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Influence of the Nutritive Composition on the Organoleptic Characters of Cakes Enriched with Fruits Almond of *Terminalia catappa*

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Authors' contributions

This work was carried out in collaboration among 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 and achieved the submitted manuscript. Authors CA, NBY 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 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.

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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 invarious content in total carbohydrates (the major nutritive compound of the flours) whereas the other nutrients increased accordingly to the ratio of the almond flour incorporated for. Oppositely, the full sensory descriptors were responded with statistically similar scores over the cakes formulated. The correlation analysis mainly showed reduction of the cakes aroma during the nutrients increase, 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: Sensory analysis; nutrients; correlations; Terminalia catappa; valorization.

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 all ages over the world [1]. However, numerous constraints in the provision of cakes are arising due to 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 focuses on the non- traditional 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 already known [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. Regarding this way of valorization, the almond flour processed from the *T. catappa* fruits has been successfully used by Douati et al. [10] for the fortification of the wheat flour in cakes formulations. According to these authors, the cakes enriched with the flour of *T. catappa* is richer in nutrients compared to the cakes prepared using only plain wheat flour. 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 needs to be yet highlighted. The main objective of the current study was to assess the correlations between sensory descriptors and nutrients contents resulting from the cakes processed by fortifying the wheat flour with the *T. catappa*.

2. MATERIALS AND METHODS

2.1 Materials

The raw plant material of the study was constituted of mature dried fruits of *T. catappa*. The fruits' almonds were blended and the resulting flour was added to the wheat flour in cakes processing.

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. A total of 540 kg of dried fruits of *T. catappa* were purchased and conveyed to the laboratory for the works.

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 1).

2.2.4 Preparation of the cakes

For processing of the cakes, 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 2). 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 of the almond flour to be added were considered according to the expected cakes formulations (Table 3).

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, butter was added and the full mixture homogenized at 300 rpm for four min. The resulting doughs were carefully run into oiled cake mould pans, and then baked for 45 min in an oven at 150°C. After baking, the cakes were cooled at room temperature, moulded, wrapped in tinfoil, and kept in dry place till analyses. The cakes prepared are shown in the Fig. 1.

Table 1. 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	F9
10	7.5	0.25	
11	7.5	0.25	

Table 2. 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	Cake 5
F8	0.4	7.5	
F9	0.25	7.5	

Table 3. 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

Fig. 1. Presentation of cakes processed from plain wheat flour (C) and addition of almond flour (F1 to F9)

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.

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 [15]. 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 using energy coefficient of the energizing macronutrients (proteins, lipids, and carbohydrates) mentioned by FAO [18].

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 macroelements (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 descriptive 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 cakes 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].

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 4. Total carbohydrates and the reducing sugars display invarious contents (P-value > 0.05) from all 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 were recovered from 100 g cakes (Table 4).

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 5). Vitamins contents also fluctuate (P-value <0.05) according to the types of cakes. Table 5 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 were rated with close similar values from the cakes formulations (Table 6), except for the appearance of the crumb which intensity was 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).

3.3 Main Correlations Related to the Sensory Profile of the Enriched Cakes

The Pearson r indexes presented in Table 7 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 between sensory profile and mineral elements contents, the statistical analysis showed a significant reduction of the aroma intensity due to the increase of the macroelements contents (Ca, Mg, Na, K, P), with negative r values between -0.65 and -0.60.

The Table 8 also showed negative influence of Fe and Zn in the feeling of the aroma (-0.62 and -0.61, respectively), whereas any increase in the Cu content resulted in reduction of the crumb appearance felt from the cakes (r = -0.60).

Otherwise, the increase in vitamins A, E, B3, and B9 contents dropped the feeling of the aroma, with r indexes between -0.63 and -0.54. The cake crumb got lower appearance with increasing contents in vitamins A (r = -0.51) and E (r = -0.53), when the moisture was also no rather felt in cakes having more vitamin E content (r = -0.50). The other sensory traits did not display any significant correlation with the cakes vitamins contents (Table 9).

Some significant correlations are also recorded between the sensory descriptors assessed. Indeed, the sweet flavour was 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).

Oppositely, the cakes crumbs display lower greasy and moisture traits in formulations with major crumbly texture (r = 0.75), which sensory parameter was negatively correlated to the silky texture (r = -0.58). More greasy and silky crumbs were also in opposition with the airy texture (r = -0.56 and r = -0.64, respectively), as shown in Table 10.

3.4 Discussion

Searching alternatives to the wheat flour through valorization of powders processed from common 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 processing in food industry against nutritional hazards and therefore for promoting such a plant [27,28].

Table 4. 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/100 g)	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/100 g)	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

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. 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

Table 5. 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}
Essential 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 6. 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 7. 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

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 ; MOI, moisture content ; TEV, total energy value ; TPC, total polyphenols content ; FLC, flavonoids content

Table 8. 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 9. 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 10. 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

The cakes prepared by addition of *T. catappa* are richer in nutrients and account significant polyphenols antioxidant content. Therefore, they fit the nutritional needs of consumers and could even be classified as functional food. 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 did not show any significant change whatever the fortification 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 are 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 coincides with the preservation of the sensory pleasure, for lack of improving it.

The aroma was 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 promoting cakes enriched with *T. catappa* almond.

The study also shows that the airy and crumbly textures of the cakes crumb induces lower greasy feeling into mouth. At 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.

4. CONCLUSION

Substituting wheat flour is fundamental for promoting local raw starchy products (cassava, yam, potato, and almond) and facing food hazards due to the rocketing in prices of the top consumption foodstuffs. The study showed that the cakes' processing with addition of *Terminalia catappa* almond succeeds in significant increase of essential nutrients for 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.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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