Chemical Composition, Functional and antioxidant properties of mango seed kernel (Kent variety) flour grown in Korhogo (Ivory Coast)

Oulai Sylvie Florence [*1,4], Touré Abdoulaye [1,2], Kamagaté Tidiane[1,2], Kouamé N'Guessan Rodrigue[1], Koné Monon[1,2], Soro Yadé Réné[3]

[1]Laboratory of Biotechnology and Valorization of Agroresources and Natural Substances, UFR of Biological Sciences, University Peleforo Gon Coulibaly of Korhogo, PO Box 1328 Korhogo, Ivory Coast.

[2]Laboratory of Biochimical Pharmacodynamy, UFR of Bioscience, University Félix Houphouët-Boigny, 22 PO Box 582 Abidjan 22, Ivory Coast

[3]Laboratory of Biotechnological, UFR of Bioscience, University Félix Houphouët-Boigny, 22 PO Box 582 Abidjan 22, Ivory Coast.

[4]Laboratory of Biocatalysis and Bioprocessing, UFR of Science and Food Technologies, University NanguiAbrogoua Abidjan, PO Box 801 Abidjan 02, Ivory Coast

*Corresponding author: oulai_s@yahoo.com

Abstract:

Mango is an important tropical fruit in the world. It is widely marketed and produced on a large scale. Unfortunately, a large part of its production is rejected in the form of waste, usually consisting of its skin and core. This leads to huge losses in the mango sector. However, the mango peel and its kernel have high functional and nutritional potential. The aim of the study was to determine the proximate composition, functional and antioxidant activity properties of flour produced from mangoes seeds kernel in order to assess its nutritional benefits. To do this, after pitting, the almonds were subjected to different pre-treatments before being ground into flour. The results obtained show us that these flours have a low moisture content of between 2 and 12.4%, with a generally acidic pH ranging from 4.78 to 5.65. The water absorption capacity of these flours ranges from 130 to 266.45%. They also have an oil absorption capacity of between 133 and 212.6%. The results of antioxidant properties show that mango kernels have polyphenol content between 0.10 mg GEA/g and 14.6 mg GEA/g and flavonoid contents ranging from 1.5 mg QE/g to 7.1 mg QE/g. These flours have an antiradical activity against DPPH radical with an IC_{50} is ranged from 0.33 to 2.4 µg/mL). Hence, the use of mango seed kernel flour can play an important role in improving nutritional value of diets.

Keywords: antioxidant activity, functional properties, mango kernel flour, polyphenols, proximate composition

1 INTRODUCTION

Cultivated for more than 4000 years in South-east Asia, the mango tree has been exported out of Asia that starting from VII[e] century. Established by the Portuguese in their African colonies then in Brazil, the mango tree was then cultivated as from the XIX[e] century in Mexico, then in the United States about 1861. Today, the mango tree is largely produced in the tropical and subtropical areas (Mukherjee 1951, 1953, and 1972). Mango belongs to the family Anacardiaceae and the genus *Mangifera* which includes 69 species with edible fruits only in some species. *Mangifera indica* is the only species, which is commercially grown among all species (Ajila *et al.,* 2007). It's very varied world production (more than 1000 indexed varieties) is currently evaluated with nearly 17 million tons and it occupies the fifth rank of the world fruit-bearing production after citrus fruits, the grapes, bananas and the apples (Singh, 1967; Martine, 1993). The period of development from flowering to fruit maturity is between 3-6 months depending on the cultivar, the size and color of ripe fruit. Mango fruit is extensively used for food, juice, flavor, fragrance and coloring purposes (Kittiphoom, 2012). Ripe mangoes are also processed into pulps, purees, jams and jellies, frozen mango products, canned products and dehydrated products (Berardini *et al.,* 2005). Mango fruit is an important source of macronutrients such as carbohydrates, lipid and fatty acids, protein and amino acids, and organic

acids. Also, mango has micronutrients such as vitamins and minerals and, finally, non-nutrients compound such as phenolic compounds, flavonoids and other polyphenols, chlorophyll, carotenoids, and volatile compounds. (Maldonado-Celis *et al.*, 2019, Desmorieux, 1992). In Africa, two countries most present on the mango world market are Ivory Coast and South Africa which occupy successively 11th and 9th place in the classification of the world exporters (FAO, 2002). In Ivory Coast, the North area is the principal zone of mangos production. Korhogo is one of the principal cities.

After pulp extraction from fruit (mesocarp part), peel and kernel are discarded as waste and becoming a source of pollution (Puravankara *et al.*, 2000); they account for 35-55% of the fruit (Bhalerao *et al.*, 1989) depending on the variety. At the same time, Mango kernel almond is reported to be a good source of carbohydrates (Anand and Maini, 1997; Diarra et al., 2010; 2011), and contains high quantities of proteins and fats (Anand and Maini, 1997). Despite this nutritional potential, mango kernel almond that represents most of these post-harvest losses is not at all consumed. It would be interesting to develop mango seed kernel in the nutritional and nutraceutical plan. In this context, the aim of this review is to discuss the nutritional, functional, and nutraceutical properties of mango seed kernel. It also shows several ways to add value to the mango seed kernel and their uses

2 MATERIALS AND METHODS

2.1. Sampling and sample preparation

Mangoes of Kent cultivar (Figure 1) were collected from the North areas of the Ivory Coast. The fresh, firm and mature fruits were harvested and transported to the laboratory for kernel almond (Figure 2) flour processing (Figure 3 and 4) before analyses. Mangoes were pulped using a knife to extract its kernel. They were washed with drinking water to remove them from all traces of pulp, and then divided into three groups for various samples production.

Figure 1: Mangoes of Kent cultivar

Figure 2: Mango almond: *a)* with protectives covers; *b)* without covers; *c)* split almond

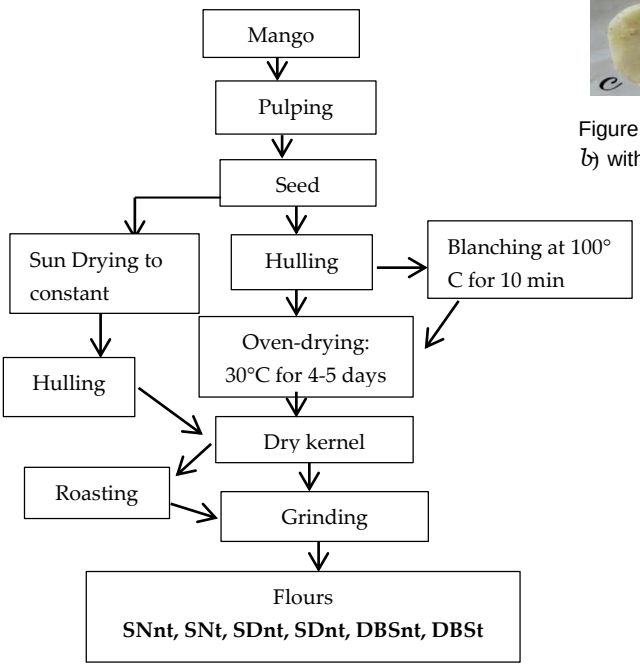

Figure 3: Different stages of mango seed kernel flours

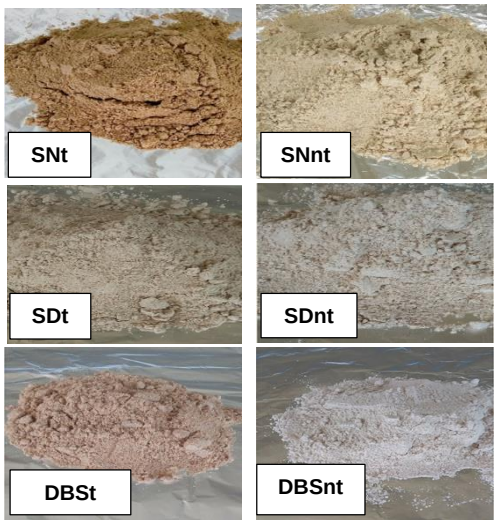

Figure 4: Different mango kernel almond flours. **SNnt,**: sun dry unroasted flour, **SNt:** sun dry roasted flour, **SDnt:** Hull unroasted flour, **SDt**: Hull roasted, **DBSnt:** blanch unroasted flour and **DBSt**: blanch roasted flour

2-2 Chemical analysis

2-2-1 Moisture and dry matter content

The moisture and dry matter content of the samples were determined by drying oven (105°C). It consists of weighing 5 g of each flour in a crucible and stove at 105°C. Then crucible and its contents were withdrawn and let cool in the desiccator then to weigh. Remake the weighing process until constant weight**.** The content is expressed by the following expression:

$$\% \text{ Moisture} = \frac{P - P_1}{P_o} \times 100 \qquad \% \text{ Dry Matter} = 100 - \% \text{ Moisture}$$

Where: P = Weight of the empty crucible and its contents; P1 = Loss of weight and P0 = Test sample

2-2-2 Reducing sugars content

The RS content was determined according to the method of Bernfeld, (1955) using 3.5 dinitrosalycilic acid (DNS).

2-2-3 Total titratable acidity

A test sample (5g of each flour) was watered into 45mL of distilled water then homogenized before being let rest during a few minutes. 10 mL of each supernatant were taken. Then Add few drops of phenolphthalein as an indicator solution and titrate with NaOH (0,1N) drop by the drop and stirring the content till first definite change to pink colour. Note down the final burette reading. Acidity is expressed by:

$$\text{Acidity value (\%)} = \frac{N \times V \times Vt}{Vp \times Pe} \times 100$$

Where: N = normality of NaOH solution
V = volume of NaOH solution
Vt = volume of sample total stock solution
Pe = sample weight

2-2-4 Determination of the pH

10 g of each sample flour was solubilized in 100 mL of distilled water. The mixture was homogenized using a magnetic stirrer during 5 min. After homogenization, the solution was filtered, and then 25 mL of the filtrate were taken to measure the pH using a pH-meter. The values are read directly on the numerical plate of the pH-meter.

2-3 Functional properties

2-3-1 Water absorption capacity (WAC)

Water absorption capacity (WAC) is determined according to the Yamazaki, (1953) method modified by Medcalf, (1965). Principle is based on the amount of water retained per 100 gram of flour after saturation. 1 gram of each flour samples (W_0) was weighed into a centrifuge tube. The whole was each weighed (W_1) again and 10 ml distilled water added. The content of the centrifuge tube was shaken for 30 min and centrifuged (Sigma type 3-16L) at 5000 g for 25 min. The supernatant was poured and tube was weighed again (W_2). WAC is determined according to the following formula:

$$WAC\ (\%) = \frac{W_2 - W_1}{W_0} \times 100$$

2-3-2 Oil Absorption Capacity (OAC)

Oil Absorption Capacity (OAC) was determined according to the method of Falade *et al*., (2015). 1 gram of sample was introduced into a previously weighed test tube. 10 mL of oil were added and the resulting mixture stirred. After a night of rest at the laboratory temperature. Mixture is centrifuged at 3200 g for 25 min. Mass of the pellet was determined by weighing. The following formula allowed us to determine the OAC.

$$OAC\ (\%) = \frac{Pm - Sw}{Sw} \times 100$$

with Pm: pellet mass , Sw: sample weight

2-3-3 Paste clarity (PC)

The paste clarity of flours was determined according to the method of Craig *et al.,* (1989). 1 % aqueous suspension was made by suspending 0.2 gram of flour in 20 ml of distilled water in a stoppered centrifuge tube and vortex mixed. The suspension was heated in a

boiling water (100ºC) bath for 30 min. After cooling, clarity of the flour was determined by measuring percent transmittance at 650 nm against water blank on a spectrophotometer (Selecta, V-1100 D).

2-3-4 Foam capacity and Foam stability

The foam capacity (FC) and Foam stability (FS) were determined as described by Narayana and Narasinga Rao, (1982) with minute modification. 1 gram flour sample was added to 50 mL distilled water in a clean, dry and graduated (50 mL) cylinders. The suspension was mixed and shaken for 5 min to foam development. The volume of foam at 30 sec after whipping was expressed as foam capacity. The volume of foam was recorded 1 hour after whipping to determine foam stability as per percent of initial foam volume. The FC (%) and FS (%) values were calculated as follows:

$$FC\ (\%) = \frac{A1 - A_0}{A_0} \times 100$$

$$FS\ (\%) = \frac{\text{Foam volume after time (1hour)}}{\text{Initial foam volume}} \times 100$$

A_1: Foam volume after whipping

A_0: Foam volume before whipping

2-3-5 Emulsion activity (%) and Emulsion stability (%)

The emulsion activity and stability were determined by the method of Yasumatsu *et al.,* (1972). The emulsion (1gram flour, 10 ml distilled water and 10 ml soybean oil) was mixed in calibrated centrifuged tube. The emulsion was centrifuged at 2000 g for 5 min. The ratio of the height of emulsion layer to the total height of the mixture was calculated as emulsion activity in percentage. The emulsion stability was estimated after heating the emulsion contained in calibrated centrifuged tube at 80° C for 30 min in a water-bath, cooled for 15 min under running tap water and centrifuged at 2000 g for 15 min. The emulsion stability expressed as percentage was calculated as the ratio of the height of emulsified layer to the total height of the mixture.

2-4 Antioxidant properties

2-4-1 Total polyphenols

The protocol used is based on that described by Singleton *et al.*, (1965) modified by Messaouda, (2013). The contents of total phenolic compounds were measured using the Folin-Ciocalteu reagent based colorimetric essay. A volume of 0.2 mL of each sample was mixed with 1 mL of Folin-Ciocalteu reagent diluted 10 times and 0.8 mL of sodium carbonate (Na_2CO_3) 7.5 %. The unit is incubated at an ambient temperature during 2 hours. The absorbance was recorded using a spectrophotometer at 765 nm after 30 min. The amount of total phenolic compounds as gallic acid equivalent was calculated from the calibration curve equation obtained from the standard curve. The total phenolic content was expressed in milligrams equivalent of gallic acid per gram of extract (mg GAE /g of extract).

2-4-2 Determination of total flavonoids

2-4-2-1 Methanolic extract

Methanolic extract was obtained according to the method described by Zirihi *et al.,* (2003) with some modification. 50 gram of different flour was introduced into a 500 ml flask containing a mixture of methanol and distilled water (70:30). The whole was subjected to magnetic stirring for 48 hours. At the end of these 48 hours, the mixture was and the filtrate obtained concentrated by rotary evaporation. Part of the aqueous solution was oven dried at 50°C until complete evaporation of the water and the other fractionated with immiscible organic solvents of increasing polarity.

2-4-2-2 Total flavonoids level

Flavonoids content was carried out by a method based on formation of a very stable complex between oxygen atoms and aluminum chloride present on the carbons 4 and 5 of the flavonoids (Lagnika, 2005). Yellowish coloration of the complex given in this method is due to the reaction of flavonoids with aluminum chloride in the presence of potassium acetate whose intensity is proportional to the flavonoids level present in the sample. The protocol used is based on that described by Zhishen *et al.,* (1999) and Kim *et al.,* (2003), with some modifications. 0.5 mL of different methanolic extract was introduced into a test tube. Then were added successively 0.5 mL of distilled water, 0.5 mL of aluminum chloride ($AlCl_3$) and 0.5 mL of potassium acetate (CH_3CO_2K). The tube was left at rest with the darkness during 20 min and the optical density was read to 415nm. Quercetin (0-100 mg / l) was used as a standard for the development of the calibration curve. A mixture of 0.5 mL of methanolic extract and 0.5 mL distilled water served as a blank. Three readings are performed per sample of methanolic extract and the results are expressed in mg Equivalent Quercetin (EQ) per gram of methanolic extract (mg QE /g of methanolic extract).

2-4-3 Antioxidant activities

2-4-3-1 Test au DPPH

Test au DPPH is the measure of antioxidant activity that evaluates the ability to reduce a stable free radical. The spectrophotometric method for 2.2-diphenyl-1-picrylhydrazyl (DPPH) described by Athamena *et al.,* (2010) is used with some modification. When a DPPH (2.2-diphenyl-1-picryl-hydrazyl) solution is mixed with an antioxidant hydrogen donor substance, there is formation of the reduced form. This causes the loss of purple coloration in yellow color. 50µL of each methanolic extract at various concentrations (from 6.25 mg/mL to 100 mg/mL) were added 1.95 mL DPPH methanolic solution (25 mg /L) into each tube. In parallel, a negative witness is prepared by mixing 50µl of methanol with 1.95 mL of DPPH methanolic solution. After 30 min of incubation to darkness and ambient temperature, the absorbances are read at 515 nm and the methanol is used as a blank sample. Positive control is represented by a solution of a standard antioxidant; the vitamin C whose absorbances was taken under the same conditions as the samples and for each concentration. The antioxidant activity is expressed as a percentage inhibition according to the following formula:

$$\% \text{ Inhibition} = [1 - (A_1 - A_0)] \times 100$$

A_1: Sample absorbance
A_0: Negative control Absorbance

2-4-3-2 Ferric reducing-antioxidant power (FRAP)

The reduction of iron (Fe^{3+}) in the extracts is given according to the method described by Besuchet and Pury, (1998); Ou *et al.,* 2001) with some modification. The method of iron reduction is based on reduction of ferric iron to iron salt by the antioxidants which give blue color. 1mL of methanolic extract of mango kernel almond four at various concentration (6.25 - 100 mg/mL) was added to 2.5 mL of 0.2 M sodium phosphate buffer (pH 6.6) and 2.5 mL of 1% potassium ferricyanide [$K_3Fe(CN)_6$] solution. The reaction mixture was incubated at 50°C for 20 min using shaker bath. At the end of the incubation, 2.5 mL of 10% trichloroacetic acid ($C_2HCl_3O_2$) was added to the mixture to stop the reaction and centrifuged at 3000 g for 10 min. The supernatant (2.5 mL) was mixed with 2.5 mL of distilled water and 0.5 mL of 0.1% ferric chloride ($FeCl_3$). The colored solution was read at 700 nm against the blank similarly prepared by replacing the methanolic extract by distilled water with reference to standard using UVSpectrophotometer. Here, ascorbic acid and BHT (butylhydroxytoluene) were used as a reference standard, the reducing power of the samples were comparable with the reference standard. The percentage of iron reduction is calculated by the following formula:

$$\% \text{ FRAP} = \frac{Ao - A_1}{Ao} \times 100$$

% FRAP: percentage of Ferric reducing-antioxidant power
Ao: Ferric chloride absorbance
A1: Sample absorbance

2-5 Statistical analysis

All determinations reported in this study were carried out in triplicates. Mean value and standard deviation were calculated. Analysis of variance (ANOVA) and correlations were also performed. Tukey's (HSD) test at $p < 0.05$ was used for mean values separation. Pearson correlation coefficients (r) for relationships between various flour properties were calculated. The variations observed in chemical, functional and antioxidants activity of the flours from mango seed kernel were examined by Principal Component Analysis (PCA) with the Minitab Statistical Software version 13.

3- RESULTS AND DISCUSSION

3-1- Chemical composition

The results chemical composition of mango seed kernel flour is shows in Table 1. The results show that the moisture content of all flour is ranged from 2% to 14%. This biochemical parameter is important in the storage of flours. The roasted flour has low moisture content than unroasted. That can be explained by the fact that roasting still eliminates water remaining in almonds after drying. Chew *et al*., (2011) reported that reduced moisture content ensured the inhibition of microbial growth, hence is an important factor in food preservation. Titratable acidity significant parameter because it makes it possible to know if an ingredient contains the quantity of acid excluded for its use in a given. Total titratable acidity content is from 32.4 to 56.25 meq/100g. It appeared that total titratable acidity content was higher than that reported for mango almond flours of five varieties (9.33 - 19 meq/100g) (Diomandé *et al.,* 2017) and lower than baobab pulp (*Adansonia digitata L.)* (156 meq/100g) (Tapsoba, 2011). On the level of pH, we observe that all of mango kernel almond flour have acidic pH (lower than 6). This result is comparable with that of Yetunde *et al.,* (2006). The pH is the sign of the acidity or alkalinity of the flour and affects largely its performances during its use in the food system. These results are higher than those of Tapsoba, (2011) for baobab pulp (3.09 to 3.17). It was observed in this study that the reducing sugar content of mango seed kernel flour varied from 0.28 % to 0.72%. This result is similar to those of Cassava varieties (0.28 to 0.34%) (Otache *et al.,* 2017). It is also below value of 1.64 to 4.9% in other examination (Diomandé *et al.,* 2017).

Table 1: Chemical composition of mango seed kernel flour

Chiemical Properties					
Sample	Moisture (%)	DM (%)	Total titratable acidity (%)	Reducing sugars (%)	pH
SNnt	14 ± 2	89 ± 1	41,40 ± 1,6	0,68 ± 1,4	5,31 ± 0,69
SNt	8 ± 1	92 ± 2	32,40 ± 4,6	0,44 ± 0,6	5,01 ± 0,99
SDnt	8 ± 1	92 ± 3	56,25 ± 3,75	0,72 ± 0,9	5,65 ± 0,35
SDt	2 ± 1	98 ± 1	48,20 ± 1,8	0,65 ± 0,06	5,45 ± 0,05
DBSnt	13 ± 1	87,6 ± 2	37,80 ± 1,2	0,28 ± 0,03	4,93 ± 0,37
DBSt	6 ± 2	94 ± 4	38,70 ± 1,3	0,41 ± 0,09	4,78 ± 0,12

***DM:** Dry matter, **SNnt**,: sun dry unroasted flour, **SNt:** sun dry roasted flour, **SDnt:** Hull unroasted flour, **SDt**: Hull roasted, **DBSnt:** blanch unroasted flour and **DBSt**: blanch roasted flour*

3-2- Functional properties

The results of functional properties are presented in Table 2.

Paste Clarity (PC) ranged between 1.5 to 3.45 %T among all the flours. PC is important property that governs different applications of flours and starches for food processing. For example, the transparent flour and starch paste are required to thicken fruit pies opposing opaque paste, which is more suitable for salad dressing (Craig *et al.,* 1989).

WAC is the ability of flour to absorb or retain water. This ability is a very important property of all flours in food preparations. Besides, WAC is an index of the maximum amount of water that flour can absorb or retain (Morha *et al.,* 1987, Marero *et al.,* 1988)]. WAC of study flours are ranged from 130 to 226.45 %. The blanched flour (DBSnt and DBSt) are the highest WAC. The high WAC was due to lipophilic environment of fat and protein. Water absorption capacity is a critical function of protein for various food products like dough and biscuits baking (Prajapati *et al.,* 2015).

The OAC ranged between 133 to 212.6% among all the flours. DBSt flour had the highest OAC while the lowest was observed for SDnt flour. OAC is defined as the difference in the flour weight before and after its oil absorption (Giami *et al.,* 1994). The ability of flour to absorb oil is important as oil acts as a flavour retainer and improves mouthfeel. It is a significant factor in food formulations. They are also important because of their storage stability and particularly in the rancidity development (Siddiq *et al.,* 2010).

Foaming capacities of this study flours (2.3 – 2.8 %) were similar to 3.75 – 3.79% reported for mango seed flour (Okpala and Gibson, 2013) but low compared to 35% reported for bush mango (Abulude *et al.,* 2008). Low foaming capacity could be due to a highly ordered globular protein which is sensitive to surface denaturation (Yusuf *et al.,* 2007).

Protein being the surface active agents can form and stabilize the emulsion by creating electrostatic repulsion on oil droplet surface (Kaushal *et al.,* 2012). Emulsion Activity (EA) of different flours ranged between 40.66 and 54.28 %. Emulsion Stability (ES) for different flours varied from 92.57 to 100 %. The roasted flour (SNt, SDt, DBSt) have higher EA while unroasted flour have higher ES.

Table 2: Functional properties of mango seed kernel flours

	Functional properties						
Sample	**Clarity (%T)**	**WAC (%)**	**OAC (%)**	**FC (%)**	**FS (%)**	**EA (%)**	**ES (%)**
SNnt	2,55 ± 0,2	146,7±3,3	160 ± 4	2,3 ±0,4	0,00	45,71 ± 3,4	100 ± 10
SNt	2,4 ± 0,4	130,2 ±4,8	175,5 ±5,5	2,5 ±0,5	0,00	43,16 ±4,2	93,02 ± 0,5
DSnt	2,6 ± 0,2	170 ±2	133 ±1	2,5 ±1,5	0,00	42,02 ± 0,5	106,9 ± 2,1
DSt	1,5 ±0,5	130 ±2	141,5 ±3,5	2,8 ±0,5	0,00	40,66 ±1,5	104,33 ±3,8
DBSnt	3,45 ±0,3	230,75 ± 5,7	212,6 ±1,4	2,5 ±1,5	0,00	54,28 ±4,8	94,76 ±4,2
DBSt	2,15 ± 0,1	266,45 ±5,4	172,75 ±3,75	2,4 ±0,4	0,00	53,04 ±1,6	92,57± 2,4

***SNnt**,: sun dry unroasted flour, **SNt:** sun dry roasted flour, **SDnt:** Hull unroasted flour, **SDt**: Hull roasted, **DBSnt:** blanch unroasted flour and **DBSt**: blanch roasted flour, **WAC:** Water absorption capacity, **OAC**: Oil absorption capacity, **FC:** foam capacity, **FS**: Foam stabiliyu **EA**: Emulsion activity, **ES:** Emulsion stability*

3-3- Antioxidant properties

Polyphenols are phytochemicals from plants and are being used for prevention of various diseases that are mainly caused by free radicals. The higher polyphenol content would then exhibit stronger inhibition and also higher antioxidant activity (Jayaprakasha *et al.,* 2003). In most studies on effect of treatment on the phenolic, the results are contradicting. Some researchers reported an increase in total phenolic content whilst others observed a decrease (Chipurura *et al.,* 2010). The total polyphenols contents of mango seed kernel flours ranged from 10 to 15 mg GAE/g (Figure 5). The roasted flour has high total polyphenols content than the unroasted flour. Different of total polyphenols contents ranged from 112 to 44,760 mg/100 g seed were reported in other mango cultivars (Sogi *et al.,* 2013; Dorta *et al.,* 2014). These differences in total polyphenols contents might be due to mango cultivars, geographical location, extraction conditions and used different standard equivalents.

Flavonoids are the most common and widely distributed group of plant phenolic compounds (Guo *et al.*, 2012) and are generally categorized as phenolics depending on their chemical structure (Sung and Lee, 2010). The total flavonoid content was found to be range from 1.53 to 7.13 mg QE/g (Figure 6). The obtained results were much lower than that reported for peel and kernel of other mango cultivars (10–3325 mg/100 g) (Ribeiro *et al.*, 2008; Abdel-Aty *et al.*, 2018). Total flavonoids contents different conditions depend on extracting methods and sources of seeds.

The methanolic extract derived from mango seed kernel showed antiradical activity against DPPH (Figure 7). The IC_{50} ranged from 0.33 to 2.4 µg/mL (Figure 8). The SNt, SNnt, DSnt and DSt flours have IC_{50} lower than that of the Vitamin C. Therefore they have an antioxidant capacity more raised than that of the vitamin C. More the IC_{50} is low more the antioxidant capacity is high. Our mango seed kernel antioxidant capacity is higher than those of MSKE (IC_{50}: 47.3 µg/mL) (Abdel-Aty *et al.*, 2018) mango seed kernel (IC_{50}: 12 to 13.93 µg/mL) (Villanueva *et al.*, 2020)

The flour ferric reducing antioxidant power assay (FRAP) is show in Figure 9. The study flour FRAP is ranged between 0.466 to 0.669 % while those of vitamin C and BHT is 0.152% and 0.167% respectively. Mango seed kernel could be a good source of FRAP.

3-4 Principal component analysis

Principal Component Analysis (PCA) was used to visualize the variation in the properties among flours from unroasted and roasted mango seed kernel. This analysis showed two axes (axis 1 and 2) explaining the essential variability. The first and the second PCs described 58.34 and 20.65% of the variance, respectively. Together, the first and two PCs represented 78.99 % of the total variability. Thus, flours were separated according to the two axes on the basis of their properties and four groups emerged: (1): SNnt and SDnt, (2) DBSnt: (3): SNt and DBSt and (4): SDt. This discrimination showed that the four groups had different properties (Figure 10). The correlation circle provides information about correlations between the measured properties (Figure 11). The properties whose curves lie close to each other on the plot were positively correlated while those whose curves run in opposite directions were negatively correlated. Correlations between the properties of flours were also supported by Pearson's correlation coefficients (Table 3).

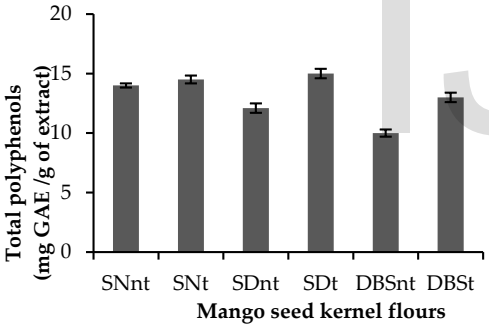

Figure 5: Total polyphenols content of mango seed kernel flour

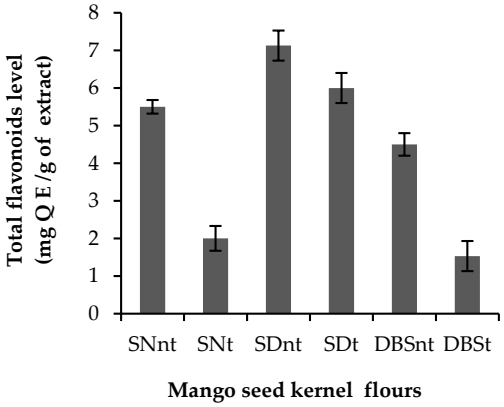

Figure 6: Total Flavonoids content of mango seed kernel flour

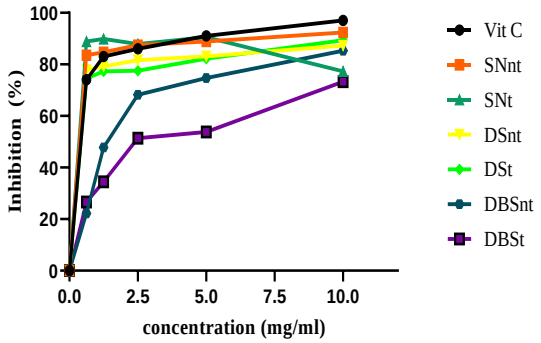

Figure 7: Mango seed kernel antioxidant activity against DPPH

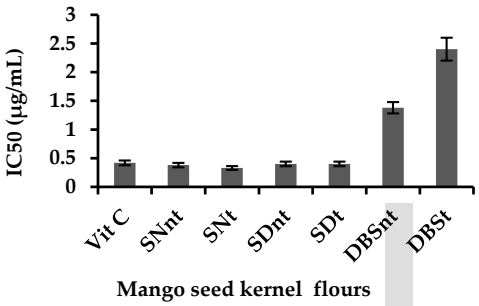

Figure 8: IC_{50} of mango seed kernel flours

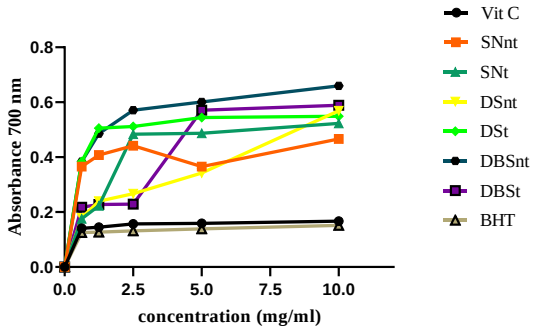

Figure 9: Ferric reducing antioxidant power assay (FRAP) of mango seed kernel

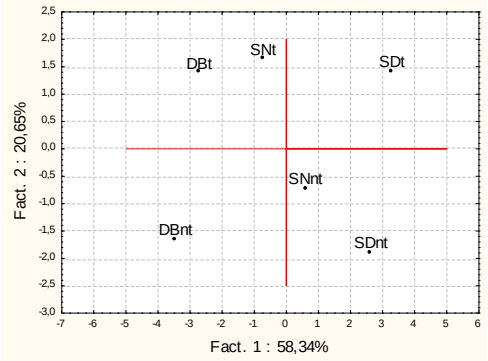

Figure: 10: Sample plot of principal components 1 and 2 of flours from unroasted and roasted

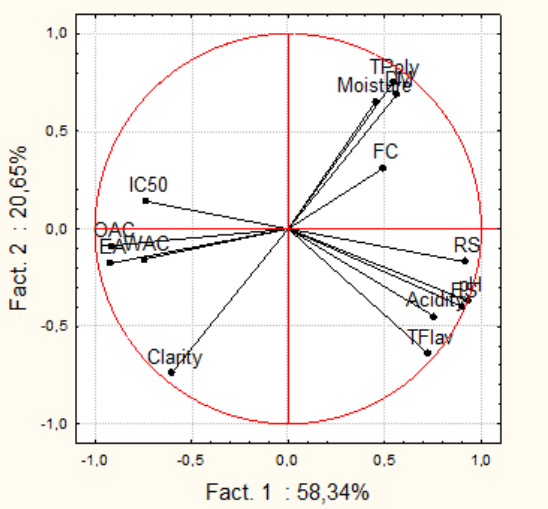

Figure: 11: Circle of correlation of various composition of mango seed kernel flours

Table 4: Pearson correlation coefficients between various composition of mango seed kernel flours

	DM	Acidity	RS	pH	Clarity	WAC	OAC	FC	EA	ES	IC_{50}	TPo
	1,00											
ity	0,32	1,00										
	0,38	0,80	1,00									
	0,27	0,86	0,91	1,00								
ty	-0,94	-0,24	-0,49	-0,28	1,00							
C	-0,25	-0,18	-0,56	-0,63	0,38	1,00						
C	-0,63	-0,76	-0,93	-0,82	0,68	0,52	1,00					
	0,68	0,32	0,14	0,33	-0,51	-0,35	-0,28	1,00				
	-0,52	-0,49	-0,75	-0,79	0,58	0,89	0,81	-0,46	1,00			
	0,31	0,93	0,88	0,97	-0,29	-0,49	-0,80	0,40	-0,69	1,00		
	-0,05	-0,31	-0,59	-0,73	0,15	0,95	0,49	-0,27	0,85	-0,59	1,00	
y	0,67	-0,05	0,44	0,22	-0,85	-0,66	-0,55	0,25	-0,67	0,13	-0,42	1,00
v	-0,00	0,83	0,73	0,89	0,01	-0,42	-0,53	0,29	-0,49	0,92	-0,59	-0,10
sture	-0,96	-0,29	-0,23	-0,18	0,83	0,14	0,52	-0,75	0,43	-0,24	-0,03	-0,51

***DM**:DryMatter, **FC**: foam capacity, **OAC**: Oil absorption capacity ;**RS**: ReducingSugar; **EA**: Emulsionactivity **TPoly**: Total polyphenols, **WAC**: Waterabsorptioncapacity **ES**: Emulsionstability, **TFlav**: Total Flavonoids*

4- CONCLUSION

We retain for this study that the mango seed kernel contain polyphenols and flavonoids whose contents vary according to the preprocessing to which these almonds were subjected. The minimal polyphenols content is higher than the flavonoids maximum content. Moreover, roasting increases mango seed kernel polyphenols content and reduces the flavonoids content. The antioxidant activity evaluation by the radical DPPH tests and iron reduction showed that the dried, roasted and unroasted mango seed kernel have an antioxidant capacity higher than that of the vitamin C which is a natural antioxidant. Also, all the flours of mango almonds have a capacity of iron reduction higher than that of natural antioxidants such as the vitamin C and the BHT. Therefore a high potential of mango seed almond is could be use as sources of natural antioxidants. From a functional point of view, mango seed kernel flour has a good water and oil absorption capacity, emulsion and stability activity. Mango seed kernel flours functional properties are a promotion to be used in food formulation.

References

Abdel-Aty M., Salama W. H., Hamed M. B., Fahmy, A.S. Mohamed S. A., (2018). Phenolic-antioxidant capacity of mango seed kernels: therapeutic effect against viper venoms. *Revista Brasileira de Farmacognosia* 28; 594–601.

Abulude, F.O., Alo, F.I., Ashafa, S.L., and Fesobi, M. (2008). Chemical composition and functional properties of *Irvingia gabonensis* seed flour. *Cont. Journal of Food Science & Technology*, 2: 33 – 36.

Ajila, C.M.; Bhat, S.G. and Prasada Rao, U.J.S., (2007). Valuable components of raw and ripe peels from two Indian mango varieties. *Food Chemistry*, 102: 1006–1011.

Anand, J.C. and Maini, S.B. (1997). Utilisation of fruits and vegetable wastes. *Indian Food Parker*, 51 : 45-63.

Athamena S., Chalghem I., Kassah-Laouar A., Laroui S. and Khebri S. (2010). Activite antioxydante et antimicrobienne d'extraits de Cuminum cyminum L. *Lebanese Science Journal*, 11(1) : 69 – 81.

Chipurura B., Muchuwet M. and Fazitah A. (2020). Effects of thermal treatment on the phenolic content and antioxidant activity of some vegetables. *Asian journal of clinical nutrition* 2 (3): 93-100.

Chew, S.H.K., Bhupinder, N.H., Karim, A.A. and Fazilah, A., (2011). Effect of fermentation on the composition of *Centell asiatica* teas. *American Journal of Food Technology*, 6 (7):581-593.

Berardini, N., Knodler, M., Schieber, A. and Carle, R. (2005). Utilization of mango peels as a source of pectin and polyphenolics. *Innovative Food Science & Emerging Technologies*. 6: 442-452.

Bernfeld, P., (1955). Amylase β and α (Assay method), in methods in enzymology I, Colowick and Kaplan, Ed., Academic press, New York, pp. 149 – 154.

Besuchet E. and Pury, DE.P. (1998). Guide pour la préparation des fruits tropicaux. Fédération internationale de la Croix Bleue, 77 p

Bhalerao, S.D., Mulmuley, G.V., Anathakrishna, S.M. and Potty, V.H., (1989). Wash and waste water management in food industry. Fruit and vegetable processing. *Indian Food Packer* 43: 5-11.

Craig, A. S. S., Cloduraido, C. M., Paul, A. S. and Hoseney, R. C.. (1989)Starch paste clarity. *Cereal chemists*, 66 (3): 173 – 182,.

Craig, S.A.S. Maningat, C.C. Seib, P.A. Hoseney, R.C. (1989). Starch paste clarity. *Cereal Chemistry*., 66:173-182.

Desmorieux. (1992). Le séchage en zone subsaharienne : une analyse technique à partir des réalités géographiques et humaines. Thèse présentée à l'INPL (Institut National Polytechnique de Lorraine). Nancy, France. 234 p.

Diarra, S.S., Saleh, B., Kwari, I.D. and Igwebuike, J.U. (2011). Evaluation of boiled mango kernel meal as energy source by broiler chikens in the semi-arid zone of Nigeria. *International journal of science and nature*, 2(2) : 270-274.

Diomande, M., Koko A. C., Kouame K.B., Beugre G.t A.M., and Bohoua L. G., (2017). Evaluation des propriétés fonctionnelles et activité antioxydante d'amandes de mangue produites en Côte d'Ivoire. *International Journal of Advancements in Research & Technology*, 6 (11): 6 – 29.
Dorta, E., Gonzez, M., Lobo, M.G., Snchez-Moreno, C.,and Ancos, B., (2014). Screening ofphenolic compounds in by-product extracts from mangoes (*Mangifera indica* L.) by HPLC–ESI–QTOF–MS and multivariate analysis for use as a food ingredient. *International food research journal*. 57: 51–60.

Falade, K O. and Okafor, C A., (2015). Physical, functional, and pasting properties of flours from corms of two Cocoyam (*Colocasiae Sculenta* and *Xanthosomas Agittifolium*) cultivars. *Journal of Food Science and Technology*, 52: 3440–3448.

FAO (2002). La mangue: un fruit prisé de tous - Ed.rev. (CPS Aliments du Pacifique Sud ; n° 3),

Giami, S.Y., Okonkwo, V.I. and Akusu, M.O. (1994). Chemical composition and functional properties of raw, heat-treated and partially proteolysed wild mango (*Irvingia gabonensis*) seed flour. *Food Chemistry*, 49: 237-24

Guo, X.D., Wu, C.S., Ma, Y.J., Parry, J., Xu, Y.Y., Liu, H. and Wang M. (2012). Comparison of milling fraction of tartary buckwheat for their phenolic and antioxidant properties. *Food Research International 49: 53-59.*

Kim, D., Chun, O., Kim, Y., Moon, H., and Lee, C**., (2003).** Quantification of phenolics and their antioxidant capacity in fresh plums. *Journal of Agricultural and Food Chemistry*., 51: 6509 – 6015.

Kaushal, P., Kuma,r V. and Sharma, H.K., (2012). Comparative study of physicochemical, functional, anti-nutritional and pasting properties of taro (*Colocasia esculenta*), rice (*Oryza sativa*), pegion pea (*Cajanus cajan*) flour and their blends. *LWT-Food Science and Technology*, 48: 59–68.

Jayaprakasha, G.J.; Selvi, T. and Sakariah, K.K. (2003). Antibacterial and antioxidant activities of grape (*Vitis vinifera*) seed extracts. *Food Research International,* 36: 117-122.

Kittiphoom, S. (2012). Utilization of Mango seed. *International Food Research Journal,* 19: 1325-1335.

Lagnika, L., (**2005***). Etude phytochimique et activité biologique de substances naturelles isolées de plantes béninoises*. Thèse de doctorat, Université Louis Pasteur, Strasbourg, 249p.

Maldonado-Celis, M.E., Yahia, E.M., Bedoya, R., Landázuri, P., Loango, N., Aguillón, J., Restrepo, B. and Guerrero O.J.C. (2019). Chemical Composition of Mango (*Mangifera indica* L.) Fruit: Nutritional and Phytochemical Compounds. *Frontiers in Plant Science*, 10: 1073-1093

Marero, L.M., Pajumo, E.M., Librando, E.C., (1988). Technology of weaning food formulation prepared from germinated cereals and legumes. *Journal of Food Science,* 53:1391-1395

Martine, F., (1993). Transformer les fruits tropicaux. Collection le point sur les technologies. Edition du GRET, Ministère de la coopération, CTA, ACCT. Paris. 222p.

Messaouda Hireche. (2013). Dosage des polyphénols de la tomate et étude de leur pouvoir antioxydant. Université de Hassiba Ben Bouali Chlef, Algérie, Master 2 nutrition humaine

Medcalf, D.J. and Gilles, K.A., (1965). Wheat starches 1. Comparison of physicochemical properties. *Cereal Chemestry*., 42: 558-568.

Mosha, A.C. and Lorri, W.S.M., (1987). High-nutrientdensity weaning foods from germinated cereals.In: Alnwick, D. Moses, S. Schmidt, O.G. eds. Improving young child feeding in Eastern and Southern Africa. Nairobi, New York, Stockholm: IDRC, UNICEF, SIDA., pp. 288-299.

Mukherjee, S.K., (1951). Origin of mango, *Indian Journal of Genetics and Plant Breeding*, 11: 49-56.

Mukherjee, S.K., (1953). The mango: its botany, cultivation, uses and future improvement, especially as observed in India. *Economic Botany*, 7: 130-162.

Mukherjee, S.K., (1972). Origin of Mango (*Mangifera indica*), *Economic Botany*, 26: 260-264.

Narayana, K. and Narasinga Rao, M.S. (1982) Functional properties of raw and heat processed winged bean flour. *Journal Food Science,* 47:1534-1538.

Ou B., Hampsch-Woodill M., Prior R L. Development and validation of an improved oxygen radical absorbance capacity assay using fluorescein as the fluorescent probe. *Journal of Agricultural and Food Chemistry.* (49): 4619-4626, 2001.

Puravankara, D., Bohgra, V. and Sharma, R.S. (2000). Effect of antioxidant principles isolated from mango (*Mangifera indica* L.) seed kernels on oxidative stability of buffalo ghee (butter-fat). *Journal* of the *Science* of *Food* and *Agriculture.* 80: 522-526.

Prajapati, R., Chandra, S., Samsher; Chauhan, N., Singh, G.R. and Kumar, S. (2015). Effect of incorporation of flours on the functional properties of composite flours. *South Asian Journal of Food Technology and Environment*, 1(3&4): 233-241.

Okpala, L.C. and Gibson-Umeh, G.I. (2013). Physicochemical Properties of Mango Seed *Flour Nigerian Food Journal,* 31 (1): 23 – 27.

Otache**,** M.A., Godwin K.A., Akpovona A.E. and Ogoh B. (2017). Quantitative Determination of Sugars in Three Varieties of Cassava Pulp. *Asian Journal of Chemical Sciences*, 3(3): 1-8.

Ribeiro, S.M.R., Barbosa, L.C.A., Queiroz, J.H., Knödler, M.,and Schieber, A., (2008). Phenoliccompounds and antioxidant capacity of Brazilian mango (*Mangifera indica* L.) varieties. Food Chemistry. 110: 620–626.

Siddiq, M., Ravi, R., Harte, J.B.and Dolan, K.D. (2010). Physical and functional characteristics of selected dry bean (*Phaseolus vulgaricus* (L.) flours. *LWT-J Food Science and Technology*. 43: 232-237.

Singh, K.K., (1967). Climate and cultivation. The mango. In. Projet de transformation et conditionnement des mangues en Côte- d'Ivoire. SIARC. Montpellier. 80p,

Singleton, V. L., Orthofer, R., and Lamuela-Ravento's R. M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants bt means of Folin-Ciocalteu reagent. *Methods in enzymology*, 299 : 152-178.

Sogi, D.S., Siddiq, M., Greiby, I. and Dolan, K.D., (2013). Total phenolics, antioxidant activ-ity, and functional properties of Tommy Atkins' mango peel and kernel asaffected by drying methods. *Food Chemistry*. 141: 2649–2655.

Sung, J. and Lee, J. (2010): Antioxidant and antiproliferative of grape seeds from different cultivars, *Food Science Biotechnology*, 19 (2): 321-326.

Tapsoba, A.R., (2011). Formulation, élaboration d'aliments et boissons locaux et atelier pilote à base de pulpe de baobab (*Adansonia digitata L.).* Université Polytechnique de Bobo-Dioulasso (UPB). 86 pp

Villanueva, P.X.; Avila, Y.C., Davila, L.R., Mendez, J.J. and Arango W. M. (2020). Characterization and use of *Mangifera indica* L seed from four varieties. *Bioresources*, 15(3): 5264 – 5280.

Yamazaki, W.T., (1953). An alkali water relation test for the evaluation of cooking, baking potentialities of soft water wheat flour. *Cereal Chemistry*, 30: 42-246.

Yasumatsu, K., Sawada, K., Moritaka, S., Mikasi, M., Toda, T. and Tshi, K. (1972). Whipping and emulsifying properties of soybean products. *Agricultural Biochemistry*, 36: 719-727.

Yetunde E.A.., Iyam, M.A., Lawal, O., Udofia, U.and Ani I.f. (2009). Utilization of Bambara ground flour blends in bread production. *Journal of Food Technology*, 7: 111-114.

Yusuf, A.A., Folarin, O.M. and Bamiro, F.O. (2007). Chemical composition and functional properties of snake gourd (*Tricosanthes cucumerina*) seed flour. *Nigerian Food Journal*, 25(1): 37 – 45.

Zirihi, G., Kra, A.K.M. and Guede-Guina F. (2003). Évaluation de l'activité antifongique de*Microglossa pyrifolia* (Lamarck) *O. Kantze* (Astéracée) «PYMI» sur la croissance in vitro de *Candida albicans*. Revue de Médecine et pharmacie Afrique **17,** 11- 18.

Zhishen, J., Mengcheng, T. and Jianming W. (**1999).** *The determination of flavonoid contents inmulberry and their scavenging effects on superoxide radicals*. Journal of Food Chemistry, 64: 555 – 559.