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Characterization of Some Physicochemical and Functional Properties and Associated Antioxidant Compounds of *Mangifera indica* L. Pulp Powder From Mali

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Abstract: Mango (*Mangifera indica* L.) is one of the most important tropical fruits consumed all around the world. The aim of this investigation was to assess the physicochemical, technological properties (water and oil holding capacity, emulsion capacity and stability) and associated antioxidant constituents (total phenolic, total flavonoïds, proanthocyanidins) of the Malian mango pulp powder (MPP). Results show that MPP exihibit a high polyphenol, flavonoïds and proanthocyanidins contents of 15660±0.06 mg EAG/ 100g, 34.33± 0.71 mgEQ/100g and 106.27±13.91 mg EC/100 g on dry matter basis, respectively. MPP possesses good water and oil absorption capacities with values of 106 and 131%, respectively. Interesting emulsifying properties were obtained with values of 47.05% and 84.37%, respectively. The results of the present study indicate that MPP is a good source of antioxidant compounds and exhibit interesting technological properties. Thus, MPP has a high potential for use as a functional ingredient in the preparation of food products.

Keywords: *mango; powder; technological properties; bioactive molecules.*

I. Introduction

Mango is one of the most widely consumed and appreciated tropical fruits in the world. The fruit has not only a flavor and an attractive color, but also a remarkable nutritional density. Mango is a rich source of prebiotic dietary fiber, vitamins (particularly vitamin C), minerals (Na, K, Ca, Mg, Fe and Mn), carotenoïds and polyphenolic antioxidant compounds [1-2]. According to Belem *et al.* [3], half a mango is enough to cover all the daily requirements of provitamin A and more than 66% of the entire advisable for vitamin C. Indeed, the ascorbic acid molecule or vitamin C seems to play a key role in mechanisms as diverse as they are important in human health: immune reactions, cellular oxidation, and prevention of certain cancers, hypertension, cardiovascular risks and cataracts [4]. Up to 25 different carotenoïds have been isolated from mango pulp such as provitamin A, lutein, α-carotene and β-carotene, which is the most abundant component and having the most vitamin A activity. Vitamin A and its metabolites are essential for vision, reproduction and immune function, in addition to performing other important physiological functions, including deactivation of reactive oxygen species [5-6]. According to Masibo and He [7], the main phenolic compounds present in mango in terms of antioxidant capacity and / or amounts are: mangiferin, catechins, quercetin, kaempferol, rhamnetine, anthocyanins, gallic and ellagic acids, propyl and methyl gallates, benzoic acid, and protocatechic acid. The nutraceutical and pharmaceutical importance of mangiferin (C2- β-Dglucopyranosyl-1, 3, 6, 7-tetrahydroxyxanthone), which is the characteristic polyphenol of mango, has been amply demonstrated and continues to attract a lot of attention; Especially for its potential to fight degenerative diseases, heart disease and cancer. According to the same authors, many studies have demonstrated the protective effect of mango mangiferin. These various studies have shown that mangiferin exhibits a wide range of pharmacological effects: antioxidant, anticancer, antimicrobial, anti-atherosclerotic, antiallergenic, anti-inflammatory, analgesic and immunomodulator. In the same way, Lauricella et al. [8] have developed the biological activity of the mango phytochemicals that counteract free radicals, thus reducing many diseases, including neurodegenerative diseases and cancers. Mango is one of the fruits that can be consumed at all stages of its development cycle (from juvenile to senescent stage) [9]. Beside the nutritional and bioactive attributes, mango fruit also owns important technological properties such as bulk density and water absorption capacity, which are higher than that of wheat flour. Accordingly, several studies have shown that mango powder (pulp, peel and kernel) possesses interesting functional properties, which makes it possible to use as ingredient in bakery product possible and as a daily supplement [10-11]. Ripe fruit is main food fruit of summer months consumed as dessert fruit. In addition, mango can be processed into other products such as jam, jelly, juice and vinegar [12-15]. However, fresh mango can be stored for less than ten days at room temperature, as mango is a climacteric fruit because its maturation continues after harvesting, which poses a problem for its conservation and even its storage. The problems of fungal diseases, the sensitivity of the fruit associated with prolonged refrigeration and its short shelf life make that mango cannot be preserved for long time. Consequently, its transport over long distances to distant markets is limited; a real conservation problem then arises. [16]. To extend the shelf life of the fruit, there are several drying techniques for fruit preservation [17-18]. However, the old technique of sun drying is still in use nowadays, especially in developing countries. The drying of mango sounds as an attractive alternative to minimize post-harvest losses [16]. So, the objectives of this study are to produce the mango powder from fresh fruit, to characterize the physicochemical and functional properties and to determine the content on some bioactive molecules of the produced powder.

II.Experimental Section

II. 1 Sample preparation

The mango named "Green Mango" was used in this study. It is the variety of mango most cultivated and appreciated by the Malian population. The fruit is bought from the market in the city of Bamako (Mali capital) august 2018. The choice of this variety is mainly justified by its greater availability and accessibility observed on local markets compared to other varieties. The fruit was chosen once it reached a certain degree of physiological maturity in order to prevent the product from browning during solar drying when it is too ripe. To remove impurities, the fruit (approximately to 200 g) was washed with tap water, then rinsed and drained. After what, the mango was peeled before being pitted. The mangoe was cutted into small homogenous slices and were dried in the sun (room temperature). After drying, the product was packaged in a sealed and waterproof plastic bag until. The sample was then transferred to laboratory. At the laboratory, the fruit has undergone a second drying in an oven (50 ° C) for 24 to 48 hours to remove this residual moisture. After drying, the mango slices were ground using a laboratory electric grinder to obtain a powder with a particle size of less than 500 µm. The powder obtained was stored in a cool and dry place (Fig. 1).

Figure 1. Mango sample: a) fresh mango; b) dried mango slices, c) mango powder

II.2 Physicochemical analysis

The MPP was analyzed for pH with a pH-meter (Adwa, AD 1000), titratable acidity (titration with NaOH), moisture (drying in the oven at 103 ± 2°C during 3h), dry matter (by subtracting the humidity value from 100), ash (in the muffle furnace) and organic matter [19].

II.3 Functional properties

Water absorption capacity (WAC) and oil absorption capacity (OAC) were determined according to the methods given by Diomande *et al.* [20]. Briefly, for WAC, 10 mL of water were added to a centrifuge tubes containing 1g of sample. The weight of the tube with the powder was noted (M1). The tubes were shaken during 30 minutes then centrifuged at 4000 rpm for 35 minutes. The supernatant was discarded and the new masses are denoted (M2). The WAC was calculated from the relation:

$$WAC = (M2 - M1) \times 100 / SW$$

Where: M1: weight of tube with powder before adding water
M2: weight of tube with powder after adding water
SW: sample weight (10g)

The results were expressed as g of water held per 100g of MPP.

Similar procedure was used for OAC, but 0.5g of sample and 6 ml of sunflower oil were used instead. Results were expressed as g of oil held per 100 g of MPP.

The Emulsifying Activity (EA) was determined by blending 1g of the sample with 3 mL of water. The mixture was stirred well. After complete dispersion, 3 mL of sunflower oil were gradually added and the blending continued for 30 min. The resultant mixtures were centrifuged at 4000 rpm for 35 min. The tubes were removed and the heights (total height and water height) were measured and recorded [20].

The EA was then calculated from the relation:

$$EA = (He/Hw) \times 100.$$

Where: He : Height of emulsified layer ;
Ht : Height of the whole solution.

For the determination of the emulsion stability (ES), the tubes were placed in water bath at 100°C. for 30 min. After what, the tubes were removed and the new emulsified layer heights have been noted (He') [20].

The ES was calculated according to the following formula:

$$ES = (He'/ He) \times 100$$

with He: Height of emulsified layer; He': new height of emulsified layer.

II.4 Preparation of the Extract

The extract was prepared according to the protocol described in our previous study [21]. Briefly, 1 g of MPP was macerated in 5 ml of aqueous methanol (80%, v / v) at room temperature for 40 min under stirring. The mixture was filtered through a filter with a nominal porosity of 45 µm and the filtrate obtained constitutes the extract for the analysis of the phenolic compounds.

II.5 Quantification of Antioxidants

Total phenolics: the amount of total phenolics in the MPP extract was determined using the Folin-Ciocalteu reagent and gallic acid as standard as described by Nickavar *et al.* [22]. In brief, 50 µL of each extract were added to 1 mL of Folin-Ciocalteu reagent (diluted ten times). After 10 min, 0.8 mL of sodium carbonate (Na_2CO_3) (75 g/L are added. The mixture kept in the dark for 30 min and the absorbance was measured at 765 nm using a UV– Vis spectrophotometer. The results are expressed as milligram Gallic Acid Equivalent per one hundred gram of the dry weight (mg GAE/100 g DW) by referring to the previously established calibration curve (y = 9.874x + 0.104)

Total flavonoïds: the total flavonoïds content was evaluated by colorimetric assay according to the methodology of Kim *et al.* [23]. Into a 10 mL test tube, 250 µL of the extract and 1 mL of distilled water were successively introduced. At the initial time (0 minutes) were added 75 µL of a solution of NaNO2 (5%), after 5 minutes, 75 µL of $AlCl_3$ (10%) were added. Finally, at 6 minutes, 500 µL of NaOH (1N) and 2.5 mL of distilled water were added successively to the mixture. The absorbance of the mixture was recorded at 510 nm and the catechin was used as standard. The results were reported as mg catechin equivalent per 100 g of dry weight (mg CE/100 g DW) by referring to the previously established calibration curve (y = 0.003x)

Total condensed tannins content: the MPP total proanthocyanidins content was assessed by the method slightly modified and described by Vermerris and Nicholson [24]. A volume of 2 mL of iron sulfate was added to 200 µL of extract. The tubes were incubated at 95°C for 15 min. The absorbance was recorded at 530 nm. The result was expressed as mg Cyanidine equivalent per 100 g of dry matter (mg EC / 100g DW) and calculated using the formula:

$$C \text{ (mg EC/100 g)} = Abs.\ MM.\ FD.\ 1000/\varepsilon.\ L$$

Where: Abs: Absorbance at 530 nm; MM: Molar weight of cyanidin (287.24 g / mol); FD: dilution factor; L: optical path; ε: molar extinction coefficient of cyanidin (ε = 34,700 L. mol-1cm-1).

III. Results and Discussion

III.1 Physicochemical Parameters

pH, titratable acidity, conductivity, moisture, dry matter, total ash and organic matter of MPP are illustrated in Table 1.

III.1.1 pH and titratable acidity

The pH is a determining parameter of the quality of a food product. A pH ranging from 3 to 6 is very favorable to the growth of yeasts and molds [25]. The result shows that the MPP pH was 3.52, testifying the acidic character of the product. The titratable acidity, expressed as a percentage of citric acid, of the sample analyzed is about 1.15%. According Arkoub-Djermoune *et al.* [25], the acidity indicates the ripeness of the fruit (it diminishes during maturation) and the ratio of sugars/acidity determines the sweet character, balanced or acidic fruit. pH and titratable acidity are usually terms used for express the acid levels. The pH of MPP found in the present study was similar to that found by Gurak *et al.* [15] on mango pulp jelly from Brazil with pH of 3.35. Such a pH is a brake on the proliferation of many pathogenic microorganisms or food spoilage that are unable to develop in such a medium but still favor the development of those that are acidophilic. The total acidity of fresh green mango pulp of cultivar Tommy Atkins from Sri Lanka was 0.52%, that of freeze-dried mango was 0.49% and that of vacuum-dried mango was 0.40% [26]. These results were low comparing to our findings; while, the titratable acidity of Egyptian fresh mango (Zebda cultivar) was of 2.41% [27]. These recorded differences may be due to the different varieties used and their growing conditions as well as to the drying methods applied. The titratable acidity of the dried mango samples -Amélie, Brooks, Lippens- analyzed by Belem et al. [3] was in the order of 1.56, 1.71 and 0.71%, respectively which are close to the results of the current study. According to the same authors, the acidity of the mangos is mainly due to the presence of citric and malic acids. Other organic acids are also present and contribute to this acidity, these are oxalic, ascorbic, succinic, pyruvic as well as tartaric, muconic, galipic, glucuronic, α-ketoglutaric and galacturonic acids. They are considered as flavor constituents that contribute to the organoleptic properties of the fruit [28].

III.1.2 Moisture content

The moisture test permits to know the water content of the MPP. The presence of water in a food product (high water activity) is a factor favoring the development of microorganisms. Thus, drying is a means of reducing water so the water activity. The moisture content reported in the present study was relatively low with a tenor of 3.4%. As for the dry matter, the content was higher 96.60%, which is expected as the moisture content was low. The moisture of MPP was higher than that reported by Mahendra [26] who had the moisture final content of 1.91% in the vacuum-dried mango powder, this permits to prolong the shelf life of the product; and lower that that recorded by Dyab *et al.* [27]. This difference may be the results of the initial mango quality and processing methods. Moisture content greater than 14% will affect the storage qualities of powders and flour as mold growth, insect infestation and clumping could occur under this condition [29]. The moisture content of Indonesian mango powder of indramayu variety dried at different temperatures of 50, 60 and 70 °C was 2.93, 2.76 and 2.36%, respectively [30]. Whereas, the pineapple powders in the study of Wong *et al*. [31] had presented moisture contents between 3 and 5%.

III.1.3 Total ash and organic content

The total ash content of the mango powder is 3%. According to Abdullah [32], several factors influence the ash rate, including the nature and quality of the raw material used in production, as well as factors influencing the proportions of total solids. As can also be noted in Table 1, the organic matter content is 97%. This organic matter is represented mainly by sugars including fructose, fibers and organic acids and also ascorbic acid (vitamin C) [33].

Table 1. *Physicochemical characteristics of MPP*

Parameter	Value
pH	3.52
Acidity (%)	1.15
Moisture (%)	3.40
Dry matter (%)	96.60
Total ash (%)	3.00
Organicmatter (%)	97.00

The ash represents the total quantity of mineral salts contain in the food. The total ash recorded in the present work was lower than that of Dyab *et al.* [27] who obtained a rate of 4.05% in mango powder (Zebda cultivar) and that found by NoorAziahas and Komathi [29], as they found estimated amounts of 7.39 and 7.32% (w/w) in peeled pumpkin pulp flour and unpeeled pumpkin pulp flour, respectively. Despite this low ash content, MPP remains an important source of minerals. The differences recorded between results may be due to the nature and components of the raw materials. According to Maldonado-Celis *et al.* [34], the principal essential minerals that mango pulp contributes are K, P and Ca, whereas, Na, Zn, and Fe are found in low levels.

III.2 Functional properties

The functional properties of MPP, such as its water and oil holding capacities and emulsifying properties, are very essential because they determine the functionality of the powder in the foods [35]. The results show a significant WAC of MPP which is around 106% which indicates that the sample has a high affinity for water; the OAC was in the order of 131%, also indicating a high affinity of MPP to absorb oil; the EA was 47.05%, while the ES was even higher around 84.37% (Fig. 2). A high WAC ratio of composite flours is suggested useful for bakery products as it serves to improve dough and prevent stale by reducing moisture loss [36]. Oil absorption capacity (OAC) is the ability of flour to absorb oil, which is important because the oil acts as a retained aroma and improves mouthfeel [37].

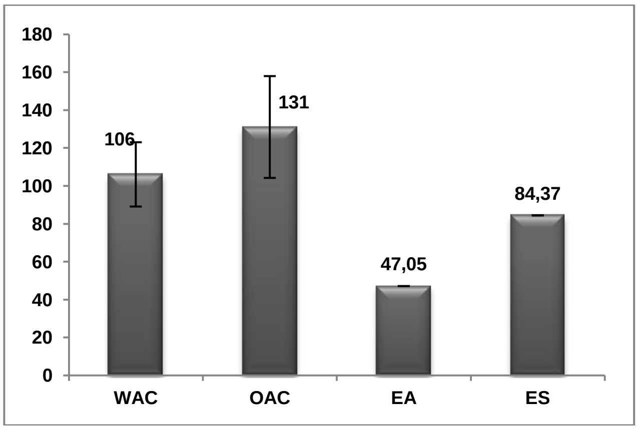

Figure 2. *Functional properties of mango powder*

The values are expressed in %; Vertical bars represent standard deviations
CAE: Water Absorption Capacity
CAH: Oil Absorption Capacity
AE: Emulsifying activity
SE: Stability of Emulsions

The water absorption capacity (WAC) of flour plays an important role in food preparation due to its influence on other functional and sensory properties. The results of the present study were approximately close to those obtained by Diomande *et al.* [20] on almond flour from the mango kernel of a few varieties in Côte d'Ivoire; WACs were between 72.36 ± 4.34 and 172.23 ± 1.45g / 100g and OACs between 99.86 ± 2.31 and 110.6 ± 0.61g / 100g; While the flour EA varied between 37.4 ± 0.88 and 47.59 ± 0.32 g / 100g, as for the ES, the results varied between 88.5 ± 2.12 and 100 ± 0.00g / 100g. In mango almond flour (cultivar *India*), Okpala and Gibson-Umehthe [38] have noted a WAC of 2 g/g, this value is higher than that found in the present study, which suggests that mango pulp powder is less hydrophilic than that of its almond. Similarly, a higher OAC value of mango almond flour of 2.16 g/g was reported by the same authors. The variation in the presence of nonpolar side chains in the flours, which bind to the carbon side chains of the oil, would be one of the reasons for the different oil retention capacities of the flours [39]. Sangnark and Noomhorm [40] stated that changes in oil retention properties could be attributed to changes in the physical structure of the product since food processing methods affect the conformation and hydrophobicity of proteins.It would be noted that food powder or flour with a high WAC makes it an appropiriate functional ingredient in products to improve their viscosity, such as soups, sauces, dairy products (yogurts and cheeses) and readyto-eat food products. In addition, the higher the WAC, the more liquid leakage from a product during storage or processing of food is reduced, for example the reduction of syneresis in yogurt. Regarding this, the MPP can be used as a functional ingredient [41].
The EA of MPP recorded in the present study is far superior to that reported by Noor *et al.* [42] on mango peel flour (Perlis Sunshine variety) which was 4.68 ± 1.25 %, while the authors obtained an ES

of the order of 79.12 ± 0.23% close to that found in the current study. In fact, the formation and stability of the emulsion are very important in the manufacture of salad dressing [43]. The low EA (47.05%) recorded in the present study can be explained by the low protein content of the mango which is considered as a good emulsifying agent as clarified by Selani *et al.* [44]. Overall, although the MPP showed a low EA, a high ES and do not have properties as emulsifying agents, the powder can still be used for emulsion stabilization in food formulation which is in accordance with the results of Selani et al. [44] on residual Brazilian mango pulp.

III.3 Antioxidant Contents

III.3.1 Total Phenolic Content (TP)

Phenolic compounds, commonly found in fruits, have demonstrated antioxidant activity, due to the reactivity of the phenol moiety, and an ability to scavenge free radicals by donation of hydrogen or electron. The methanolic extract of the mango powder showed a relatively high TP content (Table 2), in the order of 15660 ± 0.06 mg / 100 g of mango dry matter. Results from the present study were far higher from those of Ribeiro *et al.* [45] as they recorded a content varying between 50 and 250 mg GAE/100g of fresh weight in the methanolic extract of the pulp of four Brazilian mango varieties. In the ethanolic extracts of the pulp of ripe and unripe mango, Korean variety Irwin, the TP contents were 26.9 ± 3.76 and 27.8 ± 2.21 mg GAE / g dry matter, respectively [46]. Mangiferin, gallic acid, gallotannins, quercetin, isoquercetin, ellagic acid and β-glucogallin are among the polyphenolic compounds already identified in mango pulp as found by Masibo and He [7] and Morales *et al.* [47]. The result obtained in this study shows that mango powder has a high content of TP which contributes significantly to the intake of antioxidants in the diet. Several factors such as variety, genetic differences between different cultivars as well as geographic origin, soil composition and extraction method including time, temperature and solvent, could influence the content of phenolic compounds [48-49]. The content of total polyphenols in fresh mango from Sri Lanka, 0.34 ± 0.03 g GAE/ kg FW, was lower than that reported in the current investigation [50]. Similarly, Abbasi et al. [51] reported total polyphenol contents ranging between 22.06 ± 0.27 and 97.47 ± 6.76 mg GAE / 100 g of fresh weight in nine Chinese mangoes varieties. Ferulic acid was the major phenolic acid in 100g fresh weight of the pulp (33.75mg/100g), followed by protocatechuic (0.77 mg), chlorogenic (0.96–6.20 mg), gallic (0.93–2.98 mg), vanillic (0.57–1.63 mg), and caffic acids (0.25–0.10 mg) [51].

III.3.2 Total flavonoïds Content (TF)

Flavonoïds, the most important class of polyphenols, constitute a large family of phenolic compounds having a common C6-C3-C6 structure of the phenyl-2-benzopyran type. The antioxidant activity of flavonoïds has already been demonstrated many years ago. Their antioxidant capacity depends on the reactivity of the hydroxyl substituents in hydrogen atom transfer reactions [52].The mean value of TF content of MPP is presented in Table 2. Data revealed that TF content of the MPP was 34.33 ± 0.71 mg/100 g. Results from the present study were higher comparing to those recorded by Dyab et al. [27] who found a TF content of 7.06 ± 0.53mg / 100g in fresh pulp and a content between 1.12 to 1.15mg / 100g in mango pulp powder prepared with different formulas without sugre addition. On the three varieties *Willard*, *Vellaicolomban* and *Karuthacolomban* from Seri Lanka, Kuganesan *et al.* [53], recorded TF contents of 120.20±10.29 and 479.80±15.30 mg EQ / g dry weight of mango pulp ethyl acetate extract. The content of TF of 12 Indian mango pulp cultivars was between 37.07and 7.00 mg QE/100g as displayed by Muralidhara *et al.* [54], the authors stated that the TF content was found much lower in mango pulp (10-30 times) than in mango peel. In flesh extract of nine Chinese mango cultivars, five flavonoïds including epicatechin, catechin, mangiferin, fisetin and qurcetinwere identified and each variety has a predominant flavonoïd over the others [55]. The TF contents recorded by Abbasi et al. [52] ranged between 0.904 ± 0.07 and 9.252 ± 0.18mg CE/100 g fresh weight.

III.3.3 Total condensed tannins(TCT)

Condensed tannins, also called proanthocyanidins, are polymers of flavanols. The recorded rate is relatively high with a content of 106.27 ± 13.91 mg EC/100g DM (Table 2). The antioxidant activity of condensed tannins is due to its free radical scavenging capacity, chelating transition metals, inhibition of pro-oxidative enzymes and peroxidation of lipids [56].

Table 2. *Total phenolics, Total flavonoïds and Total condensed tannins content of MPP*

Constituents	**Values**
Total phenolics (TP) (mg GAE/100g DW)	15660 ± 0.06
Total flavonoids (TF) (mg CE/100g DW)	34.33 ± 0.71
Total condensedtanninsContent (TCT) (mg EC/100g DW)	106.27 ± 13.91

MPP: Mango Pulp Powder
GAE: Gallic Acid Equivalent
CE: Catechin Equivalent
CE: Cyanidin Equivalent
Each value in the table is the mean ± standard deviation (n = 3).

The TCT content of MPP was lower compared to the results from the study of Rashmi *et al.* [57] on the peel of several varieties of mango, where authors found tannin contents ranging between 8.17 and 13.66 mg/g dry weight. At 50% maturity, all of the varieties they studied had the same tannin levels, however, as maturity progressed (50-100%), tannin levels were reduced in all varieties except some. This divergence recorded between the results may be linked to the ripening conditions of the fruits and/or to the dosage techniques used. In their study on six cultivars from the Colombian Caribbean region, Marales *et al.* [47] reported a condensed tannins content of 84.30 to 161.49 mg Catechineq/100 g dry pulp. The result of the current study show that the evaluated mango varieties exhibited an important condensed tannin content, compounds whose antioxidant activity has been widely reported [58-59].

IV. Conclusion

In conclusion, this study on the physicochemical quality, functional properties and the content of bioactive molecules of Malian mango pulp powder, revealed that although the drying treatments that the fresh fruit has undergone, the MPP still remain good source of bioactive compounds with antioxidant potential in the diet. In addition, the powder obtained exhibit interesting functional properties which make it a functional ingredient. Further, fruit drying can be seen as an attractive alternative to lengthen the shelf life of such fruit and reduce post harvest losses due to its perishability as a result of its high moisture. This permit to offer an opportunity to process this fruit into a value-added food to be exploited in the agrifood industry, which is profitable for the economy of the producing country.

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