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Study of the Physico-Chemical, Biochemical and Hedonic Characteristics of Mango (*Mangifera indica*) Pulp Dryed at 50°C and 60°C in an Electric Oven

KAFANA Katitchô Leticia[1], FOFANA Ibrahim[1,2,*], ABOUO N'guessan Verdier[1], CHATIGRE Kouamé Olivier[1]

[1]Laboratory of Biotechnology, Agriculture and Development of Biological Resources, Biosciences, Training and Research Unit, Félix Houphouët-Boigny University, Abidjan, Ivory Coast
[2]Training and Research Unit *(faculty)* of Agriculture, Fisheries Resources and Agro-food industry, University of San Pedro, San Pedro, Ivory Coast
*Corresponding author: ibrahim.fofana@usp.edu.ci

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Abstract The mango (*Mangifera indica*) is a fruit with high nutritional value. Fresh mango pulp remains highly prized by the local population for its highly attractive nutritional and organoleptic characteristics. Unfortunately, mango is a highly perishable seasonal product with shortages. To remedy this problem, the pulp was dried. Drying was carried out at 50°C and 60°C in an electric oven for 72 hours. After drying, the various pulps were subjected to physico-chemical, biochemical and sensory analyses. Colorimetric parameters were also determined. Results indicate that pulps dried at 50°C retain vitamins A and C better than pulps dried at 60°C, and contribute 49.16% and 16.15% respectively to the daily intake of vitamin C and vitamin A. Pulps dried at 60°C have a higher sugar content than pulps dried at 50°C. The acceptability test showed that panelists liked both fresh and dried pulp. However, the results of the preference test showed that pulp dried at 50°C was the most popular. Colorimetric parameter values showed a very big difference in color between pulps dried at 60°C and fresh pulps, unlike those dried at 50°C, which were similar in color to fresh pulps.

Keywords: *dried mango pulp, electric oven, sensory, physico-chemical, vitamins, nutrients*

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1. Introduction

Mango (Mangifera indica) is the third most important fruit exported by Côte d'Ivoire, behind bananas and pineapples.[1] Annual national production is close to 160,000 tonnes, with over 33,000 tonnes exported to Europe [2]. As a result, Côte d'Ivoire is the third-largest supplier to the European market and also the leading African mango exporting country, far ahead of other African countries. Forecasts for fresh mangoes indicate that production is constantly on the rise, while the local market only absorbs 14,000 tonnes, and 50,000 tonnes are exported. This means that around 100,000 tonnes are lost each season between production and consumption [3]. These losses are estimated at between 30% and 60%. They are due, on the one hand, to pests responsible for several orchard diseases and, on the other, to sales difficulties linked to the narrowness of the domestic market [2]. Unfortunately, given the seasonal nature of mango, these post-harvest losses can lead to periods of shortage. Mango is a seasonal product with a relatively short harvest period, i.e. three to four months of the year. However, mango is a fruit with a high nutritional value [4]. In fact, its nutritional characteristics, and more specifically its provitamin A, vitamin C, mineral and fiber content, make it a valuable dietary supplement. Moreover, fresh mango remains a fruit prized by the local population for its highly attractive organoleptic characteristics [5]. Despite all its nutritional and organoleptic virtues and its economic importance, the use of fresh mango remains limited. It keeps for less than 10 days at room temperature, does not freeze well and turns brown under prolonged refrigeration, making it a highly perishable product [6]. Thus, several alternatives including drying have been considered for its conservation. Recent work by Mwamba et al. [7], has shown that drying is an interesting and practical alternative in rural areas. This technique can be carried out in the sun or using an electric kiln, generally at 50°C and 60°C [8]. The sun-drying commonly practiced in rural areas does not guarantee a controlled and constant temperature, which could affect the quality of dried pulp [7].

In Côte d'Ivoire, work carried out on drying mango pulp of the Kent variety using electric ovens at temperatures between 40°C and 60°C has made it possible to model mango pulp drying [8].

However, few data are available on the biochemical and organoleptic properties of dried pulp from this variety. It is in this context that this work was initiated, the aim of which was to contribute to the valorization of the mango by drying its pulp at 50°C and 60°C in an electric oven. The objectives of the project were to

Determine the physico-chemical, biochemical and colorimetric characteristics and nutrient contribution of dried mango pulp.

Perform a sensory evaluation of dried mango pulp.

2. Materials and Methods

2.1. Biological Material

Mangoes of the Kent variety were used for this study. They were purchased at the Yamoussoukro market in April 2022. Overripe mangoes (ripe and whole fruit) with no wounds were sent to the Laboratory of Industrial Synthesis Processes and the Environment (LAPISEN) at the Institut National Polytechnique Houphouët Boigny in Yamoussoukro.

2.2. Methods

2.2.1. Sampling

Sampling was carried out during the mango season in Côte d'Ivoire (April to June). A total of 150 kg of mangoes were purchased from 3 wholesalers at a rate of 50 kg per wholesaler from the above-mentioned locality and were packed in cartons for transport to LAPISEN. In the laboratory, the mangoes were sorted, washed in tap water, peeled and pitted (Figure 1). They were then cut into slices approximately 1 to 1.5 cm thick. The pulp was then pooled. A quantity of 5 kg of fresh mango pulp was taken for initial physico-chemical and biochemical analyses. The remaining pulp (60 kg) was then divided into 2 batches of equal mass (30 kg per batch) for steaming (Figure 1).

2.2.2. Production of Dried Mango Pulp

Dried mango pulp was produced using the method described by Abouo *et al*. [8], modified. The sliced pulps were placed on racks and dried in an electric oven at 2 temperatures: 50°C and 60°C. After 72 hours of steaming, the slices were removed from the oven and cooled to laboratory room temperature (28 ± 0.2ºC), then packed in plastic bags (stomatcher bags) for further processing.

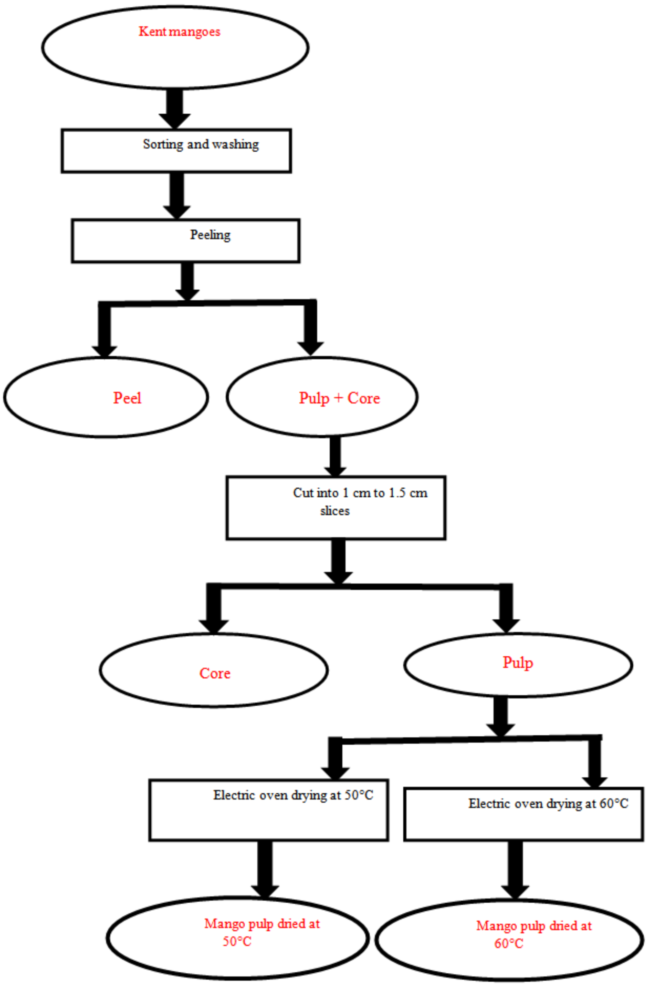

Figure 1. Diagram of dried mango pulp production

2.2.3. Determination of Dried Pulp Production Yield

Production yield was determined using the following expression:

$$\text{Yield} = \frac{M_F \times 100}{M_D} \quad (1)$$

M_F: mass of fresh pulp
M_D: mass of dried pulp

2.2.4. Physico-chemical and Biochemical Analysis of Fresh and Dried Pulp

Titratable acidity of fresh and dried pulp was determined by titrimetric assay according to the AOAC [9] method, using phenophthalein as an indicator. Brix was determined using an Atago refractometer [9]. The pH of the various mango pulp samples was obtained using a HANNA pH meter based on the AOAC [9] method.

Total sugars were determined according to the method of Dubois *et al*. **[10]**, using phenol and sulfuric acid. Reducing sugars were determined using the DNS colorimetric method [11].

The method used for vitamin C determination was that described by Pongracz *et al* **[12]**, based on the reduction of 2, 6 DCPIP (2, 6 dichlorophenol-indophenol).

The determination of ß-carotene was carried out using the spectrophotometric method described by Aké *et al*. **[13]**. The vitamin A content of the samples was determined by dividing the ß-carotene content by 6.

2.2.5 Colorimetric Measurement

The color parameters of all samples were measured using a colorimeter. The colorimetric data are those of the CIELab and CIELCh systems, with L* corresponding to sample brightness ranging from black (0) to white (100), a* representing the green-red balance ranging from green (-) to red (+), b* representing the blue-yellow balance ranging from blue (-) to yellow (+), C* corresponding to chromaticity and h* the hue angle. Measurements were carried out on sample crushed in transparent petri dishes. The instrument's cell was applied directly under the petri dish containing the sample to perform the measurement. Results represent the average of three measurements.

2.2.6. Estimation and Nutrient Contribution of Dried pulp

Daily intakes of nutrient compounds were estimated using the Codex Alimentarius method. This method takes into account the nutrient content of the food (dried mango pulp) and the daily consumption of dried mango pulp by a 70 kg adult in Côte d'Ivoire [14]. The calculation was based on the following formula:

EDI = N x DC (2)
EDI: estimated daily intake;
N: nutrient content of dried mango pulp;
DC: average daily consumption of dried mango pulp by a 70 kg adult in Côte d'Ivoire. This consumption was estimated on the basis of 100 g of dried pulp.

The contribution of dried mango pulp to the recommended daily intake of nutrients was also calculated from the estimated and recommended daily allowances [15].

Contribution (%) = (EDI x 100) / RDA **(3)**
EDA: estimated daily allowance;
RDA: recommended daily allowance

2.2.7. Sensory Evaluation

Sensory evaluation was carried out on mango pulp dried at 50°C and 60°C. Two types of hedonic tests were carried out: an acceptability test and a preference test (pairwise comparison).

2.2.7.1. Acceptability Test

After drying, the mango pulps were subjected to an acceptability test using the method described by Boutrolle [16] to determine their level of appreciation. The panel was made up of 35 untrained people (young girls and boys studying at the Université Felix HOUPHOUËT-BOIGNY in Cocody), recruited on the basis of their availability. The various descriptors evaluated were: taste, color, texture and general acceptability. The samples were served on disposable plates coded with three random digits (according to the code table) and presented simultaneously to the panelists. Taste satisfaction was assessed using a 9-point hedonic scale [17].

Numerical values were assigned to the different categories of the scale, 1 for extremely unpleasant and 9 for extremely pleasant. The test was carried out at the Biochemistry and Food Science teaching and research unit at the Felix HOUPHOUËT-BOIGNY University.

2.2.7.2. Preference Test

The 2 dried mango pulp samples were subjected to a pairwise comparison preference test. To do this, each panelist in the acceptability test was asked to choose one product over the other.

2.2.8. Statistical Analysis

Three tests were carried out for each parameter studied. Statistical analysis of the physico-chemical and biochemical parameter results and the acceptability test were carried out using STATISTICA 7.1 software. For hedonic test data, a chi-square test (X^2) was used to compare proportions. To highlight significant differences, a Turkey test at the $\alpha = 0.05$ significance level was performed. The preference test was plotted using Excel.

3. Results

3.1. Dried Pulp Production Yields

Dried pulp production yields according to the temperature used are shown in Table 1. Values remain around 12% regardless of temperature (50°C or 60°C). Statistical analysis shows no significant difference (P > 0.05).

Table 1. Production yield, titratable acidity, pH and Brix of fresh and dried mango pulp

Samples / Parameters	Fresh pulp	Dried pulp 50°c	Dried pulp 60°c
Yield		12.00± 0.57a	11.68 ± 0.20 a
Titratable acidity (meq/100g)	3.2± 0.10 c	4.83 ± 0.28 b	5.33 ± 0.15 a
Brix degree (°)	18.33±0.11c	26.46±0.37 b	30.53 ± 0.30 a
pH	4.32±0.01 b	4.52 ± 0.01 c	4.62 ± 0.01 a

The values in the table are the means of the three tests, multiplied by the standard deviations. [a,b,c] Means with the same lower-case superscript letters on the same line are not different at 5% according to the Turkey test.

3.2. Physico-chemical Characteristics of Fresh and Dried Mango Pulp

The physico-chemical parameters of mango pulp evaluated in this study are: titratable acidity, Brix degree and pH (Table I). The pH values recorded were 4.52 ± 0.01, 4.32 ± 0.01 and 4.62 ± 0.01 respectively for fresh pulp, pulp dried at 50°C and pulp dried at 60°C. Titratable acidity values for fresh pulp, 50°C-dried pulp and 60°C-dried pulp were 3.2 ± 0.10, 4.83 ± 0.28 and 5.33 ± 0.15 meq/100 g samples, respectively.

In terms of Brix level, an increase in sugar content was observed as moisture content decreased. Thus, for an initial value of 18.33° ± 0.11 (fresh pulp), the highest brix degree (30.53° ± 0.30) was recorded for pulp dried at 60°C, compared with 26.46° ± 0.37 for pulp dried at 50°C. Overall, statistical test data reveal significant differences (P < 0.05) between fresh and dried pulps, and between pulps dried at 50°C and those dried at 60°C, as regards these physico-chemical characteristics.

3.3. Biochemical Characteristics of Fresh and Dried Mango Pulps

The results of the biochemical analyses are presented in Table II. With regard to total sugars, for an initial value of 18.4 ± 0.29 g/100g sample (fresh pulp), the highest content (60.53 ± 0.25 g/100g) was observed in pulp dried at 60°C. For reducing sugars, the lowest content (11.40 ± 0.28 g/100g sample) was recorded in fresh pulp, while pulp dried at 60°C had the highest content (39.08 ± 0.10 g/100g sample). As for vitamin C, the lowest content (17.52 ± 0.01 mg/100g sample) was recorded in fresh pulp, while pulp dried at 50°C had the highest vitamin C content (39.33 ± 0.14 mg/100g sample). With regard to beta-carotene, the content of pulp dried at 50°C and 60°C was around 740 µg/100g of sample, compared with 702.66 ± 2.5 µg/100g of sample for fresh pulp.

In terms of vitamin A, fresh pulp had the lowest content (117.1 ± 0.42 µg/100g sample), in contrast to pulp dried at 50°C and 60°C, where the vitamin A content was around 126 µg/100g sample (Table 2).

Statistical analysis shows a significant difference (P < 0.05) between the different types of pulp; fresh pulp and dried pulp on the one hand, and 50°C-dried pulp and 60°C-dried pulp on the other: fresh pulp, 50°C-dried pulp and 60°C-dried pulp for total sugars and vitamin C. For reducing sugars, vitamin A and beta-carotene, a significant difference (P < 0.05) was observed between fresh and dried pulps, but no significant difference (P > 0.05) was observed between pulps dried at 50°C and those dried at 60°C.

Table 2. Sugar and vitamin content of fresh and dried mango pulp

Samples / Parameters	Fresh pulp	Dried pulp 50°c	Dried pulp 60°c
Total sugars (g/100g)	18.4 ± 0.29 c	50.66 ± 0.20 b	60.53 ± 0.25 a
Reducing sugars (g/100g)	11.40 ±0.28 b	31.08 ± 0.11a	39.08 ± 0.10 a
Vitamin C (mg/100g)	17.52 ± 0.01 c	39.33 ± 0.14 a	28.5 ± 1.00 b
Beta-carotene (µg/100g)	702.66 ±2.5 b	775.4 ± 0.51 a	741 ± 1.00 a
Vitamin A (µg/100g)	117.1 ±0.42 b	129.21 ± 0.09 a	123.49 ± 0.16 a

The values in the table are the means of the three tests, multiplied by the standard deviations. [a,b,c] Means with the same lower-case superscript letters on the same line are not different at 5% according to the Turkey test.

3.4. Color Parameters

L*, a* and b* parameters ranged from 56.18 ± 0.22 to 70.04 ± 0.10 for L*, from 27.85 ± 0.14 to 38.27 ± 0.13 for a* and from 42.19 ± 0.16 to 80.58 ± 0.98 for b*. The color variation ΔE was determined from the L*a*b* parameters (Table 3). Thus, pulps dried at 60°C show the greatest color variation (21.42) compared with fresh pulps, unlike pulps dried at 50°C where the color variation compared with fresh pulps is not very high (4.96).

Table 3. Color parameter values for fresh and dried mango pulp

Parameters / Samples	L*	a*	b*	ΔE
Fresh pulp	70.04±0.10b	34.92±0.25b	80.58±0.98a	
Dried pulp 50°c	73.68±0.28 a	38.27±0.13a	80.19±1.11a	4.96
Dried pulp 60°c	56.18±0.22c	27.85±0.14c	42.19±0.16b	21.42

The values in the table are the means of the three tests, multiplied by the standard deviations. [a,b,c] Means with the same lower-case superscript letters on the same line are not different at 5% according to the Turkey test.

3.5. Contribution of Estimated Intakes to Meeting Recommended Nutrient Requirements for Dried Pulp

The recommended daily allowances (RDA) for vitamin C, vitamin A and total sugars are 80 mg/day, 800 µg (EAR)/day and 90 g/day respectively [15]. The results of estimated intakes of vitamin C, vitamin A and total sugars from the consumption of 100 g of dried pulp are shown in Table 4. Pulp dried at 50°C recorded a vitamin C intake of 39.33 ± 0.14, compared with 28.5 ± 1.00 for pulp dried at 60°C. Total sugar intake was 60.53 ± 0.25 for pulp dried at 60°C and 50.66 ± 0.20 for pulp dried at 50°C. With regard to vitamin A, the estimated intake was around 126mg/d for pulp dried at 50°C and 60°C.

The results indicate that the contributions to vitamin C, A and total sugar requirements from consumption of dried mango pulp by an Ivorian adult are 49.16%, 16.15% and 56.28% for pulp dried at 50°C and 35.62%, 15.43% and 67.25% for pulp dried at 60°C respectively.

Table 4. Recommended daily allowances, estimated daily allowances and nutrient contribution for 100g of pulp dried at 50°C and 60°C.

		Vitamin c		vitamin A			Total sugars		
pulp	ARDA	EDA (mg/j)	Contribution (%)	RDA (µg (EAR)/j)	EDA (µg (EAR)/j)	Contribution (%)	RDA	EDA (g/j)	Contribution (%)
dried pulp 50°C	880 mg	39.33	49.16	800 µg	129.21	16.15	90 g	50.66	56.28
dried pulp 60°C		28.5	35.62		123.49	15.43		60.53	67.25

RDA: recommended daily allowance
EDA: estimated daily allowance
EAR: equivalent retinol activity

3.6. Sensory Evaluation

3.6.1. Acceptability Test

The various panelists tasted the different dried pulps and assigned scores. Table 5 shows the acceptability of pulps dried at 50°C and 60°C. Pulps dried at 50°C and 60°C had respective averages of 7.25 ± 0.22 and 7.14 ± 0.22, corresponding to the "pleasant" level (grade 7). These pulps are equally appreciated by tasters. There is no significant difference (P > 0.05) between these two types of pulp in terms of descriptors, with the exception of color.

3.6.2. Pairwise Preference Test for Dried Mango Pulps

The results of the preference test indicate that dried mangoes were appreciated in different ways. Indeed, 54% of tasters (panelists) preferred pulps dried at 50°C versus 46% for pulps dried at 60°C (Figure 2).

Table 5. Acceptability test for dried mango pulp

Descriptors	Dried pulp 50°C	Dried pulp 60°c
Color	6.09±0.19 [a]	5.27± 0.19 [b]
Taste	5.9 ± 0.17 [a]	5.12 ± 0.17 [a]
Texture	5.33 ± 0.16 [a]	5.75 ± 0.16 [a]
Acceptability	7.25 ± 0.22 [a]	7.14 ± 0.22 [a]

The values in the table are the means of the three tests, multiplied by the standard deviations. [a,b,c] Means with the same lower-case superscript letters on the same line are not different at 5% according to the Turkey test.

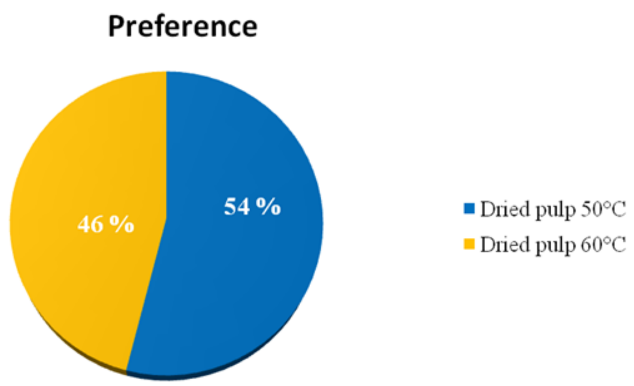

Figure 2. Preference test for different dried mango pulp samples

4. Discussion

The production of dried mango pulp revealed a production yield of around 12% for both the 50°C and 60°C temperatures used during the 72 hours. In economic terms, this rate could be an advantage for manufacturers, as it will save energy.

The results for physico-chemical, biochemical and organoleptic characteristics, as well as those for contribution to meeting nutrient requirements, show significant variations (p<0.05) from one pulp to another (fresh pulp, pulp dried at 50°C or 60°C).

Significant variations (P < 0.05) were also observed in titratable acidity, a very important parameter which contributes to preserving the sanitary quality of foodstuffs by limiting the proliferation of certain pathogenic microorganisms. The low titratable acidity of fresh pulp could be explained by the dilution effect.

With regard to sugars, in general, the results showed a variation in concentrations for all these parameters, depending on the type of pulp. This variation in sugar concentrations is thought to be due to the loss of water from the pulp during drying. Indeed, as a processing and preservation technology, drying is also a concentration process for certain substances such as sugars, which could explain the high carbohydrate contents that characterize the accentuated sweet taste of dried mango slices [18]. Also, our results are similar to those obtained by Mechlouch *et al.* **[19]**, who observed a significant increase (P < 0.05) in these different nutrients when drying Deglet Nour dates by direct solar dryer and solar air drying.

In addition, biochemical characteristics such as vitamin C and vitamin A in pulps dried at 50°C and 60°C were compared with those of fresh pulps and with each other (pulps dried at 50°C and 60°C). The different variations observed are due to the loss of water, which has a corollary effect on the concentration of these nutrients. However, the significant drop (P < 0.05) in vitamin C content in pulps dried at 60°C could be explained by the fact that this nutrient is highly unstable and sensitive to heat [20], hence its degradation at drying temperatures above 50°C.

In terms of sensory evaluation, mango pulps dried at 50°C and 60°C were well accepted by the panelists, although these products seem to be little known by the Ivorian population. However, those dried at 50°C were preferred to those dried at 60°C. These variations could be explained by reactions that took place during electric oven drying. Reactions such as the Maillard reaction, favored by high temperatures and constituting a set of interactions resulting from the initial reaction between sugars and an amino group, could be responsible for the much browner coloration of pulp dried at 60°C [21].

These observations are corroborated by the color variation values obtained during colorimetric measurements, which are of the order of 5 for pulp dried at 50°C and 21 for pulp dried at 60°C. Thus, pulp dried at 50°C has a color much closer to that of fresh pulp. According to Verma *et al* **[20]**, color is the most relevant attribute of food quality, which explains why it is directly associated with consumer appreciation of food.

With regard to the contribution of dried mango pulp at 50°C and 60°C to satisfying total sugar, vitamin C and vitamin A requirements, trade data indicate that in Côte d'Ivoire, dried mango pulp is sold in supermarkets in 100 g bags for single consumption. Furthermore, according to RDA [15], the recommended daily requirements for an adult in vitamin C, vitamin A and total sugars are 80 mg, 800 µg (EAR) and 90 g respectively. On the basis of this consumption, pulps dried at 50°C would contribute 49.16% of daily vitamin C intake and 16.15% of daily vitamin A intake. On the other hand, in terms of total sugars, pulps dried at 60°C would contribute 67.25% versus 60.53% for those dried at 50°C. Knowledge of these contributions is of great importance, as they could help raise awareness of the consumption of dried mango pulp by vulnerable populations, where micronutrient deficiencies are increasingly a public health problem.

5. Conclusion

The aim of this study was to determine the physico-chemical, biochemical and sensory characteristics of mango pulps dried at 50°C and 60°C in electric ovens. The nutrient contribution of mango pulp dried at 50°C and 60°C was also assessed. The various analyses showed an increase in the concentrations of physico-chemical and biochemical parameters in dried pulp, particularly sugars. Indeed, drying is a process that concentrates certain nutrients. In addition, pulps dried at 50°C showed higher levels of vitamins C and A than those dried at 60°C. In terms of sensory evaluation, two tests were carried out: the acceptability test and the preference test. Both tests showed that pulps dried at 50°C and 60°C were accepted by panelists. However, the pulps dried at 50°C were the most appreciated.

Finally, the intake assessment revealed that electric oven-dried pulp particularly that dried at 50°C could be a good source of nutrients, helping to meet requirements for nutrients such as vitamin C and vitamin A.

This study merits further investigation in order to identify appropriate packaging and preservation methods for dried mango pulp.

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