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Minerals and Vitamins Contents of Cakes Enriched with Almonds Powder of *Terminalia catappa* of Côte D'ivoire

Douati Togba Etienne[1*], Mahan Makado Romuald[1], Konan N'Guessan Ysidor[1], Sidibe Daouda[1], Coulibaly Adama[2] and Biego Godi Henri Marius[1,3]

[1]Laboratory of Biochemistry and Food Science, Training and Research Unit of Biosciences, Felix Houphouet-Boigny University, 22 P.O.Box 582, Abidjan, Côte d'Ivoire.
[2]Training and Research Unit of Biological Sciences, Peleforo Gon Coulibaly University, P.O.Box 1328, Korhogo, Côte d'Ivoire.
[3]Department of Public Health, Hydrology and Toxicology, Training and Research Unit of Pharmacological and Biological Sciences, Felix Houphouet-Boigny University, P.O.Box 34, Abidjan, Côte d'Ivoire.

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 MMR, 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 aim of this study is to contribute to a better valorization of *Terminalia catappa* by the determination of minerals and vitamins of cakes enriched with the powders of almonds of *Terminalia catappa*, also evaluate the nutritional contributions of their consumption.
Study Design: Six cakes (five cakes enriched and one cake no enriched) were prepared, the

**Corresponding author: E-mail: douati5@gmail.com;*

nutrients of the cake formulations obtained using the composite central plane and a cake control was determined.
Place and Duration of Study: Laboratory of Biochemistry and Food Sciences, Biochemistry department of Biosciences Unit, Félix Houphouet-Boigny University, between October and December 2015.
Methodology: The analysis of the 6 cakes consisted of the determination of their minerals and vitamins contents. Also their estimated the Ivorian daily intake.
Results: Analysis of the essential minerals gave the contents between those of the control cake and the cake 4, which are the following:
Calcium (65.97 ± 0.01 - 76.58 ± 0.01 mg / 100g), sodium (40.00 ± 0.02 - 42 ± 0.01 mg / 100g) potassium (532.3 ± 0.10 - 616.2 ± 0.01 (mg / 100g), phosphorus (512.8 ± 0.10 - 548.1 ± 0.01 mg / 100g), magnesium (143.69 ± 0.01 - 156.93 ± 0.01 mg / 100 g), iron (4.22 ± 0.01 mg / 100 g and 4.7 ± 0.01 mg / 100 g), zinc (3.58 ± 0.01 mg / 100 g and 4,00 ± 0,02 mg/100 g, Manganese (5.10 ± 0.01 - 10.21 ± 0.02 mg / 100g), sulfur (45.8 ± 0.02 and 52.81 ± 0.2, 02 mg / 100 g) and copper (9.7 ± 0.01 14.21 ± 0.01 mg / 100 g) and Selenium(14,82±0.01 and 12.32±0.01µg/100g).
The vitamins contents were as follows: β-carotene (114.87 ± 0.24 - 237.2 ± 0.01 ER / 100 g), vitamin E (1.00 ± 0.01 - 1.07 ± 0.01 mg / 100 g), vitamin B1 (0.46 ± 0.01 mg / 100 g), B3 vitamins (7.25 ± 0.01 - 7.97 ± 0.01 mg / 100 G), vitamin B6 (0.38 ± 0.01 mg / 100 g), vitamin B9 (0.05 ± 0.01 mg / 100 g). The cake 4 records the highest levels of vitamins B3, E and β-carotene as those of the control cake.
One African adult consumes an average of 23 g of cake per day, representing 2.26% of the 1018.1 g of food consumed on average daily. The daily intake of essential minerals and vitamins of composite cakes contributes in the majority to more than 2 to 5 times that 2.26% of the recommended needs. Cake 4 containing the highest levels of these essential nutrients has the best contribution to recommended daily intakes.
Conclusion: The popularization of this cake (cake 4) could contribute to increase the consumption of almonds of *Terminalia catappa*, to combat malnutrition of the populations especially in children and to generate the sources of income important for the populations.

Keywords: Enriched cakes; Terminalia catappa; daily contribution of minerals and vitamins; Côte d'Ivoire.

1. INTRODUCTION

Terminalia catappa L, a plant belonging to the Combretaceae family, originates from southern Asia and develops throughout the tropics in coastal environments [1,2]. This plant is known as Cocoma in Côte d'Ivoire, Badamier in Europe, M'handaya in the Comoros and Amandier des Indes in India [3]. *Terminalia catappa* is generally planted for its shade, for ornamental purposes and its edible nuts [4]. The leaves representing the most used part of the plant have anti-carcinogenic, antioxidant, anti-inflammatory and antidiabetic properties [5,6]. Fruits of *Terminalia catappa* also have several pharmacological properties and are used in traditional medicine in the treatment of leprosy, headaches, intestinal parasites, and wounds [7]. These fruits contain hard seeds with an edible almond [8]. Almonds can be consumed as aperitifs [9], roasted or steamed at breakfast [10]. In addition, some studies by Monnet *et al* [1], Udotong and Bassey [11], Ladele *et al* [12] , Douati *et al* [2] and many other researchers, have highlighted the richness of almonds of *Terminalia catappa* in essential nutrients (proteins, lipids, essential fibers and minerals). The proteins of its almonds have a good profile in essential amino acids and are highly digestible [13]. In addition, they are very rich in unsaturated fatty acids, particularly oleic acids (31.48%) and linoleic acids (28.93%)[14,12]. The studies by Dau *et al* [15] highlighted the richness of almonds of *Terminalia catappa* in vitamins A, C and E. These interesting nutritional properties of almonds of *Terminalia catappa* could be exploited to diversify and improve the profitability of *Terminalia catappa*, and above all to contribute to the fight against Malnutrition in Côte d'Ivoire.

Given that in Africa, and particularly in Côte d'Ivoire, food is based on cereals and tubers lacking essential nutrients. This is the cause of malnutrition, the prevalence of which in Côte d'Ivoire, in children under 5 years of age, is 30% with 12% of severe form with insufficient weight affecting 15% of children [16]. Faced with this situation, which is particularly damaging to the

future of many children, the enrichment of staple foods remains an important way to combat malnutrition [17]. Thus the incorporation of *Terminalia catappa* almonds, a local raw material available, to other essentially energetic foods, especially cakes made from wheat, could enhance their mineral and vitamin content and generate substantial revenues for the populations.

The objective of this study is to produce a composite cake based on wheat enriched with almonds of *Terminalia catappa* which can cover the need for essential minerals and vitamins of the populations.

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 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 badamier 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 desiccator until the cakes were made.

2.4 Preparation of Composite Powders

The Composite Central Plane (CCP) 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 I). For this plane, each factor presented 5 levels (-α, -1, 0, +1 and + α). Referring to Plackett and Burman [18], 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).

The grouping of these 9 tests according to the 2 factors made it possible to prepare 5 cakes distributed as follows: cake1 (F1 and F5), cake 2 (F2 and F4), Cake 3 (F3), cake4 (F6) and cake5 (F7, F8 and F9).

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 [19] (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 were cooled to room temperature, demolded, packed in aluminum foil and then stored in a dry place. After 24 h, the nutrient components were evaluated.

2.6 Samples Mineralization

Samples were mineralized in ashes by incineration at 550°C using electric muffle furnace. The ashes were obtained after incineration of 5 g flour beforehand carbonized on a Bunsen burner, for 12 h, leading to a white residue [20].

2.7 Mineral Elements Evaluation

The energy dispersive spectrophotometer apparatus used for the minerals determination

was coupled with a scanning electronic microscope, operating at variable pressure (SEM-FEG Supra 40 Vp Zeiss), and equipped with an X-ray detector (Oxford instruments) bound to a flat shape of the EDS microanalyser (Inca cool dry, without liquid nitrogen). The operative conditions of the EDS-SEM device are:

- Zoom: 10x to 1000000x;
- Resolution: 2 nm;
- Variable voltage: 0.1 KeV à 30 KeV.

The chemical elements were acquired with following parameters: zoom, 50 x; probe diameter, 30 nm to 120 nm; probe energy, 20 KeV and 25 KeV; work distance (WD), 8.5 mm. The chemical composition was explored from 3 different zones, and then the data was transferred to MS Word and Excel softwares for treatment.

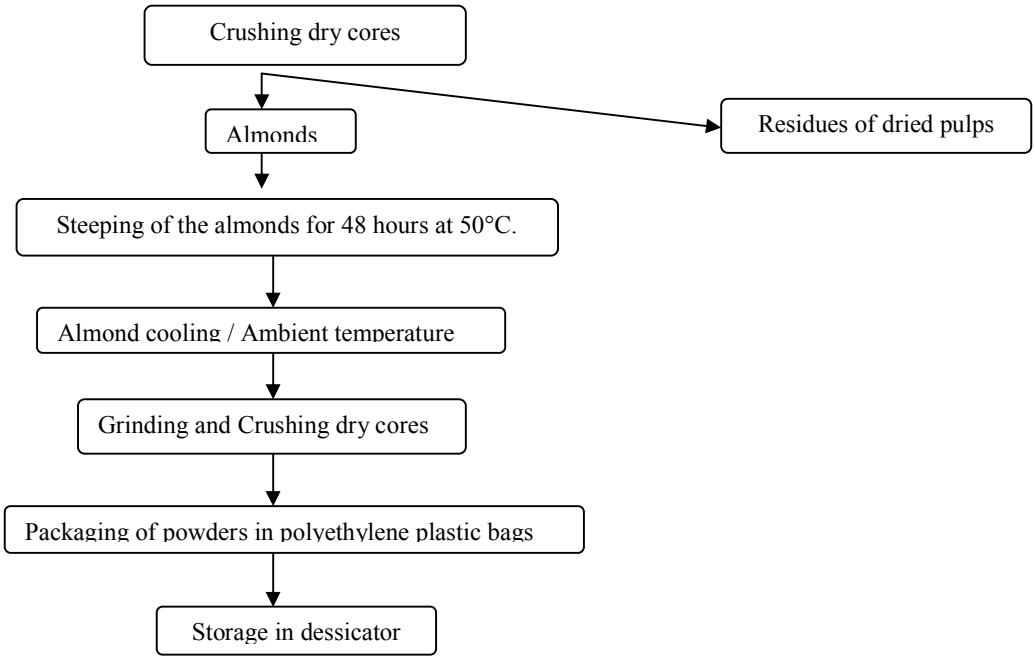

Fig. 1. Diagram for obtaining almond powder from *Terminalia catappa*

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

Test	Factors	
	X1 **Amount of *T. catappa* almond powder (%)**	**X2** **Particle size of the almond powder of *T. catappa* (mm)**
1	5	0.10
2	9.25	0.14
3	5.75	0.36
4	9.25	0.36
5	5	0.25
6	10	0.25
7	7.50	0.10
8	7.50	0.40
9	7.50	0.25
10	7.50	0.25
11	7.50	0.25

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

Table 2. Composition of cakes prepared

	Control	Cake 1	Cake 2	Cake 3	Cake 4	Cake 5
Wheat (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
Almonds powder (g)	00	5	9.25	5.75	10	7.50

Control, non-enriched cake, cake1, cakes enriched with 5% almond powder, cake2, cakes enriched with 9.25% almond powder, cake3, cake enriched with 5.75% almond powder, cake 4, cakes enriched with 10% almond powder; Cake 5, cakes enriched with 7.5% almond powder.

2.8 Determination of Vitamin Content

The concentrations of water soluble vitamins of Group B and fat-soluble were determined using a high performance liquid chromatographic system (HPLC, mark Water Alliance). This system included a Waters pump, an automatic injector, a UV / PDA detector and a Servotrace recorder. The operating conditions were adapted to the type of required vitamins.

Two grams of flour samples were extracted vigorously with an excess of n-hexane (5 times the volume) and centrifuged to 3000 rpm during 5 min. The organic solvent was aspirated and saved. The residue was reextracted with the same solvent and the same steps were repeated until the extract was almost colorless. The total volume of the extract was recorded and an aliquot was injected in the HPLC system. Fat soluble vitamins were separated on a column Kromasil C18 of 30 X 4 mm (CIL CLUZEAV) in stainless steel. The mobile phase was a mixture of acetonitrile of HPLC grade and well furnished by MERCK (Germany). The column temperature was 30 ° C, the elution length was 35 min and the flow rate was 1.2 mL / min. Water soluble vitamins were separated on a Zorbax column to silica support post grafted in C18 (150 mm X 4.6 mm) with particles of 3 mm. The mobile phase was a mixture of ammonium acetate and methanol, of grade HPLC and furnished by MERCK (Germany). The flow rate was programmed to 2 mL / min on a length of 20 min. Standard β-carotene and vitamin E were purchased from Fluka Chemie (Switzerland), while water soluble vitamins were purchased from Sigma-Aldrich (UK). Table **3** present the concentrations of the standard vitamins used for injection in the HPLC system.

2.9 Estimate of Nutritive Supply at the Consumer

Essential mineral and Vitamins supply have been estimated according to the method of the Codex Alimentarius that takes into account the concentrations in minerals recovered in the food and the daily consumption of an adult individual of 70 kg of this food. The contribution of this food in daily requirement has been calculated also from the values of daily recommended intakes [21].

$$\text{Estimated Daily Intake (EDI)} = C \times Q$$

$$\text{Contribution (\%)} = (\text{EDI} \times 100)/\text{DRI}$$

With: C, mineral concentration measured; Q: food daily consumption; DRI: Daily Recommended Intake

Table 3. Concentration in standard vitamins for injection and optimal wavelengths

Standard vitamins	Concentration (µg/ml)	Wave lengts (nm)
vit B1	0.1 to 3.5	270
vit B3	0.1 to 7	265
vit B6	0.5 to 12	257
vit B9	0.5 to 5	280
ß-carotene	0.2 to 4.5	445
vit E	0.2 to 5.5	295

2.10 Statistical Analysis

The data were recorded with Excel file and statistically treated with Statistical Program for Social Sciences (SPSS 22.0 for Windows). The statistical test consisted in a one-way analysis of variance (ANOVA) with the type of cake assessed basis. From each parameter, means were compared using Student Newman Keuls post-hoc test at 5% significance level. In addition, Multivariate Statistical Analysis (MSA) was performed through Principal Components Analysis (PCA) and Hierarchical Ascending Clustering using STATISTICA software (version 7.1) for structuring correlation between the samples studied and their minerals and vitamins traits.

3. RESULTS

3.1 Mineral Composition

The essential mineral concentrations of the cakes studied are shown in Table 4. The essential mineral contents (Ca, Mg, Na, K, Fe, Zn, P, Mn, S,Se and Cu) differ statistically (P <0.05) Of the cakes studied. The results show that all the composite cakes studied have higher essential mineral contents than those of the control cake. Cake 4 has higher levels of essential minerals than those of other cakes studied. The results also indicate that potassium and phosphorus are the majority minerals with grades between 532.3 ± 0.10 and 616.2 ± 0.01 (mg / 100g) and between 512.8 ± 0.10 and 548.1 ± 0.01 (mg / 100g), respectively. The calcium and sodium contents of the cakes studied ranged from 65.97 ± 0.01 to 76.58 ± 0.01 mg / 100 g and from 40.00 ± 0.02 to 42 ± 0.01 mg / 100 g respectively. The iron and zinc contents of the cakes studied ranged between 4.22 ± 0.01 mg / 100 g and 4.7 ± 0.01 mg / 100 g and between 3.58 ± 0.01 mg / 100 g and 4.00 ± 0.02 mg / 100 g. The composite cakes have identical zinc contents, all superior to that of the control (3.58 ± 0.01 mg / 100 g). As regards magnesium, manganese, sulfur, Selenium and copper, their contents in the cakes studied oscillate between 143.69 ± 0.01 and 156.93 ± 0.01 mg / 100 g, 5.10 ± 0.01 and 10.21 ± 0.02 mg / 100 g, 45.8 ± 0.02 and 52.81 ± 0.02 mg / 100 g, 12.32±0.01 and 12.32±0.01µg/100g and between 9.7 ± 0.01 and 14.21 ± 0.01 mg / 100 g.

3.2 Vitamin Composition

The results show that the cakes studied contain the water-soluble vitamins of group B (vitamins B1, B3, B6 and B9) and fat-soluble (β-carotene and vitamin E) (Table 4). Indeed, the cakes studied have statistically identical (p> 0.05) contents in vitamins B1, B6 and B9 which are respectively 0.46 ± 0.01 mg / 100 g, 0.38 ± 0.01 mg / 100 G and 0.05 ± 0.01 mg / 100 g. The vitamin B3, E and β-carotene contents of the cakes studied are statistically different (p <0.001). They ranged from 7.25 ± 0.01 (control cake) to 7.97 ± 0.01 mg / 100 g (cake 4), from 1.00 ± 0.01 (control cake) to 1.07 ± 0 (Cakes 4 and 2) and 114.87 ± 0.24 (control cake) at 237.2 ± 0.01 ER / 100 g (cakes 4). Cake 4 records the highest levels of vitamins B3, E and β-carotene while the control cake has the lowest contents.

3.3 Combination of Cakes Studied for Essential Minerals and Vitamins

Principal component analysis (PCA) was carried out by considering the components F1 and F2 which have an eigenvalue greater than 1, according to the Kaïser statistical rule. Emphasized groupings of the PCA were then clarified by the UPHR method (UPH) using the Unweighted Pair Group Method with Arithmetic Means (UPGMA).

3.3.1 Principal component analysis

Fig. 2. A presents the circle of correlations of the factorial axes F1 and F2, which express 95.99% of the total variability of the parameters studied. The component F1 with an eigenvalue of 13.83 expresses 86.43% of the variance. It is totally established by a negative correlation with the levels of essential minerals and vitamins. The component F2, of eigenvalue 1.53, expresses 9.56% of the variance and does not express any correlation.

The projection of the mineral, vitamin and sample characteristics in the plane formed by the components F1 and F2 emphasizes 4 groups of cakes. Group 1 consisting of cakes 4 and 2 (F6, F2, and F4) is characterized by high values of essential minerals and vitamins. Group 2 contains cakes 5 (F7, F8 and F9), whose essential nutrient levels follow those of group 1. The cake1 (F1 and F5) and cake 3 (F3) with low essential nutrient levels other than the other composite cakes constitute Group 3. Group 4 of the control cake (T) provides low levels of essential minerals and vitamins than those of composite cakes (Fig. 2B).

3.3.2 Ascending hierarchical classification

Hierarchical bottom-up classification corroborates the variability observed in the principal component analysis (Fig. 3). Indeed, at the Euclidean aggregation distance of 76, the UPGMA dendrogram shows four cake sample classes. The first class characterized by high levels of essential minerals and vitamins consists of cakes 4 and 2 (F6, F2 and F4). Cakes 5 (F7, F8 and F9) with low levels of essential nutrients than those of the first class constitute the second class. The third class consists of cake1 (F1 and F5) and cake 3 (F3) with low nutrient contents essential to that of other composite cakes. The control cake forms the fourth class with low levels of essential minerals and vitamins than those of composite cakes (Fig. 3).

Table 4. Minerals and vitamins contents of cakes studied

		control	Cake 1	Cake 2	Cake 3	Cake 4	Cake 5	F	P
Minéraux essentiels	**Ca** (mg/100g)	65.97±0.01^{f}	69.51±0.03^{e}	75.48±0.01^{b}	70.52±0.01^{d}	76.58±0.01^{a}	73.48±0.02^{c}	227333.284	<0.001
	Mg (mg/100g)	143.69±0.01^{f}	148.1±0.01^{e}	155.6±0.02^{b}	149.36±0.02^{d}	156.93±0.01^{a}	152.48±0.01^{c}	369140.200	<0.001
	Na (mg/100g)	40.00±0.02^{c}	40.72±0.01^{b}	41.8±0.02^{a}	40.91±0.01^{b}	42±0.01^{a}	40.91±0.01^{b}	1.000	0.458
	K (mg/100g)	532.3±0.10^{f}	560.2±0.02^{e}	607.7±0.01^{b}	568.6±0.10^{d}	616.2±0.01^{a}	588.20±0.02^{c}	852701.570	<0.001
	Fe (mg/100g)	4.22±0.01^{f}	4.38±0.01^{e}	4.65±0.01^{b}	4.43±0.01^{d}	4.7±0.01^{a}	4.54±0.01^{c}	964.400	<0.001
	Zn (mg/100g)	3.58±0.01^{b}	4±0.01^{a}	4±0.02^{a}	4±0.02^{a}	4.00±0.02^{a}	4.00±0.01^{a}	420.484	<0.001
	P (mg/100g)	512.8±0.10^{f}	524.6±0.10^{e}	544.5±0.10^{b}	528.06±0.02^{d}	548.1±0.01^{a}	536.33±0.06^{c}	92806.231	<0.001
	Mn (mg/100g)	5.10±0.01^{e}	8.87±0.03^{d}	9.21±0.01^{b}	8.95±0.01^{d}	10,21±0,02^{a}	9.01±0.01^{c}	521.562	<0.001
	S (mg/100g)	45.8±0.02^{f}	48.83±0.01^{e}	50.10±0.01^{b}	49.10±0.03^{d}	52.81±0.02^{a}	49.91±0.01^{c}	321.647	<0.001
	Cu (mg/100g)	9.7±0.01^{f}	12.7±0.01^{e}	13.10±0.01^{b}	12.10±0.01^{d}	14.21±0.01^{a}	13.01±0.01^{c}	215.117	<0.001
	Se (µg/100g)	9.82±0.01^{d}	12.32±0.01^{c}	14.44±0.01^{a}	12,69±0.01^{c}	14,82±0.01^{a}	13.57±0.01^{b}	512.48	<0.001
Vitamines	**ß-carotène**(ER/100g)	114.87±0.24^{f}	119.8±0.03^{e}	196.60±0.02^{b}	121.21±0.02^{d}	237.2±0.01^{a}	124.6±0.02^{c}	808478.156	<0.001
	E (mg/100g)	1.00±0.01^{d}	1.03±0.01^{c}	1.07±0.01^{a}	1.03±0.01^{c}	1.07±0.01^{a}	1.05±0.01^{b}	1701.568	<0.001
	B1 (mg/100g)	0.46±0.01^{a}	0.46±0.01^{a}	0.46±0.01^{a}	0.46±0.01^{a}	0.46±0.01^{a}	0.46±0.01^{a}	3.307	0.052
	B3 (mg/100g)	7.25±0.01^{f}	7.93±0.01^{e}	7.97±0.01^{b}	7.95±0.01^{d}	7.97±0.01^{a}	7.96±0.01^{c}	253154.900	<0.001
	B6 (mg/100g)	0.38±0.01^{a}	0.38±0.01^{a}	0.38±0.01^{a}	0.38±0.01^{a}	0.38±0.01^{a}	0.38±0.01^{a}	12.877	0.061
	B9 (mg/100g)	0.05±0.01^{a}	0.05±0.01^{a}	0.05±0.01^{a}	0.05±0.01^{a}	0.05±0.01^{a}	0.05±0.01^{a}	3.530	0.054

Means ± SD with the same letters on the same line are statistically identical to 5%., F, value of the statistical test factor; P, calculated probability value of the statistical test, control, non-enriched cake, cake1, cakes enriched with 5% almond powder of T. catappa, cake2, cakes enriched with 9.25% almond powder of T Cake, cake3, cake enriched with 5.75% almond powder of T. catappa, cake 4, cakes enriched with 10% almond powder of T. catappa, cake5, cakes enriched with 7.5% Almond powder from T. catappa.

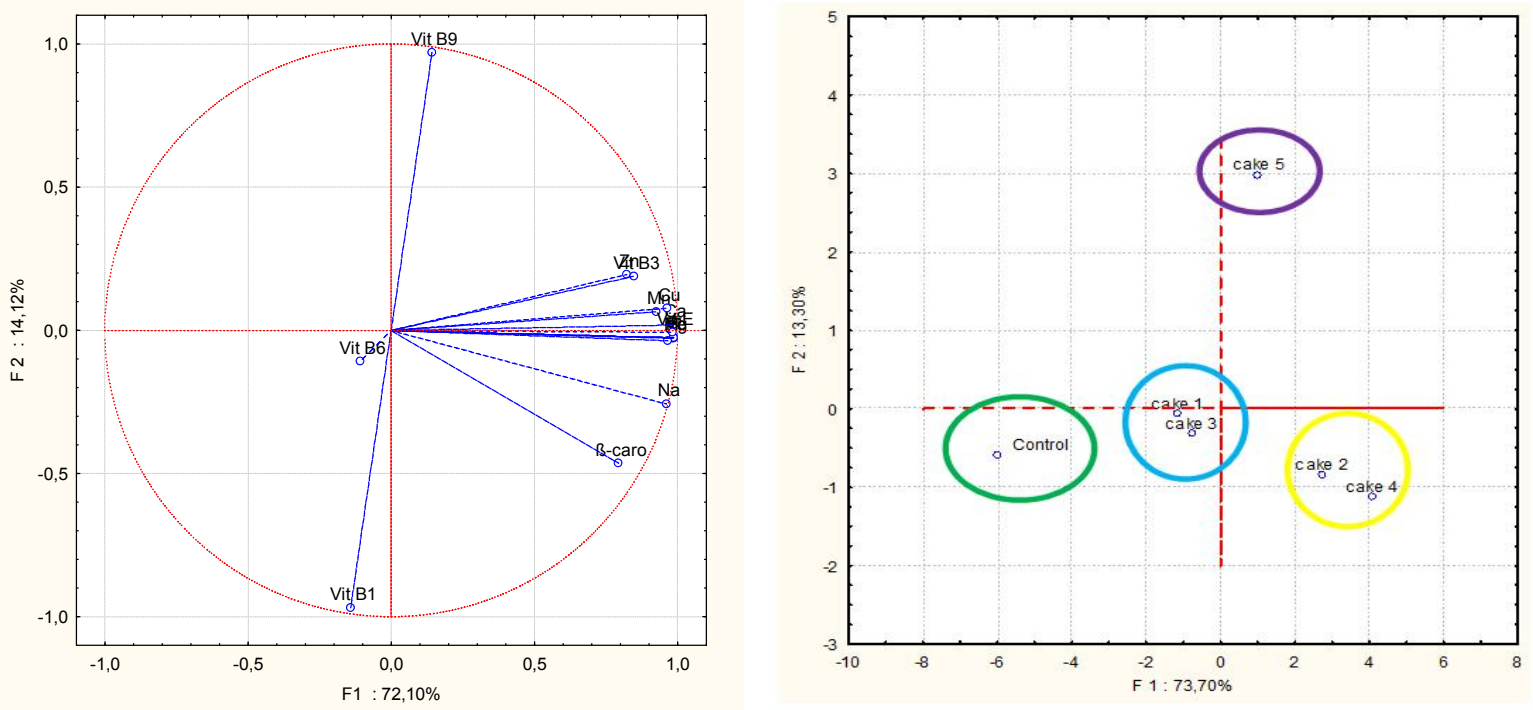

Fig. 2. Projection of minerals and vitamins characteristics and cake samples studied in Factor Plane 1-2 of Principal Component Analysis

With control, non-enriched cake, cake1, cakes enriched with 5% almond powder of T. catappa, cake2, cakes enriched with 9.25% almond powder of T. catappa, cake3, cake enriched with 5.75% almond powder of T. catappa, cake 4, cakes enriched with 10% almond powder of T. catappa, cake5, cakes enriched with 7.5% Almond powder from T. catappa.

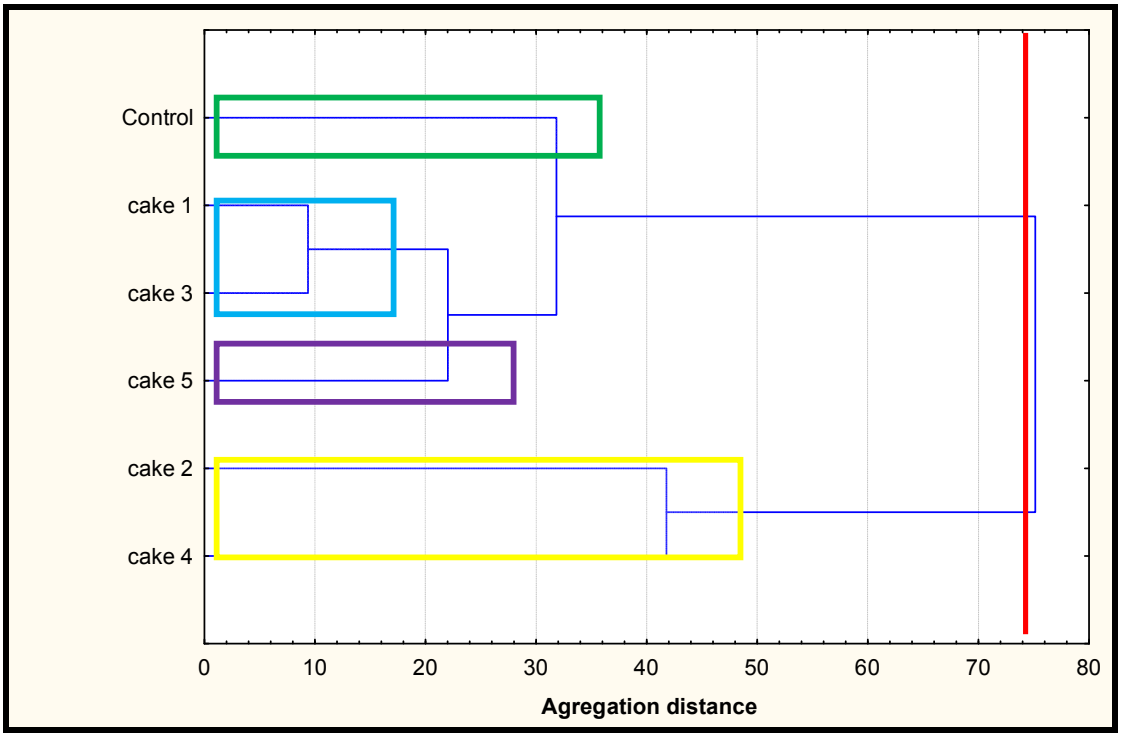

Fig. 3. Hierarchical classification of cakes studied according to minerals and vitamins characteristics

3.4 Estimated Intakes and Contribution of Essential Minerals and Vitamins in the Ivorian Adult Population

3.4.1 Essential minerals

The estimated intakes for the average consumption of 23g of composite cakes into essential minerals (Ca, Mg, Na, K, Fe, Zn, P, Mn, S, Se and Cu) are higher than those of the control cake. The estimated inputs of Ca, Mg, Na, K, Fe, P, Mn, S, Se and Cu composite cakes are between 15.98 (cake 1) and 17.61 mg / d (cake 4), 34.06 (cake 1) and 36,09 mg/d (cake 4), 9.36 (cake 1) and 9.66 mg/d (cake 4), 128.84 (cake 1) and 141.72 mg/d (cake 4), 1.00 (cake 1) and 1.08 mg/d (cake 4), 120.65 (cake 1) and 126.06 mg/d (cake 4), 2.04 (cake 1) and 2.34 mg/j (cake 4), 11.23 (cake 1)and 12.14 mg/d (cake 4), 2.832,83 ±0.01 (cake1) and 3.40±0.01µg/day and between 2.92 (cake 1) and 3.26 mg/j (cake 4). Composite cakes have the same zinc intake (0.92 mg / d). The control cake records the daily intakes of 15.17 mg / d Ca, 33.04 mg / day Mg, 9.21 mg / day Na, 122.4 mg / day K, 0.97 mg / day In Fe, 117.94 mg / d in P, 1.20 mg / d in Mn, 10.53 mg / d in S, 2.25±0.01µg/d in Se and 2.23 mg / d in Cu (Table 5).

Concerning contributions, composite cakes cover 0.37 to 18% of Na, Ca, Mg, K, Fe, Se, Zn and P requirements. The manganese and copper intakes cover the recommended daily intakes. The contributions of composite cakes to essential minerals are higher than those of the control cake (Table 6).

3.4.2 Vitamins

Estimated intakes of vitamins to ß-carotene, vitamins E and B3 of composite cakes are higher than those of the control cake. The cakes studied record the daily intake of ß-carotene, vitamins E and B3 between 26.42 (cake control) and 54.55 ER / d (cake 4), 0.23 (control cake) and 0. 25 mg / d (cakes 2 and 4) and between 1.67 (control cake) and 1.83 mg / d (cakes 2, 3, 4 and 5). However, composite cakes and control cake yielded the same amount of vitamins B1 (0.11 mg / d), B6 (0.09 mg / d) and B9 (0.01 mg / d) (Table 5).

Concerning contributions, composite cakes provide 0.01 to 11.4% of the vitamin needs higher than those of the control cake (0.01 to 10.44%). Composite cakes bring the same amounts of vitamins B1, B3 and B9 (Table 6).

Table 5. Estimated intakes of essential minerals and vitamins in the Ivorian adult population

		RDA	Control	Cake 1	Cake 2	Cake 3	Cake 4	Cake 5
Minerals	**Ca** (mg/j)	**800**	15.17±0.002	15.98±0.007	17.36±0.002	16.21±0.002	17.61±0.002	16.9±0.005
	Mg (mg/j)	**375**	33.04±0.002	34.06±0.002	35.78±0.005	34.35±0.005	36.09±0.002	35.07±0.002
	Na (mg/j)	**2500**	9.21±0.005	9.36±0.002	9.61±0.005	9.41±0.002	9.66±0.002	9.51±0.002
	K (mg/j)	**2000**	122.4±0.023	128.84±0.005	139.77±0.002	130.77±0.023	141.72±0.002	135.28±0.005
	Fe (mg/j)	**14**	0.97±0.002	1±0.002	1.06±0.002	1.02±0.002	1.08±0.002	1.04±0.002
	Zn (mg/j)	**10**	0,82±0,002	0.92±0.002	0.92±0.005	0.92±0.005	0.92±0.005	0.92±0.002
	P (mg/j)	**700**	117.94±0.023	120.65±0.023	125.23±0.023	121,45±0,005	126.06±0.002	123.34±0.3
	Mn (mg/j)	**2**	1.20±0.01	2.04±0.01	2.11±0.01	2.05±0.01	2.34±0.01	2.07±0.01
	S (mg/j)	**-**	10.53±0.01	11.23±0.01	11.52±0.01	11.29±0.01	12.14±0.01	11.47±0.01
	Cu (mg/j)	**1**	2.23±0.01	2.92±0.01	3.01±0.01	2.78±0.01	3.26±0.01	2.99±0.01
	Se (µg/j)	**70**	2.25±0.01	2,83 ±0.01	3.32±0.01	2.91±0.01	3.40±0.01	3.12±0.01
Vitamins	**ß-carotène** (ER/j)	**800**	26.42±0.1	27.55±0.3	45.22±0.6	27.87±0.4	54.55±0.1	28.65±0.2
	E (mg/j)	**12**	0.23±0.3	0.24±0.4	0.25±0.2	0.24±0.1	0,25±0.4	0.24±0.3
	B1 (mg/j)	**1.1**	0.11±0.6	0.11±0.1	0.11±0.4	0.11±0.5	0.11±0,3	0.11±0.1
	B3 (mg/j)	**16**	1.67±0.4	1.82±0.2	1.83±0.7	1.83±0.3	1.83±0.2	1.83±0.5
	B6 (mg/j)	**1.4**	0.09±0.7	0.09±0.5	0.09±0.3	0.09±0.2	0.09±0.1	0.09±0.4
	B9 (mg/j)	**200**	0.01±0.1	0.01±0.8	0.01±0.1	0.01±0.7	0.01±0.5	0.01±0.6

Control, non-enriched cake, cake1, cakes enriched with 5% almond powder, cake2, cakes enriched with 9.25% almond powder, cake3, cake enriched with 5.75% almond powder, cake 4, cakes enriched with 10% almond powder; Cake 5, cakes enriched with 7.5% almond powder, Means ± standard deviations with the same lowercase letters are statistically identical at 5% significance. F, value of the statistical Ficher test, P, probability value of the statistical test; RDA, Recommended Daily Allowance.

Table 6. Recommendations and contribution of cake nutrients to the satisfaction of recommended intakes

		RDA	Contribution (%)					
			Control	Cake1	Cake 2	Cake 3	Cake 4	Cake 5
Minerals	Ca	800	1.89±0.02	1.99±0.03	2.17±0.01	2.02±0.02	2.2±0.01	2.11±0.04
	Mg	375	8.81±0.08	9.08±0.04	9.54±0.02	9.16±0.04	9.62±0.05	9.35±0.07
	Na	2500	0.36±0.01	0.37±0.01	038±0.07	0.37±0.08	0.38±0.09	0.38±0.02
	K	2000	6.12±0.01	6.44±0.02	6.98±0.03	6.53±0.06	7.04±0.07	6.76±0.05
	Fe	14	6.92±0.03	7.14±0.05	7.51±0.04	7.28±0.03	7.71±0.04	7.43±0.01
	Zn	10	8.2±0.07	9.2±0.06	9.2±0.05	9.2±0.01	9.2±0.01	9.2±0.03
	P	700	16.84±0.04	17.23±0.07	17.89±0.06	17.35±0.05	18±0.03	17.62±0.06
	Mn	2	60±0.01	102±0.5	105±0.01	102.5±0.01	117±0.01	103.5±0.01
	S	-	nd	nd	nd	nd	nd	nd
	Cu	1	223±0.01	292±0.01	301±0.01	278±0.01	326±0.01	299±0.01
	Se	70	3.21±0.01	4.04±0.01	4.74±0.01	4.21±0.01	4.85±0.01	4.45±0.01
Vitamins	ß-carotene	800 (ER/j)	3.31±0.01	3.44±0.03	5.65±0.07	3.48±0.05	6.81±0.01	3.58±0.02
	E	12	1.88±0.02	1.97±0.03	2.04±0.01	1.98±0.01	2.06±0.03	2.01±0.05
	B 1	1.1	9.45±0.5	9.55±0.09	9.55±0.3	9.55±0.4	9,55±0,2	9.55±0.09
	B3	16	10.44±0.2	11.3±0.01	11.4±0.04	11.4±0.02	11.4±0.01	11.4±0.03
	B6	1.4	6.23±0.5	6.24±0.3	6.26±0.2	6.24±0.1	6.26±0.1	6.25±0.02
	B9	200	0.01±0.05	0.01±0.4	0.01±0.6	0.01±0.3	0.01±0.2	0.01±0.3

Control, non-enriched cake, cake1, cakes enriched with 5% almond powder, cake2, cakes enriched with 9.25% almond powder, cake3, cake enriched with 5.75% almond powder, cake 4, cakes enriched with 10% almond powder; Cake 5, cakes enriched with 7.5% almond powder, RDA, Recommended Daily Allowance..

4. DISCUSSION

The results indicate that enrichment significantly ($p < 0.001$) contributed to increase the essential mineral and vitamin contents of the cakes. Thus, cake 4 with the highest incorporation rate of almond powder (10%) is distinguished by its richness of essential minerals and vitamins compared to other cakes (cake 1, 2, 3, 5 and control). This enrichment has made it possible to obtain composite cakes whose essential minerals and vitamins are in the majority, higher than those of the control cake usually consumed. These observations are in harmony with those made by Alozie and Chinma [22], who emphasized the improvement in the nutritional content of cakes enriched with beet powders. Indeed, cake made from wheat, a cereal, is poor in essential nutrients. The increase in essential minerals and vitamins in composite cakes could be attributed to the richness of the almonds of *Terminalia catappa* in these essential nutrients [9,12,2]. However, the vitamin B1, B6 and B9 levels are comparable to those of the control cake. These essential nutrients needed in small amounts, provided by the diet, play a very important role in keeping the body healthy. Among the essential minerals in composite cakes, the copper and manganese contents totally cover the recommended daily requirements of 1mg / d and 2mg / d, respectively [23]. Copper is an essential trace element with beneficial effects on the immune system [24]. Manganese slows down aging by opposing the formation of free radicals [25]. Potassium and phosphorus, two major minerals in the cakes studied, cover 6.12% to 7.04% and 16.84% to 18%, respectively, of the recommended daily requirements. Moreover, an African adult consumes on average 23g of cake per day [26]. This represents 2.26% of the 1018.1 g of food consumed on average by one African adult per day [27]. Therefore, potassium and phosphorus contributions above 2.26% are satisfactory. Potassium contributes to fluid balance in blood and tissues [28]. Phosphorus is involved in the phosphorylation reactions involved in energy production [29].

The consumption of the cakes studied, in particular cakes 2 and 4, also covers a large part of the recommended daily requirements for iron, magnesium and zinc. Recognized as a cofactor in membrane stabilization, magnesium is also involved in oxidative phosphorylation, glycolysis, DNA transcription and protein synthesis [30]. Iron and zinc are so important to the functioning of the body that their deficit poses real public health problems. Iron deficiency anemia is responsible for 10% of maternal mortality, where 800 000 deaths represent 2.4% annual mortality due to the disease [31]. Zinc stimulates the immune system, intervenes in the metabolism of the proteins necessary for the normal development of the fetus, intervenes in the synthesis of insulin, sperm production and is an antioxidant [32,33].

In cakes studies, selenium covers 4.04 to 4.85% of the recommended daily requirements.

The greatest biological significance of selenium in the organism is associated with its occurrence in active sites of many enzymes and proteins [34].

The calcium and sodium contributions are lower and do not reach 2.26% representing the proportion of cake consumed daily. This low level of coverage of their recommended need could be explained by their low content in the almonds of *Terminalia catappa* used and also in the other constituents of the cake (wheat flour, egg and butter). To alleviate this deficiency in these essential minerals, it would be important to increase the amount of cakes consumed and also to add to these cakes other richer foods such as milk and fruits.

With regard to vitamins, except vitamins E and B9, the composite cakes studied have satisfactory contributions because they are 2 to 5 times greater than 2.26% and all of them superior to those of the control. Although satisfactory, these contributions are well below the recommended daily intakes of these vitamins, which play a crucial role in human health. Among others, vitamin E is an antioxidant involved in the protection of tissues and skin against oxidation and infections. It also protects cells against carcinogenesis [35]. As for ß-carotene, it has an essential role in the reproduction, growth, development of fetal vision, as well as in the preservation of ocular health and night vision of the mother. It strengthens the immune defenses against infections [36,37]. Prolonged impairment can cause pediatric blindness and severe infections that are often fatal in children [38]. Deficiency of β carotene remains a public health problem affecting 19 million pregnant women in Africa [39]. Thus, these composite cakes can be recommended for human consumption while increasing their quantity, in particular cake 4, in order to combat

certain nutritional diseases due to avitaminosis, in particular to the deficiency of β-carotene [40].

5. CONCLUSION

This study showed that the enrichment of the almond cake of *Terminalia catappa* is a considerable improvement of the mineral and vitamin characteristics of the cake. The composite cakes studied had the highest levels of essential minerals and vitamins compared to those of the standard cake consumed. Among the composite cakes, cake 4and cake2 were distinguished by the highest levels of essential minerals and vitamins and by a good contribution to the recommended daily intakes. The popularization of this cake could contribute to increase the consumption of almonds of *Terminalia catappa*, to combat malnutrition of the populations, especially in children and to generate the sources of income important for the populations [2,7,9,11,14,15,17,18,28,31,32,35, 36,40].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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