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Evaluation of Physicochemical, Nutritional and Antioxidant Parameters of Pulp During Post-harvest Ripening of Kent Variety Mango from Northern Côte d'Ivoire

Bosson Anoman Jean-Claude[1,2], Touré Abdoulaye[1,3,*], Zoro Armel Fabrice[1,2], Kablan Ahmont Landry Claude[1,4], Coulibaly Adama[3], Zoué Lessoy Yves Thierry[2]

[1]Biotechnology and Valorization of Agroresources and Natural Substances Laboratory, Peleforo GON COULIBALY University, BP 1328 Korhogo, Côte d'Ivoire
[2]Biotechnologie Laboratory, Félix HOUPHOUET-BOIGNY University, 22 BP 582 Abidjan 22, Côte d'Ivoire
[3]Biochimic Pharmacodynamy Laboratory, Félix HOUPHOUET-BOIGNY University, 22 BP 582 Abidjan 22, Côte d'Ivoire
[4]Organic Chemistry and Natural Substances Laboratory, Félix HOUPHOUET-BOIGNY University, 22 BP 582 Abidjan 22, Côte d'Ivoire
*Corresponding author: tourabdoulaye@yahoo.fr

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Abstract Widely grown in Northern Côte d'Ivoire, mangoes (*Mangifera indica* L.) are exploited for local consumption, export and processing. These different uses of mangoes are based on some of their pulps properties. Thus objective of this study is to evaluate physicochemical, nutritional and antioxidant of pulp during post-harvest ripening of Kent variety mango. Different variation of constituents of pulp from Kent variety were analyzed during twelve (12) days of post-harvest ripening. The physicochemical parameters study are moisture, pH, acidity, ash and soluble dry extract. Nutritional constituents related to proteins, fibers, reducing sugars, total sugars and minerals (Ca, Mg, K, P, Fe, Zn and Cu). For antioxidant constituents, vitamin C, carotenoids, polyphenols, flavonoids and tannins of mango pulps are determined. The results of physicochemical analyzes showed that values of moisture and acidity decreased during the 12 days of ripening of Kent variety. These parameters decreased from 79.82±0.30 to 77.09±0.05 % (moisture) and 27.03±0.51 to 4.74±0.36 meq/100g (acidity). The ash composition increased from 0.35±0.02 to 0.40±0.01 % until the 6th day. From the 6th to 12th day, ash value decreased from 0.40±0.01 to 0.32±0.01 %. The pH and soluble dry extract of mango pulp increased respectively form 3.83±0.05 to 4.98±0.12 and 10.90±0.10 to 23.00±0.01 °Brix until the 12th day of post-harvest ripening. For nutritional constituents of mango pulp, proteins increased from 0.59±0.03 to 0.79±0.02 % until the 10th day. They decreased between the 10th and 12th day from 0.79±0.00 to 0.70±0.00 %. Reducing sugars and total sugars increased until the 12th day of post-harvest ripening respectively from 4.11±0.24 to 12.00±0.47 % and 8.83±0.17 to 19.57±0.13 %. Fibers decreased from 2.54±0.04 to 1.53±0.05 % during the 12 days of ripening. Apart from Zn, whose was constant (0.03±00 %), contents of other minerals had increased during the 12 days of ripening. Thus, the high increased were recorded with Mg (24.77±0.65 to 28.70±0.24 %), P (18.01±0.31 to 22.15±0.16 %) and K (237.70±1.07 to 249.16±0.14 %). The low increasing of minerals of mango pulp was observed with Ca (20.44±0.10 to 21.24±0.10 %), Fe (1.05±0.05 to 1.48±0.02 %) and Cu (0.05±0.01 to 0.11±0.01 %). For antioxidant compounds, high variation in mango pulp was recorded during the 12 days of ripening. Vitamin C content decreased from 15.33 to 4.5 mg/100g. Carotenoids and polyphenols increased with respective values from 11.45 to 41.79 mg/100g and 135.25 to 64.31 mg/100g. This study showed that it is between 6th and 8th day of post-harvest ripening at 25°C that Kent variety has interesting physicochemical, nutritive and antioxidant potentials.

Keywords: *Kent variety, Mangifera indica L., physicochemical, nutritional, antioxidant, post-harvest ripening*

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1. Introduction

Mango is the fruit of mango tree which belongs to Anacardiaceae family and Mangifera genus which includes 69 species with edible fruits only in some species. *Mangifera indica* is the only species that is cultivated and marketed among all species [1]. It is an excellent source of bioactive compounds such as carotenoids, provitamin A, vitamin C and phenolic compounds, as well as dietary fiber, which is essential to human nutrition and health [2,3]. Additionally, mango is known to contain vitamins, carbohydrates and minerals such as calcium, iron and potassium, and to be low in calories and fat [4]. Furthermore, its consumption could provide an energy intake of about 2400kcal/day, equivalent to the calorific need of a resting adult [5]. World mango production reached 51 million tons in 2019. In Africa, the two countries most present on the world mango market are Côte d'Ivoire and South Africa, which successively rank 11th and 9th in the world's export ranking [6]. In Côte d'Ivoire, the Northern zone is the main mango production zone. The highly productive region remains the Savanes district located beyond 9° north latitude [7]. Ivorian mango production was estimated at 150,000 tons [8]. This production constitutes on the one hand a substantial source of income for farmers. Its marketing generates more than 7 billion FCFA in revenue and provides producers with around 1 billion FCFA in annual income [9]. Mango has been designated as a functional food for the prevention and control of metabolic disorders, obesity-related chronic diseases, fatty liver disease and other comorbidities [10].

However, despite the nutritional and economic importance of mango, not all Ivorian production is sold on international markets. According to [8] only 21.6% of production is exported. Producers are oriented towards local consumption which unfortunately cannot absorb all the non-exported production. This situation leads to post-harvest losses and a drop in producer income. To limit these losses, non-exported mangoes are processed into pulps, purees, jams and jellies, frozen products, canned products and dehydrated products [11]. However, factors such as variety and ripening stage can have a great influence on the nutritive and bioactive composition of the mango [12]. Thus, its nutritive and bioactive potential could differ during the ripening process.

Therefore, if mango is to be used as a functional food to improve health or as an ingredient for the food industry, knowledge of changes in nutrient and bioactive compounds during ripening is essential for selecting the most appropriate stage of ripening [12]**.** Thus, monitoring evolution of physicochemical, nutritive and antioxidant compounds is necessary to maximize functional potential of mango. This in order to produce high quality functional and nutraceutical products with mango.

Hence, in order to determine most appropriate quality of Kent variety, this study aims to evaluate its pulp physicochemical, nutritive and antioxidant compounds during ripening.

2. Materials and Methods

2.1. Materials

2.1.1. Biological Material

The biological material consists of Kent variety mangoes from orchards in Korhogo (northern Côte d'Ivoire).

2.1.2. Chemicals

All solvents (n-hexane, petroleum ether, acetone, ethanol and methanol) were purchased from Merck. Standards used (glucose, gallic acid, tannic acid, quercetin, beta-carotene) and reagents (metaphosphoric acid, vanillin, Folin-Ciocalteu, DPPH) were purchased from Sigma-Aldrich. All chemicals used in the study were of analytical grade.

2.1.3. Technical Materials

These materials used were blender (Nasco, South Korea), oven (Memmert, Germany), muffle furnace (Pyrolabo, France), pH-meter (Hanna, Spain), Kjeldhal apparatus, spectrophotometer (PG Instruments, England), flame emission photometer (Sherwood Flame Photometer 410), atomic absorption spectrophotometer (AAS model, SP9).

2.2. Methods

2.2.1. Preparation of Mango Pulp Samples

The Kent variety mangoes selected for study were washed with distilled water and stored in laboratory at 25°C for post-harvest ripening. A sample of mangoes was selected on the starting day of ripening (day 0) for their pulps analyses. The same operation was repeated every 2 days during ripening for 12 days (day2, day4, day6, day8, day10 and day12). The selected mangoes for each 2 days were peeled and their pulps separated from the kernel. These pulps were crushed using a blender (Nasco, South Korea). The physicochemical, nutritional and antioxidant constituents of mango crushed pulps were analyzed for each 2 days.

2.2.2. Physicochemical Analysis

Moisture and ash and were determined using [13] official methods. The moisture content was determined by the difference of weight before and after drying pulp (10 g) in an oven (Memmert, Germany) at 105°C until constant weight. Ash fraction was determined by the incineration of crushed pulp (5 g) in a muffle furnace (Pyrolabo, France) at 550°C for 12 h. The percentage residue weight was expressed as ash content. pH was determined as follow: 10 g of crushed pulp was homogenized with 100 mL of distilled water and then filtered through Whatman No. 4 filter paper. The pH value was recorded after the electrode of pH-meter (Hanna, Spain) was immersed into the filtered solution. For acidity 10 mL of filtrate or nectar have been titrated by NaOH 0.1N. The soluble dry extracts of Kent mango pulp were measured using a

refractometer. A drop of crushed pulp was placed on the screen of a refractometer and the value of soluble dry extracts was read directly in its eyepiece.

2.2.3. Nutritional Analysis

Proteins were determined through the Kjeldhal method [13]. The total sugars were determined by the phenol method [14]. 0.50 g of crushed pulp was introduced into a test tube containing 0.50 mL of sulfuric acid (12 N). The reaction medium was kept at ambient temperature (25 °C) during 1 hour before boiling it for two hours in a water bath (100 °C). Then, to the boiling medium, were added successively 5.50 mL of distilled water, 10 mL of ethanol (70%), 0.5 mL of zinc sulfate (2 g/100 mL) and 0.5 mL of potassium ferrocyanide (10.6 g / 100 mL). The mixture was filtered and the filtrate was adjusted to 50 mL with distilled water. To 0.2 mL of the filtrate was successively added 0.50 mL of phenol (5%) and 2.50 mL of sulfuric acid. After for 10 minutes at ambient temperature, the mixture is well homogenized and the absorbance was read with a spectrophotometer at 490 nm. The total sugars content was determined using a calibration curve of glucose (10 mg/100 mL) as standard. Reducing sugars content of crushed pulp was determined according to [15]**.** 1 g of crushed pulp is dissolved in 50 mL of warm distilled water.

After filtration, the volume is completed at 100 mL. To 1 ml of solution were added successively 0.5 ml of distilled water and 0.5 ml of DNS. After for 5 minutes at ambient temperature, the absorbance was read with a spectrophotometer at 580 nm. For crude fibers [16] 2 g of crushed pulp were digested with 0.25 M sulphuric acid and 0.3 M sodium hydroxide solution. The insoluble residue obtained was washed with hot water and dried in an oven (Memmert, Germany) at 100°C until constant weight. The dried residue was then incinerated and weighed for the determination of crude fibers content. The minerals contents in mango pulp were carried out according to the method described by [17]. 5g of pulp were burned to ashes in a muffle furnace. The ashes obtained were dissolved in 10 mL of HCl/HNO3, transferred into 100 mL flasks and the volume was made up using deionized water. For mineral compositions of sample, calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn) and copper (Cu) compositions were determined using atomic absorption spectrophotometer (AAS model, SP9). Potassium (K) was analyzed by using flame emission photometer (Sherwood Flame Photometer 410) with KCl as standard [18]. Phosphorus (P) was determined as phosphate by vanadium phosphomolybdate colorimetric method reported by [19].

2.2.4. Antioxidant Compounds Analysis

Vitamin C contained in mango pulp was determined by titration using the method described by [20]. Ten (10) g of crushed pulp were soaked for 10 min in 40 mL of solution of metaphosphoric acid-acetic acid (2%, w/v). The mixture was centrifuged at 3000 rpm for 20 min and the supernatant obtained was diluted and adjusted with 50 mL of bi-distilled water. Ten (10) mL of this mixture was titrated to the end point with dichlorophenol-indophenol (DCPIP) 0.5 g/L. For carotenoids content was carried out according to [21]. Two (2) g of crushed pulp were mixed three times with 50 mL of acetone until loss of pigmentation. The mixture obtained was filtered and total carotenoids were extracted with 100 mL of petroleum ether. Absorbance of extracted fraction was then read at 450 nm by using a spectrophotometer (PG Instruments, England). Total carotenoids content was subsequently estimated using a calibration curve of beta-carotene (1 mg/mL) as standard.

The polyphenols content was determined using the method reported by [22]. A quantity (1 g) of crushed pulp was soaked in 10 mL of methanol 70 % (w/v) and centrifuged at 1000 rpm for 10 min. An aliquot (1 mL) of supernatant was oxidized with 1 mL of Folin-Ciocalteu's reagent and neutralized by 1 mL of 20 % (w/v) sodium carbonate. The reaction mixture was incubated for 30 min at ambient temperature. Absorbance was the measured at 745 nm by using a spectrophotometer (PG Instruments, England).

The total flavonoids content was evaluated using the method reported by [23]. Briefly, 0.5 mL of the methanolic extract was mixed with 0.5 mL methanol, 0.5 mL of AlCl3 (10%, w/v), 0.5 mL of potassium acetate (1 M) and 2 mL of distilled water. The mixture was allowed to incubate at ambient temperature for 30 min. Thereafter, the absorbance was measured at 415 nm by using a spectrophotometer (PG Instruments, England).

Tannins of samples were quantified according to [24]. For this, 1 mL of the methanolic extract was mixed with 5 mL of vanillin reagent and the mixture was allowed to incubate at ambient temperature for 30 min.

Thereafter, the absorbance was read at 500 nm by using a spectrophotometer (PG Instruments, England).

2.2.5. Statistical Analysis

The statistical analyses were performed with Graph Pad Prism software version 8.0.2 (263). The variance analysis (ANOVA) was performed to determine differences between the averages according to method of Turkey at the 5% threshold ($p<0.05$ was considered significant). The results were expressed as averages with standard error on mean (mean ± SEM).

3. Results and Discussion

Table 1 presents physicochemical and nutritional properties of Kent variety according to its stage of ripening.

For physicochemical parameters, moisture content decreased significantly from 2nd day (79.82±0.30 %) to 8th day (77.71±0.31 %). It remained then stable until the 10th day (77.25±0.13 %). This decrease of moisture was also observed by [23] during the ripening of the Apple variety in Kenya. Our results are contrasted with those of [24] during the ripening of the Keitt variety in Ghana. This decrease could be due to fact that mango belongs to so-called climacteric fruit family. These fruits continue to breathe during ripening, which results in gas exchange leading to transpiration and other metabolic processes related to senescence [25,26]. This reduction of moisture could be advantageous since it allows a better concentration of dry matter. Concerning pH, it increase form 3.83±0.05 to 4.98±0.12 during ripening, which is inversely correlated with acidity (27.03±0.51 to 4.74± 0.36 meq/100g). This pH increase was observed by [24]

and [27] in the Keitt variety (2.47 to 3.90) and in the plantain banana (3.51 to 5.31) respectively. This acidity decrease could be due to the use of mango acids as a substrate during respiration and could have an impact on the sweet taste [28]. The soluble dry extract of Kent variety study increased form 10.90±0.10 to 23.00±0.01 °Brix during ripening. Our results are superior to those of [24] during ripening of the Keitt variety (7.00±0.04 to 15.95±0.03 °Brix) in Ghana and [23] of the Kent variety (7.00±0.10 to 14.50±0.10 Brix) in Kenya. After the 6th day of ripening, the soluble dry extract is greater than 16°Brix. These mangoes would be suitable for winemaking. For nectar production, mangoes ripened for 6 days should be used [25]. The ash contents of Kent variety are statistically identical until the 10th day with an average of 0.37 mg/100g. At the 12th day the ash content decreases until 0.32mg/100g. The work of [25] showed that this did not vary during the ripening of the Kent variety. Ash during ripening are lower than those of orange which are 0.68 mg/100g [31].

According to nutritional constituent variation in Kent variety pulp, protein content increased from 0.59±0.03 to 0.79±0.02 % until the 10th day of ripening. This trend was observed by [25] on Apple variety in Kenya (0.04 to 0.11 %) and by [29] in plantain bananas. This increase could be due to plenty of proteins in pulp during sweating. Fibers decrease as ripening progresses (2.54±0.04 to 1.53±0.05 %). The decrease in fibers was also reported by [32] during the ripening of the Dodo and Viringe varieties. This slight decrease could be due to action of pectinases which degrade insoluble pectins to soluble pectin [33,34]. An increase of reducing sugars (4.11±0.24 to 12.00±0.47 %) and total sugars (8.83±0.17 to 19.57±0.13 %) were observed during ripening. This increase of sugar levels would be due to hydrolysis of starch to simple sugars under action of amylases [35,36].

Table 2 shows evolution of minerals contents in Kent variety pulp during ripening. Apart from Zn, whose concentration was constant (0.03±01 %), contents of other minerals were statistically increased until 8th day of ripening. Thus, the high concentrations increased were recorded with Mg, P and K. The slight increase of minerals contents of mango pulp was observed with Ca, Fe and Cu. The no-variation of minerals until the 8th day was also observed by [29] during ripening of plantain bananas. The slight increase observed to could be due to migration of minerals from pericarp to pulp [37]. Potassium remains the highest mineral in mango.

Figure 1 shows evolution of antioxidant compounds according to ripening stage. Vitamin C, carotenoids and polyphenols were statistically different. Vitamin C levels were drastically reduced. On 2nd day this content was 15.33 mg/100g to be found on the 12th day at 4.5 mg/100g. This trend was observed by [26] in Keitt variety. This decrease could be due to sensitivity of vitamin C to ambient temperature and action of vitamin C oxidases during peeling [38]. It would be no benefit to consumer since vitamin C is an antioxidant that fights oxidative stress [39]. Carotenoid levels increased with ripening from 11.45 to 41.79 mg/100g. These results were in agreement with those of [40] who observed an increase of carotenoids in Keitt (12.3 to 38 µg/g) and Tommy Atkins (17 to 51.2 µg/g) varieties. This increase could be benefit for consumer because of carotenoids are precursors of vitamin A. The polyphenols content was obtained using a calibration curve of Gallic acid (1 mg/mL) as standard. These compounds decrease when ripening was prolonged (135.25 to 64.31 mg/100g). Polyphenols appear to be more sensitive to temperature and oxygen which cause them to oxidize by polyphenoloxidases and peroxidases during peeling. Consumption of mangoes after 8th day of ripening could be benefit to fight against cellular aging because polyphenols are known for their antioxidant activity and their ability to scavenge free radicals [41,42].

Table 1. Physicochemical and nutritional parameters variation during post-harvest ripening (days) of Kent mango

Parameters	Day0-2	Day4	Day6	Day8	Day10	Day12
Moisture (%)	79.82±0.30^{a}	79.22±0.21^{b}	78.85±0.07^{c}	77.71±0.31^{d}	77.25±0.13^{d}	77.09±0.05^{f}
pH	3.83±0.05^{f}	4.21±0.02^{e}	4.34±0.05^{d}	4.50±0.04^{c}	4.60±0.01^{b}	4.98±0.12^{a}
Acidity (meq/100g)	27.03±0.51^{a}	16.11±0.05^{b}	12.11±0.21^{c}	9.60±0.65^{d}	6.25±0.02^{e}	4.74±0.36^{f}
Ash (%)	0.35±0.02^{ab}	0.38±0.01^{a}	0.40±0.01^{a}	0.38±0.01^{a}	0.36±0.01^{ab}	0.32±0.01^{c}
Proteins (%)	0.59±0.03^{e}	0.63±0.02^{d}	0.63±0.03^{d}	0.74±0.01^{b}	0.79±0.02^{a}	0.70±0.01^{c}
Fibers (%)	2.54±0.04^{a}	2.42±0.04^{b}	2.29±0.04^{c}	2.01±0.17^{d}	1.74±0.25^{d}	1.53±0.05^{e}
Reducing sugars (%)	4.11±0.24^{f}	5.36±0.67^{e}	7.62±0.24^{d}	9.12±0.31^{c}	10.92±0.49^{b}	12.00±0.47^{a}
Total sugars (%)	8.83 ±0.17^{e}	9.11 ±0.12^{e}	14.45 ±0.39^{d}	17.18 ±0.28^{c}	18.49 ±0.06^{b}	19.57 ±0.13^{a}
Soluble dry (°Brix) extract	10.90±0.10^{f}	12.76±0.05^{e}	16.60±0.17^{d}	18.70±0.17^{c}	21.43±0.05^{b}	23.00±0.01^{a}

Values given are the averages of at least three experiments ±SE. Values followed by different superscript on the same column are significantly different (P=0.05).

Table 2. Evolution of minerals compositions during post-harvest ripening (days) of mango Kent variety

Composition (mg/100g)	Day 0-2	Day4	Day6	Day8	Day10	Day12
Calcium	20.44±0.10^{c}	19.82±0.52^{c}	19.47±0.17^{c}	20.12±0.08^{c}	21.77±0.08^{a}	21.24±0.10^{b}
Magnesium	24.77±0.65^{c}	25.35±0.92^{c}	26.45±0.68^{c}	27.35±0.46^{c}	28.14±0.17^{b}	28.70±0.24^{a}
Potassium	237.70±1.07^{e}	236.54±0.43^{e}	239.44±0.50^{d}	246.56±0.86^{c}	250.57±0.30^{a}	249.16±0.14^{b}
Phosphorus	18,01±0.31^{e}	18.53±0,08^{d}	19.22±0.08^{c}	19.67±0.58^{c}	21.42±0.36^{b}	22.15±0.16^{a}
Iron	1.05±0.05^{e}	1.12±0.01^{d}	1.16±0.02^{c}	1.39±0.05^{ab}	1.45±0.01^{a}	1.48±0.02^{a}
Zinc	0.03±0.01^{a}	0.03±0.01^{a}	0.03±0.01^{a}	0.03±0.01^{a}	0.03±0.01^{a}	0.03±0.01^{a}
Copper	0.05±0.01^{b}	0.06±0.01^{b}	0.06±0.01^{b}	0.07±0.01^{b}	0.10±0.01^{a}	0.11±0.01^{a}

Values given are the averages of at least three experiments ±SE. Values followed by different superscript on the same column are significantly different (P=0.05).

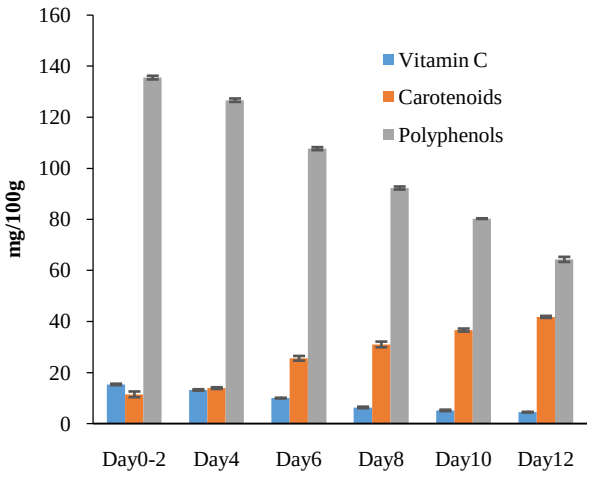

Figure 1. Evolution of phytochemical compounds compositions during twelve (12) days of post-harvest ripening of mango Kent vatiety

Figure 2 shows evolution of flavonoid and tannins contents during ripening of mango (Kent). The flavonoids and tannins contents were determined respectively using a calibration curve of quercetin (0.1 mg/mL) and tannic acid (2 mg/mL) as standard. Contents of these compounds were statistically identical until 4th day of ripening. After the 4th day, their contents decreased when ripening time was prolonged. The decrease in flavonoids (25.13 to 9.04 mg/100g) was also observed by [43] in dates (7.30 ± 0.08 to 5.65 ± 0.06 mg/100 g). These results are contrary to those of [44] which obtained an increase of flavonoids in dates in Jordan. This decrease in flavonoids could be due to the action of light and oxygen during peeling [45]. For tannins, the observed decrease is similar to those of [43] in dates in Algeria (598.79 ± 14.02 to 268.29 ± 3.91 mg/100g). This decrease could be explained by the hydrolysis of hydrolysable tannins.

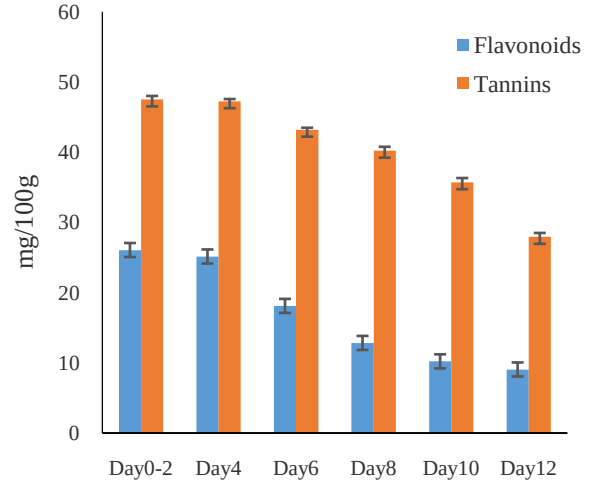

Figure 2. Evolution of flavonoids and tannins as function of ripening stage

4. Conclusion

The Kent variety is one of the main mango produced in northern Côte d'Ivoire. This study was conducted to determine the favorable period when this variety of mango has interesting physicochemical, nutritional, and antioxidant properties for uses. Different variation of constituents of pulp from Kent variety were analyzed during twelve (12) days of post-harvest ripening. This research work showed that the ripening stage of Kent variety influences the availability of its physicochemical, nutritional and antioxidant constituents. The physicochemical analyzes showed that values of moisture and acidity decreased during the 12 days of ripening. The ash composition increased until the 6th day and decreased from the 6th to 12th day. The pH and soluble dry extract of mango pulp increased until the 12th day. For nutritional constituents of mango pulp, proteins increased until the 10th day and decreased between the 10th and 12th day. Reducing sugars and total sugars increased until the 12th day. Fibers decreased during the 12 days of ripening. Apart from Zn, whose was constant, contents of other minerals had increased during the 12 days. Thus, the high increased were recorded with Mg, P and K. The low increasing of minerals of mango pulp was observed with Ca, Fe and Cu. For antioxidant compounds, high variation in mango pulp was recorded during the 12 days of ripening. Vitamin C content decreased when carotenoids and polyphenols increased. These properties of Kent variety were potentially suitable for different uses between 6th and 8th day of post-harvest ripening at 25°C. This research work has resulted in essential data for the optimal uses of Kent variety to export or processing.

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