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Study of the nutritional and microbiological quality of dried mangoes produced by two units in Korhogo (Ivory Coast)

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Abstract

Objective of this study was to evaluate the nutritional and microbiological qualities of dried mangoes produced by two production units, namely Gninnangnon and Ivoire Organics located in the town of Korhogo. Four samples were taken from each unit and everything was mixed to constitute the sample from each unit. Samples were crushed and the flours obtained were used for the analysis of nutritional and microbiological parameters. Results of the nutritional parameters of Gninnangnon and Ivoire Organics obtained are respectively: humidity (19.74 and 19.43%), pH (3.10 and 3.08), total sugars (5.45 and 5.12%), carotenoids (2.80 and 2.90 mg/100g) and compounds phenolics (197.41 and 153.96 mg/100g). Regarding microbiological parameters, the samples did not contain *Staphylococci*, *E. coli* and *Salmonella*. All samples contained GAM and yeasts and molds. In addition, the Ivoire Organics sample contained *total and fecal Coliforms* unlike that of Gninnangnon. Despite the presence of certain germs, the results suggest that mangoes dried by these companies could be consumed safely.

Keywords: Dried mango; Nutritious; Microbiological; Quality

1. Introduction

Mango tree (*Mangifera indica L.*) is one of the major fruit crops in the world. Generally speaking, there are about a thousand varieties grown around the world that differ in size, color, texture and nutritional properties. Varietal diversity of this fruit makes it one of the most popular in many subtropical and tropical regions [1]. Global production is estimated at more than 50 million tonnes with sub-regional production (Mali, Burkina Faso, Ivory Coast and Senegal) of 1.4 million tons, ranking 7th in the world [2].

In Ivory Coast, mango is the third fruit exported behind banana and pineapple, generating more than 16.8 billion CFA francs in revenue in 2021 [3]. Ivorian mango production was estimated at 180,000 tonnes [3]. This production constitutes a substantial source of income for farmers. It has become an important economic product for populations living in the north of Côte d'Ivoire. Ivory Coast's mango exports have increased significantly over the years, from 71 tonnes in 1981 to 22,533 tonnes in 2015, and reaching over 40,000 tonnes in 2019 [3].Third supplier to the European

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market, Ivory Coast is also the leading African country exporting mangoes, far ahead of other West African countries [4]. Ivory Coast saw record exports in 2021, with more than 47,500 tonnes shipped to Europe [3].

Mango has been designated as a functional food for the prevention and control of metabolic disorders, obesity-related chronic diseases, fatty liver, and other comorbidities [5]. Ivorian mango industry is facing considerable losses between the quantity of mango produced and the quantity exported. These post-harvest losses are estimated between 30 and 35% of total production, or between 54,000 tonnes and 63,000 tonnes of mangoes lost after harvest out of a production of 180,000 [3].

To reduce these post-harvest losses, one of the solutions would be their transformation into pulps, purees, jams and jellies, nectars and dehydrated products [6]. Transformation of mangoes in the form of dried products then constitutes an outlet for reducing losses. post-harvest, valorize the production surplus, give added value to the product and conserve production surpluses [7]. Transformation of mango into dried mango is an activity that is still not mature in Ivory Coast. Between 2017 and 2021, processing into dried mangoes increased from 89 tonnes to 593 tonnes respectively, representing an average annual growth of 66% [3].

Behind the benefits of transforming mango into dried mango, there are many factors linked to nutritional, hygienic and health quality.

Hence the objective of this study is to evaluate the nutritional and microbiological parameters of dried mangoes produced by two processing units located in Korhogo in the north of Côte d'Ivoire with a view to making recommendations.

2. Material and Methods

2.1. Material

Biological material consisted of dried mango of the Kent variety from two production units, namely Gninnangnon and Ivoire Organics.

Figure 1 Photograph of samples from each unit

2.2. Methods

2.2.1. Sampling

Collection of samples in the Gninnangnon and Ivoire organics processing unit was carried out on May 15, 2024. It consisted of taking 4 sachets of 100g from 4 different batches. Contents of the sachets were mixed to constitute the sample for each production unit. Samples were crushed, packaged in plastic jars and stored at 4°C for analyses.

2.2.2. Determination of nutrient parameters

Biochemical analysis

Moisture, pH and acidity were determined using [8]. Moisture content was determined by the difference of weight before and after drying sample (10 g) in an oven at 105°C until constant weight. pH was determined as follow: 10 g of crushed sample was homogenized with 100 mL of distilled water and then filtered through Whatman No. 4 filter paper.

pH value was recorded after the electrode of pH-meter was immersed into the filtered solution. For acidity 10 mL of filtrate or nectar have been titrated by NaOH 0.1N in the presence of phenophthalein.

Proteins were determined through the Kjeldhal method [9]. It consisted of mineralizing 1 g of sample then distilling the mineralization and finally titrating the distillate with 0.1 N sulfuric acid.

Reducing sugars content of crushed pulp was determined according to [10]. 1 g of crushed sample is dissolved in 50 mL of warm distilled water. After filtration, the volume is completed at 100 mL. 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.

Total sugars were determinited by the phenol method [11]. 0.50 g of crushed sample was introduced into a test tube containing 0.50 mL of sulfuric acid (12 N). Reaction medium was keep at ambient temperature (25 °C) during 1 hour before boiling it for two hours in a water bath (100 °C). After boiling, were added to the contents of the tube 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). 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.

Phytochemical analysis

Vitamin C contained in analyzed samples was determined by titration using the Method described by [12]. About 10 g of sample were soaked for 10 min in 40 mL metaphosphoricacid-acetic acid (2%, w/v). Mixture was centrifuged at 3000 rpm for 20 min and the supernatant obtained was diluted and adjusted with 50 mL of bi-distilled water. 10 mL of this mixture was titrated to the end point with dichlorophenolindophenol (DCPIP) 0.5 g/L.

Polyphénols content was determined using the method reported by [13]. 1 g of crushed sample was soaked in 10 mL of methanol (70%) 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 sodium carbonate (20%). Reaction mixture was incubated for 30 min at ambient temperature and absorbance was measured at 745 nm by using a spectrophotometer. Polyphenols content was obtained using a calibration curve of gallic acid (1 mg/mL) as standard.

Carotenoid content was determined according to the method of [14]. 2 g of sample were ground with 20 mL of a mixture of hexane and acetone (30/70). After recovery of the supernatant by decantation, the optical density was between 430 and 450 nm in order to determine the maximum optical density. Carotenoid content was then calculated according to the follow expression: $C = ODmax \times f / 196 \times m$

OD max: maximum optical density;

f: dilution factor;
m: mass of the sample.

2.2.3. Determination of microbiological parameters

Mother solution

Preparation of the stock solution consisted of introducing 25 g of crushed sample into 225 ml of buffered peptone water contained in a stomacher sachet. Whole thing was mixed with the stomacher for 1 min. Solution obtained constituted the stock solution.

Preparation of decimal dilutions

Decimal dilutions were made from the stock solution up to a 10^{-4} dilution. It consisted of taking 1 ml of the stock solution then incorporating it into 9 ml of Tryptone salt (TS). The solution obtained constituted the 10^{-1} dilution. Subsequently, 1 ml of this dilution was incorporated into 9 ml of TS, which corresponds to the 10-2 dilution. Subsequent dilutions (10^{-3} to 10^{-4}) were prepared in the same manner.

Microbiological analysis

Enumeration of GAM was carried out according to the standard [15]. 1 mL of dilution was introduced into a Petri dish. Then, 15 mL of PCA medium was poured into the box containing the samples. After stirring and solidification, 5 mL of the same medium was poured and then incubated at 37 °C for 72 h.

Yeasts and molds were counted according to the standard [16]. 0.1 mL of dilution was spread on the MYGP medium. Then, the plates were incubated at 30°C for 72 h.

Search for Salmonella spp was carried out according to the standard [17]. It consisted of pre-enrichment at 37°C for 24 h. Then, selective enrichment was carried out by introducing 0.1 mL of the pre-enriched medium into 10 mL of rappaport vassilliadis (RV10) then everything was incubated at 44 °C for 24 h. After incubation, the characteristic colonies of Salmonella spp were identified.

Search for *E. coli* was carried out according to the Standard [18]. 1 mL of dilution was introduced into a Petri dish. Then, 15 mL of EMB medium (Eosin Methylene Blue) was poured. After solidification, the plates were incubated at a temperature of 44 °C for 24 h. Characteristic E. coli colonies were counted.

Search for *Staphylococci* was carried out according to standards [19]. 0.1 mL of dilution was spread on Baird Parker agar medium. Plates were incubated at 37°C for 24 h.

The search for coliforms was carried out on VRBL (Violet Red Bile Lactose agar) medium. 0.1 ml of dilution was spread on VRBL medium. Incubation of total *coliforms* (CT) was carried out at 37°C for 24 to 48 hours and those of fecal *coliforms* (CF) were carried out at 44°C for 24 to 48 hours.

Colony enumeration was carried out according to the standard [20]. The results obtained were expressed in colony format units according to the following formula:

$$N = \frac{\sum C}{(n^1 + 0{,}1 \times n^2) \times v \times d}$$

∑C :sum of colonies on the boxes retained
V : volume of inoculum milliliters
d : dilution from which the first counts are obtained
n^1 : number of boxes retained at the first dilution
n^2 : number of boxes retained at the second dilution

2.2.4. Statistical analysis

Multiple analysis of variance (ANOVA) was used to study the quantity of chemical constituents present in each sample. Student test made it possible to identify the chemical parameter(s) which have a significant difference from each other. Significance of the difference in means was determined by comparing the probability P associated with the statistic to the theoretical threshold $P \leq 0.05$. All tests were carried out using IBM SPSS statistics version 26 software and data entry using EXCEL 2016 software.

3. Results and discussion

3.1. Nutrient parameters

Table 1 presents the biochemical composition of dried mangoes produced by the two units. The moisture contents of dried mangoes produced by the two units are statistically identical. Values are 19.74 ± 0.21 and 19.43 ± 0.81% respectively for the Gninnangnon and Ivoire Organics units. Contents recorded during our study are higher than those of [21] in mangoes dried in the sun and in the oven in DR Congo (8.25 to 14.17%) and of [22] which states that dried mango of good quality must have a humidity between 14 and 17%. On the other hand, our results are lower than those of [23] in dried figs (21.33%) in Algeria. These observed differences could be explained by the variability of drying conditions (type of dryer and drying time) and the difference in varieties used but also according to customer specifications. These high levels in the samples studied could be disadvantageous for producers because they could promote the proliferation of microorganisms, hence the need to store them in appropriate conditions.

Regarding pH and titratable acidity, the values are statistically identical. pH of dried mangoes from the Ivoire Organics unit (3.08) is lower than from Gninnangnon (3.10) which is inversely correlated with the acidity which is higher in the dried mangoes from Ivoire Organics (2.30%) than that from Gninnangnon (2.17%). These pH values are much lower than those of [24] in dried mangoes of the Brooks variety (3.45 to 4.67) in Burkina Faso and [23] in dried grapes (3.91). Results of the acidity of the dried mangoes studied are contrary to those of [24], who found values 0.71 ± 0.33% for the Lippens variety, and 1.56 ± 0.60% for Brooks. This difference could be due to the degree of ripening of the mangoes and the variety of dried mangoes [25]. High acidity could influence the taste by adding a more acidic note and play a role in the preservation and stability of the product. This acidity could have a beneficial effect on conservation because it inhibits the proliferation of microorganisms with the exception of yeasts and molds [21].

Regarding total and reducing sugars, the values are statistically different. Total sugar contents are higher in dried mangoes from the Gninnangnon unit (5.45%) than that from the Ivoire Organics unit (5.12%). Unlike total sugars, reducing sugars are more important in dried mangoes from the Ivoire Organics unit (0.38%). These values are much lower than those of [26] who recorded values of 16.39% and 11.56% respectively in total and reducing sugars in dried mangoes of the Kent variety in Cameroon but higher than those of [27] who found quantities of total sugars of 3.90 ± 0.26 and 5.10 ± 0.59% respectively in dried Amelie and lippens mangoes. These low values recorded could be explained by the reaction of reducing sugars with amino acids leading to the formation of brown compounds (non-enzymatic browning). Sugars can affect the sweetness and taste of dried mangoes. A higher concentration could indicate greater sweetness and better flavor [28].

Concerning proteins, the contents are statistically different. Values are 2.79% and 1.92% respectively for the Gninnangnon and Ivoire Organics units. These values are higher than those of [5] in the pulp of the Kent variety (0.59 to 0.79%). These high levels would be due to the concentration of proteins during drying. Consumption of 100 g of dried mangoes could help cover approximately 15 to 20% of the basic daily protein requirements estimated at between 12 and 15% of the diet [29].

Table 1 Biochemical composition of dried mangoes produced by production units

Parameters	Mango (Gninnangnon)	Mango (Ivoire Organics)
Moisture (%)	19.74± 0.21a	19.43±0.81a
pH	3.10 ± 0.00a	3.08 ± 0.02a
Acidity (%)	2.17 ± 0.57a	2.30 ± 0.57a
Total sugars (%)	5.45 ± 0.10a	5.12 ± 0.09b
Reducing sugars (%)	0.27 ± 0.00b	0.38 ± 0.02a
Proteins (%)	2.79 ± 0.24a	1.92 ± 0.26b

Means of the same column bearing the same letter do not present a significant difference at risk p=0.05

Results of vitamin C, carotenoids and phenolic compounds are presented in Figure 2. The contents of vitamin C and carotenoids are statistically identical. Residual contents in dried mangoes from the Gninnangnon and Ivoire Organics units are 8.37 and 6.31 mg/100g respectively. These values are much lower than those of [26] who recorded values oscillating between 16.61 and 24.76 mg/100g in the Amélie variety but higher than those of [30] in the leaves of o. gratissimum (4.35 and 4.42 mg/100g) and P. oleracea (4.15 and 5.31 mg/100g) dried in the oven and in the sun. Regarding carotenoids, the levels are 2.80 mg/100g for mangoes from the Gninnangnon unit and 2.90 for Ivoire Organics. These low values of vitamin C and carotenoids are due to the processing conditions of mangoes before drying, drying, storage and conservation [31]. However, residual vitamin C levels could help cover at least 15% of daily requirements estimated at 40 mg/day [32].

Contents of phenolic compounds are statistically different. Values of phenolic compounds are higher in dried mangoes from the Gninnangnon unit (197.41 mg/100g) compared to the Ivoire Organics unit (153.96 mg/100g). These values are much higher than those of fresh mango which oscillate between 65 and 140 mg/100g [5]. This increase in phenolic compounds in dried mangoes would be due to their concentration during drying due to the evaporation of the water contained in the samples. This observation was also observed by [30] during the drying of leafy vegetables in the sun and in the oven. This concentration of polyphenols could be beneficial for the consumer because phenolic compounds would be involved in the prevention of cardiovascular diseases and degeneration [33].

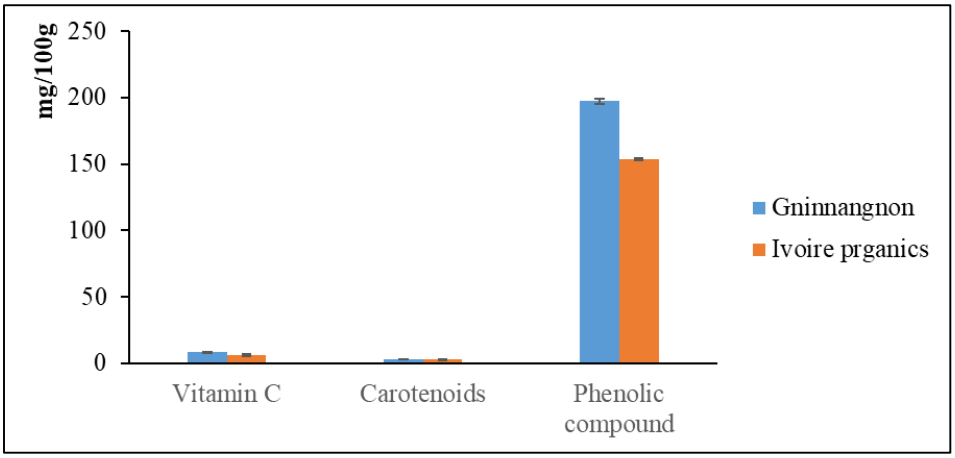

Figure 2 Composition of vitamin C, carotenoids and phenolic compounds of dried mangoes from production units

3.2. Microbiological parameters

Microbiological parameters of dried mangoes from different units are recorded in Table 2. GAMs are considered as an indicator of microbiological quality of foods. Values recorded in dried mangoes from the different units are 231.1 and 263.6 CFU/g respectively for Gninnangnon and Ivoire Organics. These values are lower than those of [21] in sun-dried mangoes (8.103 CFU/g) but included in that of [24] in dried mangoes of the Brooks variety (110 and 990 CFU/g). Our results obtained are lower than the standard [34] which recommends values lower than 104 CFU/g. These results could indicate a very low presence of pathogenic bacteria and their toxins in dried mangoes. Their low presence would also be due to the high acidity of the different samples as well as the heat treatment which would have considerably reduced their number.

Regarding yeasts and molds, their enumeration gave identical values in the different samples (136.35 CFU/g). Our values are much higher than those of [35] in the Brooks variety (10 CFU/g) and [23] in dried grapes (0 CFU/g). Our values are well below the standard [36] which must be less than 104 CFU/g. This presence of yeasts and molds would be due to the condition of the environment (pH and humidity) which would be favorable to their multiplication because they are acidophilic and to poor storage conditions [37]. Dried mangoes could be exposed to proteolysis and fungal reactions. Concerning coliforms, we observe an absence of *Total* and *fecal Coliforms* in the dried mangoes of the Gninnangnon unit unlike the Ivoire Organics unit where there are 77.27 and 9.09 CFU/g respectively of total and fecal Coliforms.

Results of dried mangoes from the Ivoire Organics unit are superior to those of [21] and [24] in which an absence is observed. Results from the Ivoire Organics unit are nevertheless lower than the standard which must be less than 103 CFU/g [36]. These low values could be explained by good hygiene practices as well as good heat treatment. Concerning the germs responsible for sanitary quality, the results show a total absence of *Staphylococci, E. coli* and Salmonella in the different samples studied. This absence could be explained by the low humidity, the high acidity, the high sugar level and the heat treatment of the samples which would influence the development of the germs.

Table 2 Microbiological parameters of dried mangoes produced by the different units

Parameters	Mango (Gninnangnon)	Mango (Ivoire Organics)
GAM (UFC/g)	231.1	263.6
Levure/Moisissures (UFC/g)	136.35	136.35
Total Coliforms (UFC/g)	00	77.27
Fecal Coliforms (UFC/g)	00	9.09
Staphylococ	00	00
E.coli	00	00
Salmonella	00	00

4. Conclusion

This study was carried out with the aim of evaluating the nutritional and microbiological qualities of dried mangoes produced by two production units in the city of Korhogo. Determination of nutritional parameters revealed moisture content, good acidity and a significant content of phenolic compounds unlike sugars, vitamin C and carotenoids. Dried mangoes from the different units meet microbiological standards. Consumption of these dried mangoes could be without risk for the consumer. We recommend raising awareness among those responsible for these units on respecting hygiene measures, especially for the Ivoire Organics unit.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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