Sensory Analysis of Cakes Enriched with Almonds Powders of *Terminalia catappa* from Cote d'Ivoire

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**Authors’ contributions**

This work was carried out in collaboration between all authors. Author DTE designed the study, wrote the protocol, fitted the data and wrote the first draft of the manuscript. Author KNY performed the statistical analysis, checked the first draft of the manuscript for submission and revised the manuscript. Authors AO, AB, CA and SD managed the literature and assisted the experiments implementation. Author BGHM expertized the results interpretations. All authors read and approved the submitted manuscript.

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**ABSTRACT**

**Aims:** The present work evaluates the sensory properties of nine (9) cakes enriched with almonds powders of *Terminalia catappa* produced in Cote d’Ivoire.  
**Study Design:** The current study focuses on the sensory properties (descriptive profile and hedonic analysis) of nine (9) cakes enriched with the powders of almonds of *Terminalia catappa*.  
**Place and Duration of Study:** Laboratory of Biochemistry and Food Sciences, Biochemistry department of Biosciences Unit, Félix Houphouët-Boigny University, between October and December 2015.
Methodology: The collected fruits were crushed, their almonds extracted were ground, sieved and the powders obtained were separated according to the size of their particle and their proportion. Nine (9) cakes enriched with powdered almonds of *Terminalia catappa* have been prepared and subjected to sensory analyses. Sensory analyses were realized to reveal the descriptive profile regarding nine sensory descriptors, namely color crumb, ventilation crumb, texture silky, texture crumbly, sweet flavor, fat sensation, wet sensation, aroma and bitter, and then hedonic analysis.  

Results: Regarding acceptability, the sensory properties, color, taste, mellow texture, mouth appearance and aroma, differ significantly (p < 0.001) from the cakes enriched with almond flour from *T. catappa*. As for the scores attributed to the different cakes, they are statistically identical. Means are high and range from 6.07/9 to 7.13/9. At the perception level, the profiles showed significant differences at p<0.001 for fortified cakes. The cake scores show no statistical difference except for the color of the crumb. At this profile, the color of the crumb was more noticeable in the F3 cake with a score of 8.11/10, while the F2 cake showed the lowest score (3.3/10).  

Conclusion: The almond flour of *T. catappa* weakly influences the sensory characteristics of the made cakes. It could be used to enrich the cakes and thus allow a better valorization of this plant.

Keywords: Sensory analysis; almonds; cake; Terminalia catappa; Côte d’Ivoire.

1. INTRODUCTION  

The consumption of bakery and pastry products is increasing today, due to changes in the eating habits of the populations. Indeed, the cake is one of the most appreciated and tasteful pastry products, prepared from flour, yeast, egg and gasoline [1]. Although the cake is not considered a staple food such as bread, it is accepted and consumed by people of various ages [2]. It is usually made from flour. In tropical countries, wheat production is limited, which implies the need to import flour to meet demand [1]. The surge in the world market for staple food prices is a constraint on manufacturers, as production costs increase [3,4]. In addition, gluten in wheat flour is a hazard to some consumers with intolerance to this substance [5]. The search for new flavors and flavors by pastry chefs in order to satisfy consumers’ desires, but also to take into account their well-being by presenting functional foods, requires the search for substitute products [6,7]. Faced with these concerns, the almond-based flour of *Terminalia catappa* (“cocoma” local calling) seems an alternative.

Indeed, *T. Catappa* is a fruit tree of the family Combretaceae, it was introduced in the côte d’Ivoire in favor of colonization, through urban decoration [8]. The almonds produced are consumed as an aperitif in more or less salty forms [9]. They also contain high levels of protein (23.78%) and are a good source of essential amino acids [10,11]. Almonds also showed high levels of oleic and linoleic acids [12]. These substances contribute beneficially to the growth and development of children and also reduce the risk of cardiovascular disease and also help fight against inflammation and immunological disorders [13,14]. Then almonds *T. Catappa* have the advantage of being locally produced, free of speculation and there by saving money for industry professionals over imports.

Considering the nutritional and economic potential and to contribute to improving the processing of almonds *T. Catappa*, we will proceed in this work for making cakes enriched with these almonds monitoring their sensory evaluation.

2. MATERIALS AND METHODS  

2.1 Vegetable Material  

The vegetable material consisted of dried ripe fruits from *T. catappa* collected from suppliers in different regions of Côte d’Ivoire.

2.2 Sampling  

The ripe dried fruits of *T. catappa* were collected between October and December 2016 from farmers in two regions of Côte d'Ivoire, namely Tonkpi region (Man and Danané cities) and Guemon region (Duékoué city), where this crop is cultivated. Per location, 3 suppliers were considered, from each of them 60 kg of dried fruits of *T. catappa* were collected. Thus, a total volume of 540 kg of dried fruits were collected, convoyed in the laboratory for analyses.

2.3 Preparation of Powdered Almonds of Dried Fruits of *Terminalia catappa*  

Dried fruits of *T. catappa* were crushed using nutcracker. Once extracted, the almonds were dried at 50°C for 48 h in an oven (MEMMERT,
Germany). After cooling to room temperature, they were crushed (Magimix Crusher) and sieved using a column of sieves of different meshes (0.1, 0.14, 0.25, 0.36 and 0.4 mm) thus giving 5 batches of flour (Fig. 1). These batches of flour were stored in sealed polyethylene bags and stored in the desiccators until the cakes were made.

### 2.4 Preparation of Composite Powders

The Composite Central Plane (PCC) was used to obtain a well-structured range of almond powders that will provide various nutrient characteristics. Two controllable factors have been taken into account: the quantity of *T. catappa* almond powder varying from 5% to 10% and the particle size of the almond powder of *T. catappa* which oscillates between 0.1 mm and 0.4 mm (Table 1). For this plane, each factor presented 5 levels (−α, −1, 0, +1 and +α). Referring to Plackett and Burman [15], the combination of the levels of the two factors studied led to the implementation of 11 trials corresponding in reality to 9 formulas, since tests 9, 10 and 11 have the same proportions and Sizes of almond powder to be used (Table 1).

#### Table 1. Experimental plan for the composite plan used for the formulation of different cakes

<table>
<thead>
<tr>
<th>Test</th>
<th>Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>Amount of <em>T. catappa</em> almond powder (%)</td>
</tr>
<tr>
<td>X2</td>
<td>Particle size of the almond powder of <em>T. catappa</em></td>
</tr>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>9.25</td>
</tr>
<tr>
<td>3</td>
<td>5.75</td>
</tr>
<tr>
<td>4</td>
<td>9.25</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
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<tr>
<td>6</td>
<td>10</td>
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<tr>
<td>7</td>
<td>7.50</td>
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<tr>
<td>8</td>
<td>7.50</td>
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<tr>
<td>9</td>
<td>7.50</td>
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<tr>
<td>10</td>
<td>7.50</td>
</tr>
<tr>
<td>11</td>
<td>7.50</td>
</tr>
</tbody>
</table>

X1, the amount of almond powder of *T. catappa* which varies from 5% to 10%, X2, the particle size of the almond powder of *T. catappa*

### 2.5 Preparation of Cakes

The bakery flour, the 9 types of almond powders of *T. catappa*, fresh eggs, butter, sugar and baking powder were used for the preparation of cakes. Thus, from these ingredients, 5 cakes were prepared according to the method described by Bennion and Bamford [16] (Table 2). Indeed, using a Kenwood drummer (Kenwood Chef - Model A910D), the sugar was whitened in white and egg yolk at 240 rpm for one minute. Then baking flour and yeast were added to the mixture and the mixture was blended at 300 rpm for five minutes. To this mixture, the almond powder of *T. catappa* was added and mixed at 240 rpm for one minute. Finally, the butter was added and mixed again at 300 rpm for four minutes. The paste obtained was carefully reversed in a pre-induced oil mold, introduced into a preheated oven and baked at 150°C for 45 minutes. After cooking, the cakes (Fig. 2) were cooled to room temperature (25°C), demolded, packed in aluminum foil and then stored in a dry place. After 24 h, cakes were evaluated.

### 2.6 Sensory Evaluation

The sensory analysis consisted in the tasting of the various cakes enriched with almond powders of *T. catappa*. Hedonic assessments and descriptive tests have been carried out. The tasting sessions have been made at the laboratory of biochemistry and food sciences of the Felix Houphouët-Boigny University of Abidjan. Every tasting has been made with 20 g of samples served in disposable rubber plates. The answers have been given by the scores on a scale of 9 points where 1 expressed the lack of sensation and 9 expressed the full sensation.

#### 2.6.1 Hedonic analysis

The analysis was carried out by a group of 30 people (15 male and 15 female) of age understood between 20 and 30 years. The panelists have been invited to express their level of acceptance of the the color, taste, texture silky, appearance in mouth and aroma. Preference tests were carried out on a 9-point hedonic scale where level 1 translated "extreme disagreeability" while 9 was "extreme pleasant" [17].

#### 2.6.2 Descriptive analysis

A panel of 10 volunteers aged 20-30 years was selected on the basis of their availability, their faculty to recognize and appreciate the level of perception of the flavor, color, flavor and texture
characteristic of food products. Panelists have been trained in the methodology of analysis and appreciation of qualitative characteristics selected according to the requirements of sensory analysis, trained on the taste areas of the tongue and familiarized with cakes [18]. For the sensory evaluation of the cakes, panelists were invited to taste samples with codes (A, B and C) and and filled into various orders of presentation, then to fit the rating scale by indicating the value for the intensity perceived [19]. The values varied also from 1, when the sensory parameter is not perceived, to 9 when it is extremely felt.

2.7 Statistical Analysis

The statistical processing of the data consisted of an analysis of variance (ANOVA) with a classification criterion using the SPSS software (SPSS 16.0 for Windows, SPSS Inc.). Means were compared by the Newman Keuls test at the 5% significance level. A Principal Component Analysis (PCA) was also performed using STATISTICA software (STATISTICA version 7.1) in order to structure the variability between cakes and sensory descriptors. Data from the hedonic assays were analyzed using a Chi-square ($\chi^2$) of proportions of comparison.

3. RESULTS

3.1 Hedonic Analysis of Cakes

Regarding acceptability, the sensory properties namely color, taste, mellow texture, mouth appearance and aroma, differ significantly ($p < 0.001$) from the cakes enriched with almond flour from *T. catappa*. As for the scores attributed to the different cakes, they are statistically identical. Means are high and range from 6.07 / 9 to 7.13 / 9 (Table 3).

3.2 Descriptive Analysis of Cakes

At the perception level, the profiles showed significant differences at $p < 0.001$ for fortified cakes. The cake scores showed no statistical differences except for the color of the crumb (Fig. 2). At this profile, the color of the crumb was more noticeable in the F3 cake with a score of 8.11 / 10, while the F2 cake showed the lowest score (3.3 / 10). The aeration of the crumb, the soft texture and the aroma were moderately perceived. Thus the aeration displayed scores between 5.77 / 10 and 7.55 / 10, the soft texture between 5.62 / 10 and 8.61 / 10 and the flavor between 5.35 / 10 and 8, 61/10. The friable texture and wet sensation were less evident with averages varying from 1.9 / 10 to 4.66 / 10 and from 2.04 / 10 to 4.63 / 10, respectively. On the other hand, the sweetness and the sensation of fat displayed the highest intensities. They varied from 7.91 / 10 to 9.1 / 10 and from 6.34 / 10 to 8.78 / 10 respectively (Fig. 3).

3.3 Sensory Variability of Cakes

The F1-F2 factorial design of main component analysis, which accounts for 85.05% of the variability, shows a strong correlation between cakes F3, F5, F8 and color, taste, texture, appearance and 'aroma. On the other hand, cakes F1, F2, F4, F6, F7 and F9 are not associated with any of the sensory profiles studied (Fig. 4).

Table 2. Composition of cakes prepared

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Nature</th>
<th>Cake F1</th>
<th>Cake F2</th>
<th>Cake F3</th>
<th>Cake F4</th>
<th>Cake F5</th>
<th>Cake F6</th>
<th>Cake F7</th>
<th>Cake F8</th>
<th>Cake F9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat (g)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Sugar (g)</td>
<td>64.4</td>
<td>64.4</td>
<td>64.4</td>
<td>64.4</td>
<td>64.4</td>
<td>64.4</td>
<td>64.4</td>
<td>64.4</td>
<td>64.4</td>
<td>64.4</td>
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<tr>
<td>Fresh eggs (g)</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Butter (g)</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Baking powder (g)</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Almond powder (g)</td>
<td>00</td>
<td>5</td>
<td>9.25</td>
<td>5.75</td>
<td>9.25</td>
<td>5</td>
<td>10</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
</tr>
</tbody>
</table>

With, Nature, cake enriched without (0%) almond powder, F1 and F5, cakes enriched with 5% almond powder, F2 and F4, cakes enriched with 9.25% almond powder, F3, cake enriched with 5.75% almond powder, F6, cake enriched with 10% almond powder, F7, F8 and F9: cakes enriched with 7.5% almond powder
Fig. 1. Diagram for obtaining almond powder from *Terminalia catappa*

Fig. 2. Control cake and cakes enriched prepared

With, C: control cake enriched with 00% almonds powders, F1 and F5, cakes enriched with 5% almonds powders, F2 and F4, cakes enriched with 9.25% almond powder, F3, cake enriched with 5.75% almonds powder, F6, cake enriched with 10% almond powder, F7, F8 and F9: cakes enriched with 7.5% almond powder.
Table 3. Acceptability (out of 9) of sensory parameters of cakes

<table>
<thead>
<tr>
<th>Cakes</th>
<th>Color</th>
<th>Taste</th>
<th>Soft texture</th>
<th>Appearance in mouth</th>
<th>Aroma</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>6.5±1.19&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.67±1.24&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.47±1.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.7±1.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.8±1.06&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>F2</td>
<td>6.23±1.19&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.47±1.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.3±1.11&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.53±1.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.13±1.35&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>F3</td>
<td>7±1.17&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.13±1.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.47±1.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7±1.28&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.83±1.14&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>F4</td>
<td>6.53±1.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.87±1.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.53±1.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.53±1.65&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.87±1.13&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>F5</td>
<td>6.73±1.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.07±0.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.73±1.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.83±1.11&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.87±0.97&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>F6</td>
<td>6.07±1.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.77±1.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.47±1.33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.57±1.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.6±1.24&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>F7</td>
<td>6.23±1.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.0±1.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.87±1.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.83±1.17&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.67±1.37&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>F8</td>
<td>6.5±1.16&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.07±1.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.67±1.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.07±1.11&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.93±0.94&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>F9</td>
<td>6.3±1.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.77±1.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.43±1.10&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.43±1.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.67±1.18&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>F</td>
<td>6874</td>
<td>8562</td>
<td>7525</td>
<td>7879</td>
<td>8911</td>
</tr>
</tbody>
</table>

Means ± SD with the same letters on the same line / column are statistically identical to 5%. F, value of the statistical test factor; P, calculated probability value of the statistical test.

Fig. 3. Profiles of color perception, aeration, soft and friable texture (A) and aroma, bitter and sweet flavor, wet and wet feel (B) of the studied cakes

4. DISCUSSION

Today's research into quality foods to satisfy organoleptic needs and contribute to the improvement of consumer health is a major challenge for manufacturers. Several studies have been carried out for the substitution or enrichment of wheat flour mostly used in the field.
of bakery and pastry. These studies have generally focused on starches (yam, cassava, sweet potato etc.), cereals (but, rice, beans etc.) and other plants [20,21]. The use of almond flour from T. catappa has been considered to enrich wheat flour. The sensory analysis of the enriched cakes obtained revealed a weak influence of this flour on the organoleptic characteristics of the cakes. The cakes, thus enriched, have retained their quality, unlike the use of banana flour [22] and soya flour [23]. Enriched cakes have been much appreciated in terms of sweetness and the sensation of fat. Indeed, these attributes are characteristic of a good cake [24]. Moreover the cakes produced are not bitter.

Principal component analysis revealed that cakes F3, F5 and F8 are the most preferred and therefore the best, because they are correlated to both color, taste, texture, appearance and aroma. Concerning the cakes F1, F2, F4, F6, F7 and F9, they are not correlated to any of the attributes but do not remain of less good quality.

The combination of the quantity of T. catappa almond flour and the particle size showed that the quantities (5, 5, 75 and 7.5) and sizes (2.5, 3.6 and 4) were used. They made it possible to form the following characteristic torques: F3 (5.75, 3.6), F5 (5.2.5) and F8 (7.5;4). These combinations did not reveal any significant difference in the texture of the different cakes, but rather in the coloring. Indeed, coloring is an important quality factor directly linked to the acceptability of the cakes produced.

5. CONCLUSION

The use of the almond flour of T. catappa to enrich the cakes presents itself as a way of valorization of this plant more and more forsaken. The various combinations provided by the composite central plane at the level of the quantity of flour and the size of the particles, allowed to retain 9 cakes. Sensory analysis revealed that cakes F3, F5 and F8 are the most appreciated by tasters. The analysis also showed the low interaction of T. catappa flours on color, taste, texture, appearance and aroma on prepared cakes. The flour of almonds of T. catappa could be used to enrich cakes made from wheat flour without altering their original organoleptic appearance.

COMPETING INTERESTS

Authors have declared that no competing interests exist.
REFERENCES


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