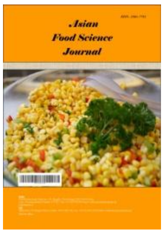

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Morphological, Physical and Biochemical Characteristics of the three Main Varieties of Mango (*Mangifera indica* L.) Cultivated in the Poro Region (North of Côte d'Ivoire)

Guédé Séri Serge [a*], Adombi Caroline Mélanie [a] and Touré Abdoulaye [b]

[a] Biochemistry, Microbiology and Valorization of Agricutural Resources Laboratory, Agropastoral Management Institute, Peleforo Gon Coulibaly University, BP 1328 Korhogo, Côte d'Ivoire.
[b] Biotechnology and Valorization of Agroresources and Natural Substances Laboratory, Faculty of Biological Sciences, Peleforo Gon Coulibaly University, BP 1328 Korhogo, Côte d'Ivoire.

Authors' contributions

This work was carried out in collaboration among all authors. Author TA conceived and designed the study. Author GSS managed the analyses of the study and the literature searches. Author GSS performed the statistical analysis. Authors GSS and ACM wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Mango processing in Côte d'Ivoire is limited by data failure on characteristics of mango varieties. The purpose of this work is to contribute to the valorization of the main varieties of mango (Amelie, Kent and Keitt) cultivated in Côte d'Ivoire through the evaluation of their morphological, physical and biochemical parameters.

Between May and June 2020, ten ripe fruits of each variety were randomly selected from ten batches of mangoes from different producers in the Poro region. After sampling, morphological, physical and biochemical parameters were determined at the biochemistry - microbiological laboratory of Peleforo Gon Coulibaly University in the month of June 2020.

This study showed that the mangoes Kent and Amelie were bigger than those of Keitt. However, when ripe, the three mango varieties studied had each a specific gravity close to 1 g/cm^3; they

**Corresponding author: Email: sguede2017@gmail.com;*

could therefore float on water. They were elongated in shape and corresponded to the caliber group B of mangoes exportable to the European market. The high values of pulp proportions (82.70 to 83.62%), pulp/stone ratios (12.71 to 13.33) and waste indices (4.69 to 5.20) gave them interesting aptitudes for industrial processing. With high moisture contents (77.80 to 84.80%), low fiber contents (0.53 to 0.84%) and acidity values (0.20 to 0.50%), interesting ascorbic acid contents (45.02 to 46.25 mg/100g), TSS contents (15.51 to 18.50 °Brix) conforming to standard for fruit juices and nectars, the mango varieties studied would be suitable for making puree, juice or ice cream. However, with a higher sugars/acidity ratio (73.46), mango variety Kent would be more suitable for drying and making frozen or canned mango pieces; while those of Amelie and Keitt would be suitable for the manufacture of purees, concentrates and drinks.

The results of this study could guide processors in the choice of varieties according to the types of derived products. They are interesting and should be deepened by including other varieties (improved and local) cultivated in Côte d'Ivoire.

Keywords: Manguifera indica; mango varieties; Côte d'Ivoire; morphological parameters; physical parameters; biochemical parameters.

1. INTRODUCTION

The mango tree (*Manguifera indica* L.) is a tree that belongs to the Anacardiaceae family. It is one of the most cultivated fruit species in the world with a production of over 30 million tonnes. Mango occupies the fifth position behind citrus fruits, grapes, bananas and apples. The share of exports has increased fivefold in ten years and exceeds 550,000 tonnes, all markets combined [1].

The mango tree is cultivated in tropical Africa for its fruits which play a very important role in the diet of rural populations, especially [2]. Indeed, the mango is a very nutritious fruit, rich in water, mineral salts, vitamins, carbohydrates and also contains proteins, lipids, carotenoids, polyphenols, omega-3 and omega-6 fatty acids [3].

In Côte d'Ivoire, there are around thirty mango varieties, which are divided into traditional and grafted varieties. The first are generally consumed and marketed at their place of production. The second are mainly for export; Amelie, Kent and Keitt are the main varieties grown in Côte d'Ivoire and exported to Europe. The mango production area is located in the north of the country: Korhogo, Sinematiali, Ferkessédougou and Boundiali [4, 5]. With an annual production of 100,000 to 150,000 tonnes of mangoes, Côte d'Ivoire is the leading mango producing country in Africa. Having shipped more than 30,000 tonnes of mangoes to Europe in 2016 and 2017, it is the world's third-largest mango exporter behind Brazil and Peru [5].

Despite the nutritional and economic potentiality of mango, post-harvest losses are significant and are estimated to about 30-50%. These losses are often due to the unequality of mango distribution networks across the country, parasitic attacks and the absence or insufficiency of adequate post-harvest technologies to stabilize the fruit either in fresh state or in transformed state [6, 7].

In West Africa, particularly in ECOWAS (Economic Community of West African State) countries, where post-harvest losses regularly exceed one-third of the production, processing should become a key step in valuation of mango. However, to date, the mango processing remains a marginal activity, using less than 2 to 5% of harvest. This transformation is carried out in artisanal and semi-industrial units; in addition, very little industries are installed for this activity [8]. Côte d'Ivoire is no exception to this precariousness of the mango processing link.

The majority of studies previously carried out on mango in Côte d'Ivoire had focused on mango diseases and pest attacks [9, 10, 11, 12, 13, 14, 15, 16, 17, 18]. The distribution of mango varieties in orchards was also investigated [19], as well as the influence of harvest time on the quality and ripening of Kent mango variety [20, 21]. Likewise, chemical compositions and nutritional values of cultivated mango varieties had been studied in order to contribute to their valuation [22, 23, 24, 25, 26]. Another work had presented the nutritional values determination of unconventional ruminant feeds made from mango by-product [27]. However, there is very little data on the morphological, physical and biochemical characteristics of mango varieties grown in Côte d'Ivoire. Knowing these characteristics can help better orient the local processing of the different cultivated mango varieties in order to reduce post-harvest losses. It is within this framework that the present work was carried out, which aims to contribute to a better valuation of mango varieties cultivated in Côte d'Ivoire by evaluating their morphological, physical and biochemical parameters.

2. MATERIALS AND METHODS

2.1 Plant Material

The plant material used consisted of ripe fruits of the mango tree (*Mangifera indica* L.) from the three main varieties grown in Côte d'Ivoire: Amelie, Kent and Keitt [4]. These fruits were harvested in Poro region located in the north of Côte d'Ivoire, 635 km from Abidjan and between 9°27 north latitude and 5°38 west longitude. Covered with open forests and shrub savannas, this zone is characterized by a Sudanese-type climate with two seasons: dry season (from October to May) and rainy season (from June to September). The average annual precipitation is 1400 mm in a wet year, and 1000 mm in a dry year [28].

2.2 Methods

2.2.1 Sampling

For each mango variety, from May to June 2020, ten ripe fruits were randomly selected from ten batches of mangoes from different producers (P). The lots themselves were randomly chosen from a set of over forty-five lots for each variety. The fruits were taken in batches (one fruit per batch) and followed by a marking to identify them (noted from P1 to P10 followed by the initial of the variety name: A, Ke and Kt for Amelie, Kent and Keitt, respectively). All the selected fruits had approximately the same stage of maturity.

2.2.2 Morphological characterization of the mango

Fruit and stone length (L), width (w), thickness (t), and fruit circumference (c) were measured using a digital caliper (EHB Stainless, Hardened, Germany) and expressed in centimeters (cm). Length measurement was taken on the polar axis, between the apex and the opposite end, while width and thickness were determined from the center or equator. Fruit volume (V), expressed in cm^3, was calculated by the formula $V = L.t^2.\pi$ [21]. Fruit shape was assessed by caliber index = $\sqrt[3]{L.w.t}$, sphericity index = $\sqrt[3]{L.w.t}/L$ [29] and shape index Is = L/l [30]. Shape index allows varieties to be classified into three (03) shape categories:

- if Is <0.8, the mango is flattened;
- if Is >1, the mango has an elongated shape;
- and if 0.8< Is<1, the mango is round.

2.2.3 Physical characterization of the mango

Fruit mass (M) was measured using a precision balance 0.01 g. After that, the fruit was washed with running water, and cut open lengthwise with a stainless steel knife. The peel and stone were completely separated from the pulp, and the mass of each component of the fruit was also determined by weighing, then divided by fruit mass to obtain its proportion expressed as a percentage (%). All masses were expressed in grams (g). Then, fruit specific gravity (ρ) and index waste (Iw) were calculated according to the following formulas:

$$\rho\ (g/cm^3) = M/V$$
$$Iw = Mpu/(Mpe + Mst)$$

where Mpu, Mpe and Mst represent the masses of pulp, peel and stone, respectively.

The pulp was finely dissociated using a NASCO mixer (Model BL1008A-CB, SOCIAM Company, Abidjan, Côte d'Ivoire). Finally, the resulting mash was put into cups and frozen for subsequent biochemical analyzes.

2.2.4 Biochemical characterization of the mango pulp

From mango pulp, moisture (or dry matter), ash and fiber contents were determined by gravimetry, and pH by potentiometry according to standard methods n° 925.09, 923.03, 984.04 and 981.12, respectively [31]. Moisture content was measured after drying in a vacuum oven (Model UFB 400, Memmert, Schwabach, Germany) at 105 °C. Ash content was quantified after incineration in a muffle furnace (Nabertherm, L5/11/B410 Model, Maximum Temperature of 1200 ºC, Bremen, Germany) at 550 ˚C. Fiber content was estimated after acid hydrolysis followed by alkaline hydrolysis using sulfuric acid (2.04 N) and potassium hydroxide (1.78 N), respectively. pH was measured using a pH-meter (Model HI 8915, Hanna Instruments, Lingolsheim, France). The juice was extracted from the mango pulp by centrifugation using a centrifuge (Model Z 300 K, Hermle Labor-technik, Wehingen, Germany), then filtered through filter paper. The filtrate obtained was homogenized before each sample taking for biochemical analyzes. Titratable acidity, expressed as a percentage (%) of citric acid, was determined by acid-base assay according to the standard method n° 942.15 using phenolphthalein ($C_{20}H_{14}O_4$) as color indicator [32]. Ascorbic acid was quantified by titration method using 2,6 dichlorophenol indophenol according to the standard method n° 967.21 [31]. The result was expressed in mg/100g of pulp. A digital hand-held refractometer (PAL-1, ATAGO Co., Ltd., Tokyo, Japan) was used for the measurement of total soluble solids (TSS) which was expressed in degrees Brix (°Brix) at ambient temperature. Then, total and reducing sugars were estimated by the method described by [33] and expressed as a percentage (%). Non-reducing sugars content was calculated by subtracting reducing sugars from total sugars and multiplying the difference by the factor 0.95 as suggested by [33]. Finally, sugars/acidity ratio was calculated.

2.2.5 Statistical analyzes

The data obtained from the above experiments were subjected to statistical analysis using Statistica 7.1 software. The results were expressed as mean ± standard deviation. And for each parameter, the significance of the difference between the means was analyzed by analysis of variance (ANOVA). When a significant difference was observed between the means, the analysis was followed by Turkey's Honestly Significant Difference (HSD) test for classification of means (*P* = .05).

3. RESULTS

3.1 Morphological Characteristics of the Mango Varieties Studied

Table 1 presents morphological parameters of the mango varieties studied. The three varieties did not demonstrate any significant difference (*P* > .05) in fruit length and width, stone width and thickness, with values oscillating from 12.15 ± 0.61 to 12.35 ± 0.86 cm; 9.94 ± 0.53 to 10.53 ± 0.63 cm; 4.79 ± 0.63 to 4.97 ± 0.81 cm; and 1.55 ± 0.30 to 1.75 ± 0.35 cm, respectively. Kent demonstrated significantly (*P* < .05) higher fruit thickness (6.97 ± 0.35 cm), volume (466.12 ± 66.95 cm^3), and circumference (30.00 ± 1.38 cm) compared to Keitt which had more modest parameters, 6.18 ± 0.30 cm; 367.15 ± 35.00 cm^3; 28.44 ± 0.91 cm, respectively. In contrast, stone length (9.00 ± 0.58 cm) of Keitt was significantly (*P* < .05) higher compared to that (8.21 ± 0.61 cm) of Kent which was the most modest. As for Amelie, these parameters had intermediate values. Fruit size, sphericity and shape indices of the three varieties were not significantly different (*P* > .05), ranging from 9.08 ± 0.29 to 9.62 ± 0.49; 0.74 ± 0.04 to 0.79 ± 0.02; and 1.16 ± 0.04 to 1.23 ± 0.10, respectively.

3.2 Physical Characteristics of the Mango Varieties Studied

Table 2 summarizes physical parameters of the mango varieties studied. Kent had significantly (*P* < .05) higher fruit (457.64 ± 52.11 g) and pulp

Table 1. Morphological parameters of the mango varieties studied

Morphological parameters	Mango varieties		
	Amelie	Kent	Keitt
Fruit length (cm)	12.35 ± 0.86^{a}	12.15 ± 0.61^{a}	12.22 ± 0.58^{a}
Fruit width (cm)	10.33 ± 0.81^{a}	10.53 ± 0.63^{a}	9.94 ± 0.53^{a}
Fruit thickness (cm)	6.58 ± 0.48^{ab}	6.97 ± 0.35^{a}	6.18 ± 0.30^{b}
Fruit volume (cm^3)	423.45 ± 76.57^{ab}	466.12 ± 66.95^{a}	367.15 ± 35.00^{b}
Fruit circumference (cm)	29.34 ± 1.11^{ab}	30.00 ± 1.38^{a}	28.44 ± 0.91^{b}
Stone length (cm)	8.77 ± 0.86^{ab}	8.21 ± 0.61^{b}	9.00 ± 0.58^{a}
Stone width (cm)	4.97 ± 0.81^{a}	4.79 ± 0.63^{a}	4.97 ± 0.53^{a}
Stone thickness (cm)	1.58 ± 0.24^{a}	1.75 ± 0.35^{a}	1.55 ± 0.30^{a}
Caliber index	9.43 ± 0.62^{a}	9.62 ± 0.49^{a}	9.08 ± 0.29^{a}
Sphericity index	0.76 ± 0.03^{a}	0.79 ± 0.02^{a}	0.74 ± 0.04^{a}
Shape index	1.20 ± 0.08^{a}	1.16 ± 0.04^{a}	1.23 ± 0.10^{a}

**All parameters were determinated in triplicate. For each parameter, values with the same superscript letter are not statistically different (P > .05).*

(383.65 ± 52.69 g) masses compared to Keitt which had more modest parameters, 369.74 ± 31.30 g and 308.45 ± 31.34 g, respectively. Kent and Amelie had significantly (*P* < .05) higher stone masses, 29.71 ± 3.29 g and 28.67 ± 6.01 g, respectively, compared to Keitt, whose parameter was more modest, 23.56 ± 3.29 g. For fruit specific gravity, peel mass, pulp, peel and stone proportions, pulp/stone ratio and waste index, the differences between the three varieties were not statistically significant (*P* > .05), with mean values of 1.00 g/cm^3; 43.87 g; 83.22%; 10.69%; 6.61%; 13.04; and 4.92, respectively.

3.3 Biochemical Characteristics of the Mango Varieties Studied

Biochemical parameters of the mango varieties studied are shown in Table 3. Ash and ascorbic acid contents of the three varieties were not significantly different (*P* > .05), with values between 0.44 ± 0.03 and 0.45 ± 0.03%; 45.02 ± 3.06 and 46.25 ± 2.46 mg/100 g, respectively. Kent demonstrated significantly (*P* < .05) higher contents in dry matter (22.20 ± 1.75%), TSS (18.50 ± 0.44 °Brix), total sugars (14.56 ± 0.33%) and, a sugars/acidity ratio (73.46 ± 11.30) compared to the other two varieties. In addition, pH (4.67 ± 0.12) and content in reducing (4.50 ± 0.27%) and non-reducing (9.56 ± 0.46%) sugars of Kent were significantly (*P* < .05) higher than those of any of the other varieties. Moisture content (84.80 ± 2.70%) and TA (0.50 ± 0.13%) of Amelie were significantly (*P* < .05) higher compared to Kent which had more modest parameters. As for Keitt, its fiber content (0.84 ± 0.03%) was significantly (p <0.05) higher than that of the other two varieties. Finally, among thirteen biochemical parameters determined, eight parameters of Kent had the highest values.

Table 2. Physical parameters of the mango varieties studied

Physical parameters	Mango varieties		
	Amelie	**Kent**	**Keitt**
Fruit mass (g)	427.10 ± 69.64^{ab}	457.64 ± 52.11^{a}	369.74 ± 31.30^{b}
Fruit specific gravity (g/cm^3)	1.01 ± 0.02^{a}	0.99 ± 0.04^{a}	1.01 ± 0.02^{a}
Pulp mass (g)	354.64 ± 65.61^{ab}	383.65 ± 52.69^{a}	308.45 ± 31.34^{b}
Pulp proportion (%)	82.70 ± 2.45^{a}	83.62 ± 2.23^{a}	83.33 ± 2.10^{a}
Peel mass (g)	43.79 ± 5.31^{a}	44.28 ± 2.15^{a}	43.53 ± 9.42^{a}
Peel proportion (%)	10.47 ± 2.03^{a}	9.80 ± 10.30^{a}	11.81 ± 2.52^{a}
Stone mass (g)	28.67 ± 6.01^{a}	29.71 ± 3.29^{a}	23.56 ± 3.29^{b}
Stone proportion (%)	6.83 ± 1.61^{a}	6.58 ± 1.15^{a}	6.41 ± 1.03^{a}
Pulp/Stone Ratio	12.71 ± 2.97^{a}	13.08 ± 2.44^{a}	13.33 ± 2.28^{a}
Waste Index	4.87 ± 0.72^{a}	5.20 ± 0.79^{a}	4.69 ± 0.83^{a}

**All parameters were determinated in triplicate. For each parameter, values with the same superscript letter are not statistically different (P > .05).*

Table 3. Biochemical parameters of the mango varieties studied

Biochemical parameters	Mango varieties		
	Amelie	**Kent**	**Keitt**
Moisture (%)	84.80 ± 2.70^{a}	77.80 ± 1.75^{b}	82.80 ± 3.16^{a}
Dry matter (%)	15.20 ± 2.70^{b}	22.20 ± 1.75^{a}	17.20 ± 3.15^{b}
Ash (%)	0.45 ± 0.03	0.44 ± 0.03	0.44 ± 0.03
Fiber (%)	0.53 ± 0.04^{b}	0.58 ± 0.16^{b}	0.84 ± 0.03^{a}
pH	4.58 ± 0.21^{ab}	4.67 ± 0.12^{a}	4.41 ± 0.30^{b}
Titratable acidity or TA (%)	0.50 ± 0.13^{a}	0.20 ± 0.03^{b}	0.40 ± 0.13^{a}
Ascorbic acid (mg/100 g)	45.10 ± 3.52	46.25 ± 2.46	45.02 ± 3.06
Total soluble solids or TSS (° Brix)	15.51 ± 0.29^{c}	18.50 ± 0.44^{a}	16.49 ± 0.36^{b}
Total sugars (%)	13.03 ± 0.06^{c}	14.56 ± 0.33^{a}	13.30 ± 0.26^{b}
Reducing sugars (%)	3.10 ± 0.53^{b}	4.50 ± 0.27^{a}	4.33 ± 0.29^{a}
Non-reducing sugars (%)	9.43 ±0.53^{a}	9.56 ± 0.46^{a}	8.53 ± 0.41^{b}
sugars/acidity ratio	27.69 ± 7.58^{b}	73.46 ± 11.30^{a}	35.59 ± 9.56^{b}

**All parameters were determinated in triplicate. For each parameter, values with the same superscript letter are not statistically different (P > .05).*

4. DISCUSSION

4.1 Morphological Characteristics

Fruit volumes of Kent and Keitt were lower than those, respectively 514.48 and 488.83 cm^3, reported for the same varieties grown in Chad [34]. On the other hand, fruit volume of Kent was higher than those, between 353.91 and 428.58 cm^3, reported for Kent also from the North of Côte d'Ivoire, and harvested on four harvest periods: 90, 95, 100 and 105 days after inflorescence [21]. Furthermore, in their study on mango Boko in Congo, [35] found a fruit volume of 380 cm^3 which is lower than those of Kent and Amelie; but, superior to that of Keitt. Thus, the mangoes Kent and Amelie were obviously larger than those of Keitt. However, when ripe, the three mango varieties studied had a specific gravity close to 1 g/cm^3. So they could therefore float on water. The buoyancy of ripe mangoes can be used as a sorting process for ripe and unripe fruits when harvesting and transporting mangoes.

Stone lengths, widths and thicknesses of Kent and Keitt were close to the recorded values, respectively 8.01 and 9.87 cm; 4.31 and 4.58 cm; 2.01 and 1.76 cm, for the same varieties cultivated in Chad [34]. Stone length and width of Kent and Keitt were also close to the values, respectively 8.70 and 8.17 cm; 5.02 and 4.50 cm, reported for the same varieties cultivated in Mozambique [36]. However, these varieties from Mozambique had a stone thickness, 0.40 cm [36], significantly less. For the variety Kent cultivated in northwestern Peru, [37] reported stone length and thickness, respectively 8.05 cm and 2.05 cm, quite close to those obtained in this study; but these authors recorded a stone width, 3.65 cm, significantly less. According to [38], stone (endocarp) is generally flattened at the edges, more or less swollen in the middle, longer than wide. Its shape is oval or kidney-shaped. In addition, [39] reported that the fruits of improved varieties, such as Amelie, Kent and Keitt, have a small flattened stone.

Mango caliber index is an important quality criterion which is determined from the fruit dimensions (length, width and thickness). This parameter did not vary significantly between the three varieties. Indices caliber of Kent and Keitt were close to those, respectively 9.72 and 9.52, reported for the same varieties grown in Chad [34]. In contrast, the three varieties demonstrated higher caliber indices than that of the mango cultivar Boko from Congo, which was 8.62 when length (L); width (w) and thickness (e) are expressed in cm [35]. Moreover, according to [40], fruit caliber depends on the accumulation of water and dry matter in the three compartments of the fruit: stone, pulp and peel.

Sphericity and shape indices of Kent and Keitt from Côte d'Ivoire were similar to those of the same varieties from Chad, which were respectively 0.88 and 0.79; 1.12 and 1.29 [34]. For the cultivar Boko from Congo, [35] obtained a sphericity index of 0.88 which is also similar to those of the three varieties studied. These results show that the mangoes Amelie, Kent and Keitt cultivated in Côte d'Ivoire were all elongated in shape because their shape index is higher than 1. The oblong shape of mangoes, independently to the varieties, shows that this characteristic could be determined genetically.

4.2 Physical Characteristics

In their study on varieties also cultivated in the north of Côte d'Ivoire, [23] reported higher fruit masses of Amelie and Kent, respectively 499.69 and 580.87 g, compared to our results; while fruit mass of Keitt was quite close to that recorded by these authors, which was 353.23 g. In previous work, several authors reported higher fruit masses compared to our results for Amelie, Kent and/or Keitt from Burkina Faso [41], Nigeria [42], Cameroon [34], Mozambique [36], Egypt [43] and Peru [37]. Nevertheless, the three varieties studied can all be exported to the European market because their fruit masses correspond to the caliber group B established by the mango standard [44]. In addition, mass fruit of Kent is in the caliber range (between 450 and 650 g) of the mangoes that most importing and consuming countries in the European Union (EU) prefer according to [45].

Pulp, peel and stone proportions of the three varieties were not significantly different. Pulp proportions were higher than those, between 72.93 and 82.34%, reported for Amelie, Kent and/or Keitt from Burkina Faso [41], Nigeria [42], Cameroon [34], Sudan [46] and Peru [37]. However, they were lower than the results (between 92.00 and 92.50%) recorded for Kent and Keitt from Egypt [43]. Peel proportions of Amelie, Kent and Keitt were comparable to those obtained for the same varieties from Burkina Faso [41], and for Kent from Peru [37]. However, they were superior to peel proportions of the same varieties also from Côte d'Ivoire, which were respectively 4.43, 3.86 and 6.16% [23]. In addition, they were lower than that (16.25%) of Kent from Nigeria [42]. Stone proportions were lower than those, between 7.00 and 10.81%, reported for Amelie, Kent and/or Keitt from Burkina Faso [41], Nigeria [42], Egypt [43] and Peru [37]. Pulp is the mango edible part. With regard to the high values of their pulp proportions (82.70 ± 2.45% - 83.62 ± 2.23%), pulp/stone ratios (12.71 ± 2.97 - 13.33 ± 2.28) and waste indices (4.69 ± 0.83 - 5.20 ± 0.79), the three varieties studied showed interesting aptitudes for industrial processing. According to [47], pulp/stone ratios and waste indices are a good indicator of the suitability of different mango varieties for industrial processing.

4.3 Biochemical Characteristics

The study of mangoes biochemical parameters is necessary and important to assess the suitability of mango varieties for industrial processing. Among 13 biochemical parameters determined, eight parameters (pH, dry matter, TSS, total sugars, reducing sugars and non-reducing sugars, sugars/acidity ratio) of Kent had the highest values. Moisture content and TA of Amelie were the highest. As for Keitt, its fiber content was higher than that of Amelie and Kent. However, the three varieties (Amelie, Kent and Keitt) had fairly similar pulp ash and ascorbic acid contents. These results would be due to the fact that the mangoes Kent had a more advanced level of maturity compared to the mangoes Amelie and Keitt. Indeed, fruits sugars/acid ratio is a quality attribute and an indicator of fruit maturity [48]. In addition, according to [49], the mango chemical characteristics vary according to the variety and the ripeness level.

Moisture content of the varieties studied, ranging from 77.80 ± 1.75 to 84.80 ± 2.70%, indicated that the mango samples were fresh because moisture content of fresh fruits ranges from 65% to 95% according to [50]. Total fiber contents obtained in the present study were lower than those, ranging from 1.87% to 2.77%, recorded for Amelie, Kent and Keitt from Burkina Faso [41]. Total fiber contents obtained were lower than those obtained for Amelie from Cameroon [49], Kent from Nigeria [42] and Keitt from Mozambique [51], which were respectively 0.7%; 1.11% and over 1.34%. With less fibrous pulp, the mango varieties studied would be suitable for making candies, mash, juice or ice cream; and are more accepted by consumers according to [6].

pH and TA are the parameters through which the overall content of organic acids is evaluated. The highest pH was recorded for Kent (4.67 ± 0.12). Conversely, TA (0.20 ± 0.03%) of Kent was the lowest. Keitt exhibited the lowest pH (4.41 ± 0.30); however, Amelie recorded the highest TA (0.50 ± 0.13%). For Amelie and Kent, pH values obtained in the present study were higher than those obtained, respectively 3.71 and 3.93, for varieties from Burkina Faso [41]. However, TA obtained were lower than those (respectively 1.56% and 1.49%) found by the same author. Furthermore, pH values were similar to those of Kent and Keitt from Cameroon, respectively 4.56 and 4.61 [52]; but lower than that (5.52) of Kent from Nigeria [42]. TAs were comparable to those of Kent and Keitt from Mozambique [36] and Egypt [43], which were respectively 0.29 and 0.44%; 0.32 and 0.23%. The results obtained showed that TAs of the three varieties studied were low, corresponding to high pH values. Indeed, when TA decreases, pH increases [53]. The decrease in TA is due to the transformation of organic acids into sugars during mango ripening [54].

Kent had the highest TSS and total sugars, 18.50 ± 0.44 °Brix and 14.56 ± 0.33%; while those of Amelie, 15.51 ± 0.29 °Brix and 13.03 ± 0.06%, were the lowest. These results showed that TSS content is positively correlated with total sugars content in fruits. A study of 15 mango varieties from Sudan [55] and another concerning 8 varieties of Nigerian mangoes [56] also demonstrated that TSS and total sugars contents evolve in the same direction. In addition, TSS contents (in °Brix) of the three varieties were above the minimum Brix value recommended for reconstituted fruit juices and reconstituted purees, which is 13.5 °Brix [57].

Total sugars content and sugars/acidity ratio are two important parameters for measuring fruit quality [47, 58]. Sugars/acidity ratio determines fruit flavor and its acceptability by the consumer. According to [59], fruits with good flavor have a high sugars/acidity ratio while fruits with a lower flavor have a low ratio. In the present study, Kent recorded the highest sugars/acidity ratio (73.46 ± 11.30) due to its higher total sugars content and lower TA. While Amelie exhibited the lowest sugars/acidity ratio (27.69 ± 7.58) due to its lower total sugars content and higher TA. Sugars/acidity ratio of Kent in the present study was higher than those, between 14.26 and 67.62, obtained for eight Nigerian varieties [56]. According to [48], mango varieties with intense yellow-orange color, soft texture and low sugars/acidity ratio are used for making mango puree, concentrates and drinks; while the varieties which have a high sugars/acidity ratio, a more intense texture are used for drying and for making frozen or canned mango pieces. In view of these observations, mangoes Amelie and Keitt could be adapted for the manufacture of purees, concentrates and drinks. As for mango Kent, it would be suitable for drying and making frozen or canned pieces of mango.

5. CONCLUSION

The mangoes Kent and Amelie were obviously larger than those of Keitt. However, when ripe, the three mango varieties studied had a specific gravity close to 1 g/cm^3. So, they could float on water. Caliber, sphericity and shape indices of the three varieties did not differ significantly. They revealed that the mango varieties studied were elongated in shape and corresponded to the caliber group B of mangoes exportable to the European market. Pulp, peel and stone proportions of the three mango varieties were not significantly different. In addition, in view of their high values of pulp proportions, pulp/stone ratios and waste indices, the three mango varieties studied showed interesting aptitudes for industrial processing. Pulp biochemical analysis of mango varieties demonstrated high moisture contents, low fiber contents and acidity values, interesting ascorbic acid contents, TSS contents conforming to the general standard for fruit juices and nectars. These results suggest that the mango varieties studied would be suitable for making mash, juice or ice cream. However, mango variety Kent, with the higher sugars/acidity ratio, would be more suitable for drying and making frozen or canned mango pieces. As for mango varieties Amelie and Keitt, with lower sugars/acidity ratios, they would be more suitable for making purees, concentrates and drinks. The results of this study could guide processors in the choice of varieties according to the types of derived products. They are interesting and should be deepened by including other varieties (improved and local) cultivated in Côte d'Ivoire.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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