Original Research Article

Influence of the nutritive composition on the organoleptic characters of cakes enriched with fruits almond of *Terminalia catappa*

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ABSTRACT

Aims: The study focuses the organoleptic trend according to the nutritive composition of cakes processed from wheat flour enriched with the almond flour of *T. catappa*, a plant growing in some regions of Côte d'Ivoire.
Study design: Nine formulations of cakes processed from addition of almond flour of *Terminalia catappa* to wheat flour and then submitted to nutrients and descriptive sensory analyses.
Place and Duration of Study: Laboratory of Biochemistry and Food Sciences, Biochemistry department of Biosciences Unit, Felix Houphouet-Boigny University, running 2015.
Methodology: The contents in nutriments, namely macronutrients, minerals (macroelements and oligoelements), vitamins, and polyphenol antioxidants of the enriched cakes were determined using standard methods and their sensory description achieved. Then, the influence between both types of characteristics was assessed through the Pearson correlation coefficient (r) at ±0.5 significance using statistical software SPSS.
Results: The cakes investigated recorded unvarious content in total carbohydrates, the major nutritive compound of the flours, whereas the other nutrients increased accordingly to the ratio incorporated for the almond flour of *T. catappa*. Oppositely, the sensory descriptors were responded with quasi-similar scores over the cake formulations. The correlation analysis mainly showed reduction of the cakes aroma during the growth of the nutrients, with r coefficients of –0.65 to –0.54. Thus, the study shows no rather nutritional influence of the nutritive enrichment of cakes on the sensory profile.
Conclusion: The valorization of the cakes enriched with almonds of *T. catappa* could be sustained on the basis of their acceptance by consumers.

Keywords: Fruit almond - descriptive sensory analysis - nutrients - correlations - Terminalia catappa

1. INTRODUCTION

Originally, cakes are mainly processed using wheat flour, to which eggs, sugar, milk, and sodium bicarbonate are often added. These products are widely enjoyed by the consumers of overall ages over the world [1]. However, numerous constraints in the provision of cakes are arising dealing with the demographic growth, nutrients requirements for healthy and good quality life, industrial technologies, inconstancy of the supply and access to the wheat flour, as well as the research of new attractive flavours for consumers. Such imperatives enhance the researches and uses of new flour resources from starchy raw products recording higher nutritious profile. Thus, an increasing interest focusses the non- traditional

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plants displaying some assets for both local development of populations and processing industries [2]. Successfully, numerous technologies implemented to substitute the wheat flour by local starchy food resources, namely cassava, maize, taro, and sweet potato are known henceforth [3, 4]. In this investigation field, several reports reveal fruit almond of *Terminalia catappa* L. as significant nutritious raw product with important contents in proteins, lipids, fibres, vitamins and essential minerals [5, 6, 7]. In addition, Matos *et al.* [8] mentioned the great presence of unsaturated fatty acids in these almonds, especially the oleic acid and linoleic acid (omega 6). These almonds are often consumed as appetizers [9] and can be used to strengthen the quality of starchy products displaying nutritional deficiencies. For this valorization, the use of the almond flour or the ground almond resulting from fruits of *T. catappa* for fortification of the wheat flour in the cakes processing has been successfully achieved by Douati *et al.* [10]. According to these authors, the cakes enriched with the flour of *T. catappa* is richer in nutrients compared to the cakes prepared with the only wheat flour basis. The nutrients enriched cakes are generally enjoyed by consumers, whatever the ratio of the *T. catappa* flour added [**11**]. However, the influence of the nutritional characteristics upon the sensory parameters dealing with the acceptance of these cakes by populations is not highlighted yet. The main objective of the current study is to assess the correlations between sensory descriptors and nutrients contents resulting from the cakes processed by fortifying the wheat flour with the *T. catappa*.

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2. MATERIAL AND METHODS

2.1 Material

The biological material was constituted of mature dried fruits of *T. catappa*. The flour deriving from the grinding of these fruits' almonds was used for fortification of cakes processed on wheat flour basis.

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2.2 Methods

2.2.1 Sampling

The dried fruits of *T. catappa* were collected from farmers in the Tonkpi and Guemon regions, western Côte d'Ivoire, between October and December 2015. The sampling was implemented in the cities of Man and Danane (Tonkpi) and Duekoue (Guemon). Per location, three producers were considered, at the rate of 60 kg of dried fruits. At all 540 kg of dried fruits of T. catappa were purchased and conveyed to the laboratory for the works.

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2.2.2 Grinding of the dried fruits almonds of *T. catappa*

The dry fruits of T. catappa have been broken and their almonds extracted and dried again at 50 °C for 48 h in an oven (MEMMERT, Germany). Thereafter, the dried almonds were cooled at room temperature, ground with Magimix grinder, and processed on a range of 5 successive sifters, namely 0.4, 0.36, 0.25, 0.14 and 0.1 mm diameters, leading to 5 sets of flours with various grain sizes. These flour sets were sealed into polyethylene bags and kept in desiccator until the cakes preparation.

2.2.3 Formulations of the composite flours

A central composite design (CCD) was used accounting two quantitative grinding descriptors, namely the ratio of the *T. catappa* ground product added to the wheat flour (5% to 10%) and the size of the ground product particles (0.1 mm to 0.4 mm), each trait engaging five levels (-α, -1, 0, +1, and +α) [10, 11]. Considering Plackett and Burman instructions

(1946), the combination of the levels of both factors studied led to the implementation of 11 essays that really corresponded to 9 formulas, since three essays (essays 9, 10, and 11) presented the same proportions and sizes of the ground product used (table I).

2.2.4 Preparation of the cakes

For the cakes processing, only the rate of *T. catappa* flour added was considered as quantitative variable, the particles size being planned for the qualitative appreciation of the final product. So, the nine formulas allowed preparation of 5 cakes with various rates of *T. catappa* flour, after gathering the formulas engaging similar ratios of flour (table II). Each cake was prepared using 100 g of total flour (baker wheat flour added with almond flour), 64.4 g sugar, 75 fresh eggs, 60 g butter, and 1.25 g baker yeast [12]. The weights added for the almond flour processed from *T. catappa* fruits have accounted the cakes formulations expected (table III).
Using a Kenwood tool (Kenwood Chief - Model A910D), the sugar was whitened in the egg content at a rate of 240 rpm for one min. Then, the baker wheat flour and yeast were added and the mixture was homogenized at 300 rpm for five min. Thereafter, the *T. catappa* flour samples were added to this mixture and treated at 240 rpm for one min. Finally, the butter was added and the full mixture homogenized at 300 rpm for four min. The resulting doughs were carefully run into oiled cake moulds, and then cooked for 45 min into an oven previously heated at 150 °C. After cooking, the cakes were cooled at room temperature, moulded, wrapped in tinfoil and kept in dry place till analyses

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Table I. Formulation matrix deriving from the combination between the ratio and the particles size of the flour produced from *T. catappa* using the composite central design

Essay N°	Ratio of *T. catappa* flour /100 g total flour (%)	Particles sizes from *T. catappa* flour (mm)	Resulting formulations
1	5	0.1	**F1**
2	9.25	0.14	**F2**
3	5.75	0.36	**F3**
4	9.25	0.36	**F4**
5	5	0.25	**F5**
6	10	0.25	**F6**
7	7.5	0.1	**F7**
8	7.5	0.4	**F8**
9	7.5	0.25	
10	7.5	0.25	**F9**
11	7.5	0.25	

Table II. Gathering of cakes formulations according to the ratio of *T. catappa* flour added

Formulations	Sizes of particles (mm)	Ratio T. catappa flour/100 g total flour (%)	Number of Cakes
F1	0.1	5	**Cake 1**
F5	0.25	5	
F2	0.14	9.25	**Cake 2**

F4	0.36	9.25	
F3	0.36	5.75	**Cake 3**
F6	0.25	10	**Cake 4**
F7	0.1	7.5	
F8	0.4	7.5	**Cake 5**
F9	0.25	7.5	

Table III. Ingredients composition for formulations of cakes enriched with *T. catappa* almonds

Ingredients	Cake 1	Cake 2	Cake 3	Cake 4	Cake 5	Control
Wheat flour (g)	95	90.75	94.25	90	92.5	100
Almond powder (g)	5	9.25	5.75	10	7.5	0
Total flour (g)	**100**	**100**	**100**	**100**	**100**	**100**
Sugar (g)	64.4	64.4	64.4	64.4	64.4	64.4
Fresh eggs (g)	75	75	75	75	75	75
Butter (g)	60	60	60	60	60	60
Baking powder (g)	1.25	1.25	1.25	1.25	1.25	1.25

2.2.5 Assessment of the nutritive components of the cakes enriched with *T. catappa*

The enriched cakes prepared were investigated for the nutritive traits. Thus, the residual moisture rate was determined as well as the contents in glucides (total carbohydrates, soluble carbohydrates, reducing sugars, fibres), proteins, fat, ash, polyphenol compounds (total polyphenols and flavonoids), energy, vitamins, and essential mineral elements.

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2.2.5.1 Determination of the contents in biochemical compounds

The moisture and ash rates were measured with thermo-gravimetric methods [13]. Proteins and lipids contents were determined using respective methods for total nitrogen with Kjeldhal technique and solvent extraction with Soxhlet device. The determination of fibres content was achieved according to Wolf [14] using sulfuric acid 0.25 N. The moisture, proteins, fat, and fibres contents allowed the calculation of total carbohydrates according to FAO [14]. The soluble carbohydrates were measured using phenol-sulfuric method [16], whereas the reducing sugars content were determined with 2, 4 - dinitro salicylic acid [17]. The theoretical energy value of the studied cakes was then calculated accounting the energy coefficient of energizing macronutrients (proteins, lipids, and carbohydrates) mentioned by FAO [18].

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2.2.5.2 Quantification of polyphenol compounds

Regarding phenolics antioxidants, the total polyphenols were assessed in cakes using folin-ciocalteu reagent [19, 20]. The flavonoid content was thus deduced from total polyphenols according to Marinova *et al*. [21].

2.2.5.3 Assessment of essential mineral elements and vitamins

The main essential minerals, namely macro elements (K, Ca, Mg, Na, P, and Na) and oligo elements (Fe, Mn, Cu, and Zn), were assessed from the cakes ash samples, using electronic microscope apparatus coupled to an energy dispersion spectrophotometer (SDE). Regarding vitamins, the measures were separately performed for lipo-soluble compounds (vitamins A and E) and hydro-soluble compounds (vitamins B1, B3, B6, and B9) using high performance liquid chromatography method (Water Alliance, USA) constituted of a Waters pump, an automatic injector, an UV/PDA visible detector, a Servotrace recording; in operative conditions relating to the sounded vitamin.

2.2.6 Assessment of sensory descriptors from the cakes enriched with *T. catappa*

The sensory assessment of the cakes was achieved from 10 volunteer tasters previously taught for the sensory analysis and appreciation methodology regarding selected descriptors (aroma, aspect, flavour, and texture), trained about the taste areas of the tongue areas and accustomed to the cakes [22]. Panelists were then requested to taste different cake samples displaying three digits codes representing the studied formulations (F1, F2, F3, F4, F5, F6, F7, F8, and F9) and provided in random order. The practice consisted in scoring the perceptive intensity of each sensory descriptor on a 10 points rating scale where 1 expressed the lack of perception and 10 the full presence of the descriptor [23].

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2.2.7 Statistical analysis

The data were submitted to statistical treatment using Statistical Program for Social Sciences software (SPSS 22.0 for Windows, SPSS Inc.). Each descriptor was given mean, standard deviation, and variance factors (F-value and P-value) at 5% significance. Then, the bilateral statistical correlations were revealed through Pearson r indexes between sensory descriptors and nutrients in formulated cakes.

3. RESULTS AND DISCUSSION

3.1 Changes in the nutritive composition of the cakes

The biochemical and polyphenol characteristics of the studied cakes are reported in table IV. Total carbohydrates and the reducing sugars displayed unvarious contents (P-value > 0.05) from overall cakes, with respective general average of 55.43 and 0.015 g/100 g. The other parameters show statistically different contents (P-value <0.05) according to the cakes. On average, the cakes contains 6.45% residual moisture, with respective contents in total soluble carbohydrates, proteins, and fat of 0.33 g/100 g, 11.56 g/100 g, and 27.95 g/100 g, and could allow the production of 528.44 kcal energy. In addition, averages of 5.30 g fibres, 6.55 g ash, and 342.23 mg Gallic acid equivalent as polyphenol compounds accounting 14.32 mg flavonoid in quercetin equivalent are recovered from 100 g cakes (table IV).

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Table IV: Nutritive composition of the cakes enriched with *T. catappa* almonds

Characteristics	Cake 1	Cake 2	Cake 3	Cake 4	Cake 5	General mean	Control	F_{-value}	P_{-value}
MOI (%)	6.40±0.01	6.53±0.02	6.40±0.01	6.55±0.02	6.50±0.01	**6.45±0.25**	6.20±0.01	201.121	<0.001
TGC (g/100 g)	55.36±0.07	55.51±0.23	55.38±0.27	55.54±0.21	55.44±0.32	**55.43±0.20**	55.16±0.07	0.22	0.95
TSC (g/100 g)	0.26±0.01	0.40±0.01	0.28±0.01	0.42±0.01	0.34±0.01	**0.33±0.16**	0.1±0.01	167.19	<0.001
RSC (g/100 g)	0.01±0.01	0.02±0.01	0.01±0.01	0.02±0.01	0.02±0.01	**0.015±0.01**	0.01±0.01	1.318	0.32
PRC (g/100 g)	10.70±0.09	12.02±0.02	10.92±0.03	12.25±0.02	11.47±0.02	**11.56±1.12**	9.13±0.02	343.93	<0.001
FAC (g/100 g)	26.77±0.01	29.10±0.01	27.17±0.01	29.50±0.01	28.14±0.02	**27.95±1.05**	24.03±0.01	15518.03	<0.001
SFC (g/100g)	5.14±0.01	5.35±0.02	5.17±0.01	5.40±0.01	5.30±0.01	**5.30±0.84**	4.88±0.02	120.3	<0.001
ASC (g/100g)	6.35±0.07	6.62±0.01	6.40±0.02	6.62±0.03	6.50±0.02	**6.55±0.36**	6.08±0.02	140.51	<0.001
TEV (Kcal/100 g)	505.17±0.01	532.02±0.03	509.73±0.01	536.66±0.01	520.90±0.01	**528.44±9.63**	473.43±0.02	4328.14	<0.001
TPC (mg EAG/100 g)	316.4±0.01	347.34±0.01	321.86±0.02	352.8±0.01	334.6±0.01	**342.23±9.05**	280±0.01	9.94	<0.001
FLC (mg EQ/100 g)	12.5±0.01	14.62±0.01	12.87±0.01	15±0.01	13.75±0.01	**14.32±0.54**	10±0.01	5.87	<0.001

ake 1 *(F1and F5): enriched with 5% almond powder;* ***Cake 2*** *(F2 and F4): enriched with 9.25% almond powder;* ***Cake 3*** *(F3): enriched with 5.75% almond powder;* ***Cake 4*** *(F6): enriched with 10% almond powder;* ***Cake 5*** *(F7, F8 and F9): enriched with 7.5% almond powder.* ***F-value****, statistical Ficher value of the ANOVA;* ***P-value****, statistical value of probability test of the ANOVA.* ***MOI****, moisture content ;* ***TGC****, total glucides content ;* ***TSC****, total soluble carbohydrates content ;* ***RSC****, reducing sugar content ;* ***PRC****, protein content ;* ***FAC****, fat content ;* ***SFC****, soluble fibre content ;* ***ASC****, ash content ;* ***TEN****, total energy value ;* ***TPC****, total polyphenols content ;* ***FLC****, flavonoids content.*

With the essential minerals, the cakes record macroelements contents between 41.08 mg/100 g (Na) to 588.18 mg/100 g (K) and oligoelements contents from 4 mg/100 g (Zn) to 13.23 mg/100 (Cu). Except for Na, each mineral content varies significantly (P-value < 0.05) according to the cakes formulation (table V). Vitamins contents also fluctuate (P-value <0.05) according to the types of cakes. Table V displays general average of 159.88 Retinol Equivalent/100 g (vitamin A), 1.05 mg/100 g (vitamin E), 0.46 mg/100 g (vitamin B1), 7.95 mg/100 g (vitamin B3), 0.38 mg/100 g (vitamin B6) and 0.05 mg/100 g (vitamin B9).

3.2 Changes in the sensory descriptors of the enriched cakes

The sensory descriptors are rated with close similar values from the overall cake formulations (table VI), except for the appearance of the crumb which intensity is more recorded in the formula F3 but lower in formulas F2 and F6. The silky texture, aroma, greasy sensory, and especially sweet flavour of the cakes crumb display more intensive perceptions (respective average of 7.24/10, 7.34/10, 7.73/10, and 8.62/10) compared to the crumbly texture (3.46/10), moisture sensory (3.75/10), appearance (5.17/10), and airy texture (6.58).

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3.3 Main correlations related to the sensory profile of the enriched cakes

The Pearson r indexes presented in table VII show only negative values for significant correlations between the perception intensity of aroma and the main macronutrients contents of cakes. The significant r values fluctuate between – 0.63 and – 0.55. The other sensory descriptors do not show any significant correlation with the nutrients assessed.

For correlations regarding sensory profile and mineral elements contents, the statistical analysis results in significant reduction of the aroma intensity according to the macroelements contents (Ca, Mg, Na, K, P), with negative r values between -0.65 and -0.60.

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The table VIII also shows significant negative influence of Fe and Zn (-0.62 and -0.61, respectively) on the perception of aroma, whereas any increase in the copper content results in reduction of the perception for the crumb appearance of cakes (r = -0.60).

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Otherwise, the enrichment in vitamins A, E, B3 and B9 induces the loss of perception of the aroma, with r indexes from -0.63 to -0.54. The cake crumb gets lower appearance with increasing contents in vitamins A (r = -0.51) and E (r = -0.53), when the moisture is also no rather felt in cakes having more vitamin E content (r = -0.50). The other sensory traits do not display any significant correlation with the cakes vitamins contents (table IX).

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Some significant correlations are also recorded between the sensory descriptors assessed. Indeed, the sweet flavour is more felt in cakes presenting more intensive crumb appearance (r = 0.60). Besides, when the crumb shows greater silky texture, the feeling of greasiness and moisture are more rated (r = 0.74 and r = 0.52, respectively).

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Oppositely, the cake crumbs displayed lower greasy and moisture traits in formulations with major crumbly texture (r = 0.75), which sensory parameter is negatively correlated to the silky texture (r = -0.58). More greasy and silky crumbs are also in opposition with the airy texture (r = -0.56 and r = -0.64, respectively), as shown in table X.

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Table V: Essential minerals and vitamins contents recorded from the enriched cakes studied

	Parameters	Cake 1	Cake 2	Cake 3	Cake 4	Cake 5	General mean	Control	F_{-value}	P_{-value}
Essentrial minerals	**K** (mg/100 g)	560.2±0.02	607.7±0.01	568.6±0.10	616.2±0.01	588.20±0.02	**588.18±22.36**	532.3±0.10	852701.57	<0.001
	P (mg/100 g)	524.6±0.10	544.5±0.10	528.06±0.02	548.1±0.01	536.33±0.06	**536.32±9.39**	512.8±0.10	92806.23	<0.001
	Mg (mg/100 g)	148.1±0.01	155.6±0.02	149.36±0.02	156.93±0.01	152.48±0.01	**152.49±3.53**	143.69±0.01	369140.2	<0.001
	Ca (mg/100 g)	69.51±0.03	75.48±0.01	70.52±0.01	76.58±0.01	73.48±0.02	**73.11±2.83**	65.97±0.01	227333.28	<0.001
	S (mg/100 g)	48.83±0.01	50.10±0.01	49.10±0.03	52.81±0.02	49.91±0.01	**49.25±1.32**	45.8±0.02	321.64	<0.001
	Na (mg/100 g)	40.72±0.01	41.8±0.02	40.91±0.01	42±0.01	40.91±0.01	**41.08±3.23**	40±0.02	1	0.458
	Cu (mg/100 g)	12.7±0.01	13.10±0.01	12.10±0.01	14.21±0.01	13.01±0.01	**13.23±0.53**	9.7±0.01	215.12	<0.001
	Mn (mg/100 g)	8.87±0.03	9.21±0.01	8.95±0.01	10.21±0.02	9.01±0.01	**9.02±1.13**	5.10±0.01	521.56	<0.001
	Fe (mg/100 g)	4.38±0.01	4.65±0.01	4.43±0.01	4.7±0.01	4.54±0.01	**4.54±0.13**	4.22±0.01	964.4	<0.001
	Zn (mg/100 g)	4±0.01	4±0.02	4±0.02	4.00±0.02	4.00±0.01	**4.00±0.13**	3.58±0.01	420.48	<0.001
vitamins	**Vit A** (ER/100 g)	119.8±0.03	196.60±0.02	121.21±0.02	237.2±0.01	124.6±0.02	**159.88±50.01**	114.87±0.24	808478.16	<0.001
	Vit E (mg/100 g)	1.03±0.00	1.07±0.00	1.03±0.00	1.07±0.00	1.05±0.00	**1.05±0.02**	1.00±0.00	1701.57	<0.001
	Vit B1 (mg/100 g)	0.46±0.00	0.46±0.00	0.46±0.00	0.46±0.00	0.46±0.00	**0.46±0.00**	0.46±0.00	3.31	0.042
	Vit B3 (mg/100 g)	7.93±0.00	7.97±0.00	7.95±0.00	7.97±0.00	7.96±0.00	**7.95±0.02**	7.25±0.00	253154.9	<0.001
	Vit B6 (mg/100 g)	0.38±0.00	0.38±0.00	0.38±0.00	0.38±0.00	0.38±0.00	**0.38±0.00**	0.38±0.00	12.88	<0.001
	Vit B9 (mg/100 g)	0.05±0.00	0.05±0.00	0.05±0.00	0.05±0.00	0.05±0.00	**0.05±0.00**	0.05±0.00	3.53	0.034

Cake 1 *(F1and F5): enriched with 5% almond powder;* ***Cake 2*** *(F2 and F4): enriched with 9.25% almond powder;* ***Cake 3*** *(F3): enriched with 5.75% almond powder;* ***Cake 4*** *(F6): enriched with 10% almond powder;* ***Cake 5*** *(F7, F8 and F9): enriched with 7.5% almond powder.* ***F-value****, statistical Ficher value of the ANOVA;* ***P-value****, statistical value of probability test of the ANOVA.*

Table VI: Quantitative profile of sensory descriptors of the cakes enriched with T. catappa almond flour (10 points rating scale)

Cakes	Formulations	CRUAP	CRUAE	CRUST	CRUTE	CRUSF	CRUGF	CRUMO	CRUAR
1	F1	4.23±3.58	6.69±2.71	5.62±4.06	3.6±3.17	8.25±1.83	6.85±2.79	4.38±3.44	8.61±1.78
	F5	5.57±3.29	5.77±3.11	8.61±1.74	2.96±2.64	8.22±2.71	8.38±2.27	4.07±3.36	7.47±3.21
2	F2	3.3±2.96	7.55±3.24	5.79±3.35	4.66±3.45	7.91±3.27	6.34±3.61	2.04±1.85	7.41±3.38
	F4	4.91±3.29	6.5±3.41	6.68±3.10	4.62±3.47	8.75±1.39	7.9±2.54	2.81±2.40	5.35±3.90
3	F3	8.11±1.98	6.52±3.27	7.24±3.00	3.95±3.50	9.1±1.17	6.88±2.66	3.89±3.01	7.89±3.13
4	F6	3.94±3.57	6.64±3.15	8.44±1.93	2.76±3.90	8.7±2.10	8.21±2.76	4.64±3.16	6.4±4.13
5	F7	3.65±3.80	5.99±2.84	7.98±2.13	3.3±2.64	8.89±1.54	8.07±2.17	3.73±3.13	8.44±2.04
	F8	6.33±2.46	7.11±3.16	7.53±3.27	3.36±3.41	8.9±1.64	8.17±3.26	4.09±3.48	8.15±2.53
	F9	6.22±3.21	6.48±2.94	7.27±2.65	1.9±2.93	8.85±1.75	8.78±1.94	4.08±4.27	6.3±3.76
General Means		**5.17±3.37**	**6.58±2.99**	**7.24±2.94**	**3.46±3.22**	**8.62±1.98**	**7.73±2.71**	**3.75±3.14**	**7.34±3.22**
F_{-value}		02.42	0.29	1.34	0.74	0.38	0.94	0.66	1.18
P_{-value}		0.02	0.97	0.23	0.66	0.93	0.49	0.73	0.32

CRUAP, *crumb appearance;* ***CRUAE***, *crumb aeration;* ***CRUST***, *crumb silky texture;* ***CRUTE***, *crumbly texture;* ***CRUSF***, *crumb sweet flavor;* ***CRUGF***, *crumb greasy feeling;* ***CRUMO***, *crumb moisture;* ***CRUAR***, *crumb aroma.* ***F-value***, *statistical Ficher value of the ANOVA;* ***P-value***, *statistical value of probability test of the ANOVA.*

Table VII: Pearson r indexes showing correlations between sensory descriptors and macronutrients and polyphenols contents of the cakes enriched with almond flour of *T. catappa*

	TGC	TSC	RSC	PRC	FAC	SFC	ASC	MOI	TEV	TPC	FLC
CRUAP	-0.48	-0.47	-0.40	-0.46	-0.46	-0.44	-0.45	-0.48	-0.46	-0.46	-0.46
CRUAE	0.45	0.45	0.36	0.45	0.45	0.41	0.48	0.41	0.45	0.45	0.45
CRUST	0.00	-0.01	0.06	0.00	0.01	0.07	-0.06	0.05	0.00	0.01	0.01
CRUTE	0.20	0.20	-0.04	0.18	0.18	0.06	0.26	0.05	0.18	0.18	0.18
CRUSF	0.00	0.02	0.18	0.04	0.04	0.13	0.02	0.08	0.04	0.05	0.05
CRUGF	0.07	0.09	0.33	0.09	0.09	0.21	0.04	0.23	0.09	0.09	0.09
CRUMO	-0.41	-0.43	-0.34	-0.41	-0.41	-0.34	**-0.51**	-0.36	-0.41	-0.41	-0.41
CRUAR	**-0.63**	**-0.62**	-0.45	**-0.62**	**-0.62**	**-0.57**	**-0.62**	**-0.55**	**-0.62**	**-0.62**	**-0.62**

Table VIII: Pearson r indexes showing correlations between sensory descriptors and minerals elements contents of the cakes enriched with almond flour of *T. catappa*

	Ca	Mg	Na	K	P	S	Fe	Zn	Mn	Cu
CRUAP	-0.44	-0.46	-0.47	-0.46	-0.46	-0.39	-0.45	-0.48	-0.38	**-0.60**
CRUAE	0.44	0.45	0.44	0.45	0.45	0.23	0.45	0.49	0.20	0.18
CRUST	0.03	0.01	-0.10	0.01	0.01	0.33	0.01	-0.38	0.30	0.28
CRUTE	0.13	0.18	0.39	0.18	0.18	-0.19	0.18	0.35	-0.12	-0.24
CRUSF	0.09	0.04	-0.17	0.05	0.05	0.15	0.05	-0.38	0.05	-0.09
CRUGF	0.14	0.09	-0.15	0.09	0.09	0.26	0.09	-0.34	0.15	0.35
CRUMO	-0.39	-0.41	-0.46	-0.41	-0.41	0.12	-0.41	-0.46	0.15	0.11
CRUAR	**-0.60**	**-0.62**	**-0.65**	**-0.62**	**-0.62**	-0.48	**-0.62**	**-0.61**	-0.47	-0.46

Table IX: Pearson r indexes showing correlations between sensory descriptors and vitamins contents of the cakes enriched with almond flour of *T. catappa*

	vit A	vit E	vit B1	vit B3	vit B6	vit B9
CRUAP	**-0.51**	**-0.53**	-0.24	-0.24	-0.17	-0.48
CRUAE	0.38	0.46	0.40	0.46	0.36	0.49
CRUST	-0.02	-0.08	-0.42	0.00	-0.49	-0.38
CRUTE	0.29	0.25	0.47	0.20	0.41	0.45
CRUSF	-0.21	-0.08	-0.39	0.26	-0.14	-0.38
CRUGF	-0.10	0.06	-0.44	0.08	-0.16	-0.34
CRUMO	-0.32	**-0.50**	-0.45	-0.46	-0.45	-0.46
CRUAR	**-0.63**	**-0.63**	-0.33	**-0.54**	-0.23	**-0.61**

*Bold values are significant correlations. **CRUAP**, crumb appearance; **CRUAE**, crumb aeration; **CRUST**, crumb silky texture; **CRUTE**, crumbly texture; **CRUSF**, crumb sweet flavor; **CRUGF**, crumb greasy feeling; **CRUMO**, crumb moisture; **CRUAR**, crumb aroma. **TGC**, total glucides content ; **TSC**, total soluble carbohydrates content ; **RSC**, reducing sugar content ; **PRC**, protein content ; **FAC**, fat content ; **SFC**, soluble fibre content ; **ASC**, ash content ; **TEN**, total energy value ; **TPC**, total polyphenols content ; **FLC**, flavonoids content, **MOI**, moisture content. Vit, vitamins.*

Table X: Pearson r indexes showing correlations between sensory descriptors of the cakes enriched with almond flour of *T. catappa*

	CRUAP	CRUAE	CRUST	CRUTE	CRUSF	CRUGF	CRUMO	CRUAR
CRUAP	**1**							
CRUAE	-0.16	**1**						
CRUST	0.20	**-0.64**	**1**					
CRUTE	-0.19	0.43	**-0.58**	**1**				
CRUSF	**0.60**	-0.28	0.41	-0.29	**1**			
CRUGF	0.16	**-0.56**	**0.74**	**-0.75**	0.44	**1**		
CRUMO	0.30	-0.45	**0.52**	**-0.75**	0.40	0.49	**1**	
CRUAR	0.01	0.01	-0.10	0.02	-0.10	-0.38	0.24	**1**

*Bold values are significant correlations. **vit**, vitamin; **CRUAP**, crumb appearance; **CRUAE**, crumb aeration; **CRUST**, crumb silky texture; **CRUTE**, crumbly texture; **CRUSF**, crumb sweet flavor; **CRUGF**, crumb greasy feeling; **CRUMO**, crumb moisture; **CRUAR**, crumb aroma.*

Discussion

Searching alternatives to the wheat flour through valorization of flours deriving from commonly consumed local products as cassava, yam, maize, and sweet potato is getting ahead [24, 3]. These perspectives strengthen the hypothesis of substitution of wheat flour or significant reduction of its rate during production of pastries without any loss of their nutritional quality [25, 26]. The incorporation of ground almond of *T. catappa* stated by Douati *et al*. [11] into the wheat flour basis pastries also allows increase in nutritive potential of the formulated products. Indeed, the addition of *T. catappa* powder provided more nutritional features (biochemical compounds, vitamins, mineral, and antioxidants) to cakes compared to the use of only wheat flour. Otherwise, the increase in the ratio of the added almond flour provided more significant nutrients to cakes. This technology is advantageous in *T. catappa* fruits valorization in food industry against nutritional hazards and therefore for promoting such a plant [27, 28].

Thanks to this enrichment, the cakes could contribute in nutritional needs recovery and could even be classified as functional food since they account significant polyphenols antioxidant content. Also, Van Aardt *et al*. [29] reported the presence of unsaturated fatty acids (omega 3 and omega 6) in T. catappa almonds, necessary for strengthening the antioxidant activity in the organism. The consumption of cakes enriched with the almond flour of this plant could therefore help in the struggle against physiological functional concerns as cancer, cardiovascular and degenerative diseases and the precocious ageing [30, 31].

Except the crumb appearance, the sensory descriptors of the formulated cakes do not show any rather change whatever the enrichment rate. Thus, the appreciation of foods enriched with T. catappa almond could be independent from the amount of this ingredient added. The weak influence of new flours in the preparation of cakes has also been revealed from the works of Karaoglu and Kotancilars [32]. The enriched cakes keep their organoleptic quality, compared to the total substitution of wheat by the flour processed from soya or banana [33, 34]. Besides, they are appreciated for the sweet taste and the greasiness, which characteristics usually expected for good quality cakes [35]. In fact, the lower influence of the studied almond flour on the organoleptic traits could be a positive trend for the industrial environment because, in this case, the nutritional satisfaction of the consumers coincided with the preservation of the sensory pleasure, for lack of improving it.

Comment [w44]: change this word

Comment [w45]: derived

Comment [w46]: not needed.

Comment [w47]: change

Comment [w48]: recast

Comment [w49]: did not show any significant change whatever the fortification rate. Is that your thinking?

Comment [w50]: Are the

The aroma is the main sensory descriptor significantly correlated to the biochemical and nutritional properties of the cakes. It was felt in contrary intensity with the nutrients contents. Similar correlations between the aroma feeling and the contents in common salt (food salt) and the vitamin A has been respectively reported by Gillis [36] and Causse *et al*. [37]. According to these authors, the increase of salt logically confers salty taste and strengthens the appearance and the texture of cheeses but hides their aromas and flavours, when the fortification in the vitamin A (ß- carotene) lightens the aromas from tomatoes. Yet, in previous studies, Douati *et al*. [11] revealed that overall formulated cakes enriched with *T. catappa* almond are enjoyed by consumers. Although decreasing with the increase of the nutrients contents resulted from the addition of almond flour, the aroma doesn't significantly impede the final appreciation of the cakes. The decrease of the cakes aroma from the increase in their nutritional value could even be considered as advantageous trend for the valorization of cakes enriched with *T. catappa* almond.

Comment [w51]: was

Comment [w52]: change

The study also shows that the airy and crumbly textures of the cake crumbs induced lower greasy feeling into mouth. On the contrary, the more silky texture the more moisture and greasiness are felt, showing greater hydration and oily level.

The most sensory descriptors are not correlated with the nutritive properties, showing that the cakes can be valorized without consideration of any particular sensory trait except the aroma. The global acceptance of the cakes by the consumers, as revealed by Douati *et al*. [11] confers good perspectives for the valorization of these products enriched with the *T. catappa* almond.

Comment [w53]: change

4. CONCLUSION

Substituting wheat flour is fundamental for the valorization of the local raw starchy products (cassava, yam, potato, and almond) and to face the food hazards due to the rocketing in prices of the top consumption foodstuffs. The study showed that the addition of *Terminalia catappa* almond succeeds in significant enrichment of cakes for food nutrients essentials to human health. Nevertheless, there isn't any obvious influence of this nutritional enrichment on the organoleptic profile. The valorization of the cakes enriched with the fruits almonds of *T. catappa* could be considered on basis of their sensory acceptance by consumers.

Comment [w54]: Utilization of the underutilized crops is fundamental........

Comment [w55]:

Comment [w56]: Recast in line with the comment stateted in 54 above.

COMPETING INTERESTS

Authors have declared that no competing interests exist with this document.

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