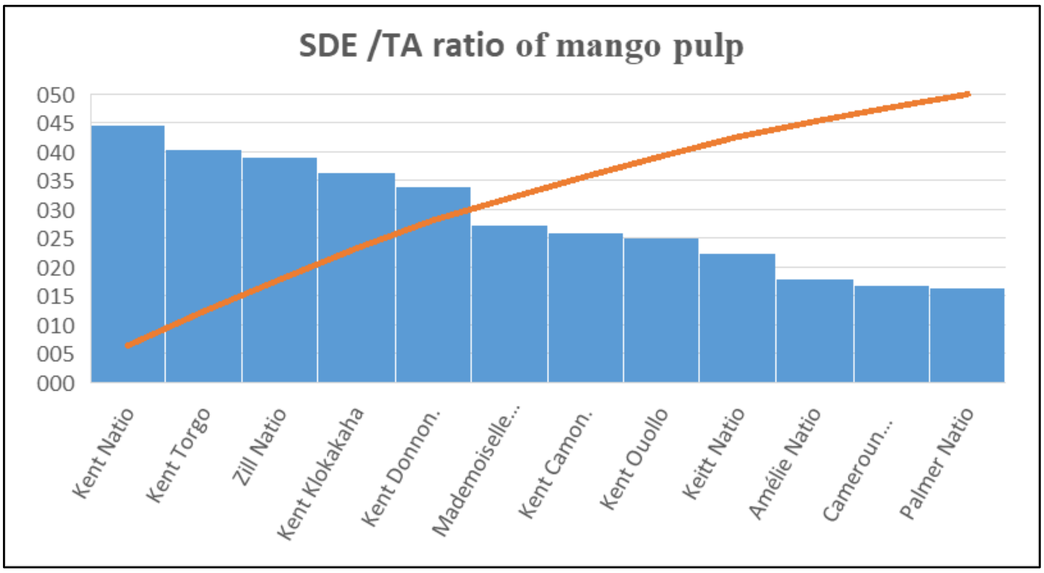

Figure 2 SDE / TA ratio of mango pulps studied

Total sugars in almonds ranged from 0.80 ± 0.00 g/100g to 2.80 ± 0.00 g/100g. The lowest value was obtained for Klokakaha Kent almonds, while the highest values were observed for Natio Kent and Natio Palmer almonds. Peel values ranged from 1.40 ± 0.00 g/100g to 4.80 ± 0.00 g/100g. The lowest values were obtained in the peels of Kent de Torgo and Kent de Ouollo. In the pulps, contents ranged from 2.20 ± 0.00 g/100g to 5.73 ± 0.01 g/100g. The lowest content was obtained in Kent de Ouollo pulp, and the highest in Kent de Camonnon pulp.

Reducing sugar levels varied from 0.05 ± 0.0 g/100g (Kent Ouollo) to 0.26 ± 0.01 g/100g (Kent de Natio) ; from 0.12 ± 0.01 g/100g (Amélie de Natio) to 0.54 ± 0.05 g/100g (Kent de Camonnon) and from 0.11 ± 0.01 g/100g (Kent de Donnonnakaha) to 0.66 ± 0.02 g/100g (Keitt de Natio) for almonds, peel and pulp respectively.

4. Discussion

In the present study, the almonds, peels and pulps of the Kent, Palmer, Keitt, Zill, Mademoiselle, Amélie and Cameroun mango varieties were processed into powder for analysis.

The dry matter content of the almonds ranged from 82.83 ± 0.29% to 90.24 ± 0.39%. Klokakaha almonds had the highest dry matter content, while Torgo almonds had the lowest. Peel and pulp dry matter contents ranged from 84.03 ± 0.06% (Kent Klokakaha) to 89.37 ± 0.55% (Kent Natio) and from 78.18 ± 0.08% (Kent Torgo) to 89.10 ± 0.17% (Kent Natio) respectively. The samples analyzed have a high dry matter content. This may be due to the fact that most of the water has been evaporated by drying. These high levels of dry matter are synonymous with a high content of nutrients, notably carbohydrates, proteins, lipids and mineral salts. These results are lower than those obtained by Boni and colleagues [17]. Indeed, these authors found water contents of 7.78 ± 0.39% and 7.44 ± 0.19% respectively for Keitt and Kent almonds, i.e. 92.22% dry matter for Keitt almonds and 92.56% for Kent almonds. Kiendrebeogo and colleagues [18] obtained 78.68% for Kent almonds in Burkina Faso.

In terms of physico-chemical parameters, titratable acidity and pH are the parameters through which the overall content of organic acids is assessed. They influence the carbohydrate/acid balance of the fruit, which is a quality attribute and an indicator of fruit maturity [19, 20]. Almond acidity ranged from 2.57 ± 0.29% (Zill de Natio) to 14.11 ± 0.19% (Cameroun de Natio) for pH values ranging from 4.3 ± 0.7 to 6 ± 0.2; For peels, results ranged from 5.64 ± 0.19% (Kent de Natio) to 16.93 ± 0.21% (Keitt de Natio), and acidity levels varied from 8.98 ± 0.03% (Kent de Natio) to 24.37 ± 0.29% (Palmer), with pulp pH ranging from 3.0 ± 0.2 to 4.5 ± 0.5. This means that Kent de Natio pulp is the least acidic of the mango pulps studied, while the pulp in general is the most acidic part of the mango. All these data highlight the variability of mango acidity according to variety and growing conditions [4]. Several authors have reported that as TA levels fall, pH rises [21, 22, 23]. These authors have also argued that the decrease in TA is due to the transformation of organic acids into carbohydrates during mango ripening. According to Padda and colleagues [24] and Sajib and colleagues [25], soluble dry extract is directly correlated with fruit acidity. In general, fruit acidity decreases and soluble solids increase as the fruit matures and ripens [24, 25]. Mango pulp with a pH > 4.5 needs to be acidified before storage at temperatures below 100°C [26, 23]. Consequently, for transformation into mango nectar or for pulp storage at temperatures < 100°C, none of the varieties studied will require acidification (pH varies between 3 and 4.5).

Soluble dry extract (SDE) and the SDE/AT ratio are the two most important parameters for measuring fruit quality [27, 23]. The SDE / TA ratio determines the fruit's flavor and consumer acceptability. According to Rodriguez Pleguezuelo and colleagues [28], high quality fruit (good flavor) has a high SDE / TA ratio, while low quality fruit has a low SDE / TA ratio. Soluble dry extract levels varied from 0.50 ± 0.00 (Zill Natio) to 3.00 ± 0.17% (Cameroun Natio); from 2.00 ± 0.26 (Zill Natio) to 4.00 ±0.10% (Kent Camonnon) and from 3.00 ± 0.17 (Amélie Natio) to 5.07 ± 0.21% (Kent Torgo) for almonds, peel and pulp respectively. The soluble dry extract values obtained in the present study are low. These values are below the minimum Brix value for reconstituted fruit juices and purées, which is 13.5% [29]. This may be due to the fact that our mangoes are unripe. According to Léchaudel and Joas [30], soluble dry extract is a biochemical parameter used to determine fruit ripeness, and varies according to the physiological stage of the fruit. Pulps contain more soluble dry extract than peels and almonds.

The pulp of the Kent de Torgo variety had the highest soluble solids content, with an SDE / TA ratio of 40.33 ± 0.34%, due to its low titratable acidity content. The pulps of the Amélie and Mademoiselle varieties had the lowest SDE content (3%), with SDE / TA ratios of 17.99 ± 0.52% and 27.20 ± 4.00% respectively for Amélie and Mademoiselle. This difference could be due to the fact that Amélie had an acidity level of 16.68 ± 0.33% and Mademoiselle 11.03 ± 0.05%. Natio's Kent variety recorded the highest SDE / TA ratio (44.54%) despite having an SDE content of 4%.

Total sugars in almonds ranged from 0.80 ± 0.00 g/100 g to 2.80 ± 0.00 g/100 g. The lowest value was obtained for Klokakaha Kent almonds, while the highest values were observed for Natio Kent and Natio Palmer almonds. As for peels, values ranged from 1.40 ± 0.00 g/100 g to 4.80 ± 0.00 g/100 g. The lowest value was obtained in the peels of Kent de Torgo and Kent de Ouollo. In the pulps, contents ranged from 2.20 ± 0.00 g/100 g to 5.73 ± 0.01 g/100 g. The lowest content was obtained in Kent de Ouollo pulp, and the highest in Kent de Camonnon pulp. Almost all of the mango's total sugars are concentrated in the pulp. The low total sugar content of the samples analyzed shows that unripe mango is a poor source of energy. These results are largely inferior to those reported by Elie (2006) [10], who worked on fresh mango pulp and dried pulp (Kent). The results were in the order of 11.56 g/100 g and 34.17 g/100 g, whereas at our level, pulp total sugar contents ranged from 2.20 ± 0.00 g/100 g to 5.73 ± 0.01 g /100/ g. This difference could be due to the degree of maturity. In fact, the total sugar content of around 5 % in young fruit increases gradually as the fruit grows, reaching a maximum of 13 % on average, decreasing slightly and then stabilizing at around 12 % in perfectly ripe mango [31]. Diffusion during drying could result in sugar losses. Mangoes also come from different orchards. Soil type and cultivation conditions can influence the composition of a given food [32].

5. Conclusion

The present work has made it possible to characterize the different mango varieties existing in the departments of Sinématiali and Korhogo in order to enable their appropriate use by mango industry stakeholders. In Sinématiali, all other varieties have disappeared in favor of the Kent variety for economic reasons. However, in Korhogo, precisely in Natio, there are still a few trees of the Amélie, Cameroun, Zill, Mademoiselle, Keitt and Palmer varieties in the orchards. The pulps of Palmer, Cameroun, Amélie, Keitt, Kent de Camonnon, Kent de Ouollo and Mademoiselle contain the highest levels of titratable acidity. Due to their high titratable acidity, pH < 4 and relatively low SDE / TA ratio, they can be recommended for the manufacture of drinks (juice), purée, vinegar and mango concentrate. The highest SDE / TA and soluble solids ratios are found in the pulp of Kent de Torgo, Kent de Natio, Zill, Kent de Klokakaha and Kent de Donnonnakaha. These varieties are therefore the sweetest. They can be used for mango drying and for making mango jam and preserves. The results of this study could guide processors in their choice of varieties for the types of finished products. These by-products (almond and peel), which have a high dry matter content, could be used to replace corn in broiler feeds. The pulp, as the main edible part, is packed with sugars for human nutrition and health, reinforcing its basic nutritional role. However, further studies are needed to develop processing methods adapted to local realities. This will optimize the value of mango and encourage more sustainable and innovative agriculture. We recommend that Côte d'Ivoire's research centers popularize the other six varieties, namely Amélie, Zill, Cameroun, Keitt, Palmer and Mademoiselle, among mango growers, in order to provide more varieties for export and processing.

Compliance with ethical standards

Disclosure of conflict of interest

Sara Atchoumtcho Coulibaly, Abdoulaye Toure, Aminata Akoubet-Ouayogode, Richmont Jean-Francois Kablan, Ahmont Landry Claude Kablan declare that they do not have any conflict of interest.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study."

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