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Nutritional properties of cookies enriched with *Terminalia catappa* (Combretaceae) almond flour

Bakayoko Losséni [1, 2, *], Méité Alassane [1, 2], Diaby Aboubacar [1] and Kati-Coulibaly Seraphin [1]

[1] *Biology and Health Laboratory, Félix Houphouët-Boigny University, Abidjan, Côte d'Ivoire.*
[2] *Doctoral School-Sciences of Technology and Sustainable Agriculture.*

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Abstract

This study aims to analyze the nutritional properties of almond flour enriched cookies from *Terminalia catappa* in order to promote these almonds in the treatment of protein-energy malnutrition. To this end, five (5) types of cookies were produced, including a control cookie composed of 100% wheat flour (BFB) and four composite cookies in which the wheat flour was substituted by the almond flour *Terminalia catappa* at respective rates of 10% (BFTC10), 20% (BFTC20), 30% (BFTC30) and 40% (BFTC40). The cookies were prepared at the "Bivoire Abobo Banco bakery" which has an authorization from the Ministry of Commerce of the Republic of Côte d'Ivoire. The nutritional properties of cookies were evaluated on the basis of their physicochemical composition, physical and organoleptic characteristics. Analysis of the physical-chemical composition of the cookies showed a significant increase ($p< 0.05$) in proteins (10.07 0.02 to 19.2 0.01%), lipids (14.3 0.1 to 27.4 0.2%), ash (0.66 0.02 to 1.66 0.8%) and fibres (1.12 0.01 to 1.56 0.01%). On the other hand, a significant decrease ($p < 0.05$) in the carbohydrate content (70.31 0.01 to 46.64 0.03%) and a significant increase ($p< 0.05$) in the energy value (450.2 0.01 to 510 0.01 kcal) of the cookies were observed. The physical parameters of the cookies (weight, diameter, thickness, spreading ratio) were influenced by the increase in the level of incorporation. Sensory analysis revealed that the overall acceptability of cookies was affected by the increased level of substitution. It seems that these composite cookies could help fight protein-energy malnutrition.

Keywords: *Terminalia catappa*; Almond; Cookies; Nutritional properties; Protein-energy malnutrition.

1. Introduction

Malnutrition is a global public health problem. It leads to delayed nutritional development in children. It is responsible for infant morbidity and mortality (Cissouma et al., 2022). According to Jin et al. (2023) malnutrition is exacerbated by protein deficiency. Unicef estimates that only one in three children suffering from protein-energy malnutrition receives the care they need to survive and thrive (Khan et al., 2023).

Côte d'Ivoire has not been spared this scourge. According to an assessment of the nutritional status of the population, acute malnutrition affects 6.9% of children (Kouamé et al., 2017). The treatment of malnutrition in Côte d'Ivoire, as in any other developing country, requires the supply of specialized food products (SFPs). According to the Ivorian National Nutrition Program (PNN), products such as F75, F-100, Plumpy'nut, Plumpy'sup, and CSB supplied by the WFP (World Food Program) are no longer available. Thus, the unavailability of these products compromises the treatment of malnutrition (Carine et al., 2018).

* Corresponding author: Bakayoko Losséni

Therefore, it is interesting to explore the use of local ingredients for the manufacture of therapeutic foods through food fortification. It involves adding a potentially nutritionally interesting food to another commonly consumed food in order to increase the level of consumption (Agossadou et al., 2018).

The aim of this work is to determine the physico-chemical and sensory characteristics of wheat cookies fortified with *Terminalia catappa* almonds.

2. Materials and methods

2.1. Biological Materials

The biological material is composed of *Terminalia catappa* flour. The flour is obtained from the fruit of *T. catappa*. These fruits were picked in the commune of Plateau (Abidjan, Côte d'Ivoire) during the months of November 2021 to January 2022.

2.2. Food products

Food products include wheat flour, baking powder, sugar, and vanilla. All these commercial products were used to formulate the cookies.

2.3. Methods

2.3.1. Production of **Terminalia catappa** *flour*

The fruits of *Terminalia catappa* were crushed to obtain flour. The almonds were then sorted and cleared of all kinds of waste. They were oven dried at 50 °C for 48 hours, then ground using a blender (BINATONE Brender with grinder) to obtain *Terminalia catappa almond* flour. The flour obtained was stored in sealed polyethylene bags, then kept in a dry place (a desiccator) until analysis. The flour obtained was used to produce *Terminalia catppa* flour cookies (BFTC).

2.3.2. Cookie production

The cookies were produced at « boulangerie bivoire Abobo Banco » according to the method described by Vodouhe-Egueh et al., (2017). The bakery named « boulangerie bivoire Abobo Banco » has obtained authorization from the ministry of commerce of the Republic of Côte d'Ivoire. The wheat flour was substituted by *Terminalia catappa* almond flour at 10% (BFTC10), 20% (BFTC20), 30% (BFTC30), and 40% (BFTC40), respectively. The proportions of ingredients used were the same for each type of cookie (Table I). Water was measured during kneading according to the degree of absorption of the flours.

Table 1 Recipe for control and composite cookies

Ingredients	**Cookie diets**				
	Indicator (BFB)	BFTC10	BFTC20	BFTC30	BFTC40
T. catappa flour	0 %	10 %	20 %	30 %	40 %
Butter (g)	33	33	33	33	33
Sugar (g)	36	36	36	36	36
Vanilla (g)	0.25	0.25	0.25	0.25	0.25
Yeast (g)	1.25	1.25	1.25	1.25	1.25
Wheat flour	100 %	90 %	80 %	70 %	60 %
Water	Added according to dough texture				

BFB : Cookie made with 100% wheat flour; BFTC10 : Cookies made with 10 % *Terminalia catappa* almond flour; BFTC20 : Cookies made with 20 % *Terminalia catappa* almond flour; BFTC30 : Cookies made with 30 % *Terminalia catappa* almond flour; BFTC40 : Cookies made with 40 % Terminalia catappa almond flour

For cookie production, the ingredients were fed into the mixer in a precise order (Table I). Sugar and butter were added and whipped to a cream. Vanilla has been added to the cream. Sifted *Terminalia catappa* almond flour was then added to the wheat flour. The mixture is blended with the yeast. The mixture was kneaded for 20 minutes. After kneading and

resting, the dough was shaped into individual portions. Cooking was carried out using moist heat at 150°C for 15 to 20 minutes in an electric oven. Once out of the oven, the cookie was left to cool to room temperature. The cookies were then packed in polyethylene bags and stored at room temperature until use.

2.4. Determining the physical parameters of cookies

The physical parameters of the cookies determined are diameter (cm), thickness (cm), mass (g), and spread ratio, as described by Labuschagne et al., (1996). Mass is measured using an electronic balance. A caliper is used to measure diameter and thickness. The spread ratio is calculated as the ratio of diameter to thickness.

$$\textbf{Spead ratio} = \frac{\text{Cookie diameter (cm)}}{\text{Cookie thickness (cm)}}$$

2.5. Physico-chemical composition of cookies

The chemical composition is determined according to the process described in (AOAC, 2004). Moisture content is determined by oven drying at 70 °C for 24 hours. The protein content of the samples is determined by the Kjedahl method AOAC (2004). In this method, the cookies produced are mineralized in hot sulfuric acid in the presence of catalysts. The ammonia is then distilled in an excess of sodium hydroxide and recovered in boric acid. Nitrogen titration is performed with hydrochloric acid in the presence of a color indicator (methyl red). The Soxhlet method is used to determine fat content. Fat is extracted by boiling pure hexane. This is then removed by evaporation, and the residue is dried and weighed (AOAC, 2004). Ash content is obtained by weighing the residue of the sample incinerated at 550 °C in a muffle furnace for 6 hours. Total carbohydrates are obtained from the difference between the measured elements and the starting sample. The energy values of the foods were obtained using the calculation method.

2.6. Sensory analysis

Sensory analysis methods are based on panel selection, sample coding, and test execution. A total of two types of tests were carried out: the descriptive test and the hedonic test.

2.6.1. Descriptive test

The method consists of determining the color, texture, crispness, flavor, and aroma of the cookies according to a grading scale. The various cookies produced were presented to a panel of judges who had been recruited, trained, and introduced to the analysis methodology. These cookies were coded with three digits and presented simultaneously in randomized order (Vodouhe-Egueh et al., 2017). The selection of the panel consisted of recruiting fifteen (15) people (men and women) from the Félix Houphouët-Boigny University. The people recruited have undergone strict training in food quality analysis and assessment methodology.

2.6.2. Hedonic test

The cookies were evaluated by 60 untrained people on the acceptability of color, texture, taste, and aroma. These people were recruited from the Félix Houphouët-Boigny University (Abidjan, Côte d'Ivoire). Panelists were recruited based on their availability and knowledge of cookies. Testing took place in three (3) sessions. Cookie samples were randomly coded with three (3) digits and presented in monadic mode to each taster. The acceptability of each sample was assessed using a nine-point hedonic scale, ranging from 1 (extremely unpleasant) to 9 (extremely pleasant), as described by Vodouhe-Egueh et al., (2017). These hedonic tests took place at Félix Houphouët-Boigny University.

3. Results

3.1. Physico-chemical composition of cookies

The formulated cookies are shown in Figure 1. These cookies have been substituted at rates of 0, 10, 20, 30, and 40%. The physico-chemical compositions of all the cookies are shown in Table II. All the physico-chemical characteristics of the composite cookies (BFTC10, BFTC20, BFTC30 and BFTC40) are statistically different from those of the control diet (BFB) ($p < 0.05$). The differences observed relate to several parameters, such as moisture content.

A significant reduction ($p<0.05$) in the moisture content of the cookies was observed. This reduction is proportional to the rate of incorporation of *Terminalia catappa* almond flour. The highest value of 6.27 ± 0.32 g/100 g is obtained for the BFB cookie, while the lowest value is estimated at 2.19 ± 0.67 g/100 g for the BFTC40 cookie. So the addition of *Terminalia catappa* almond flour led to a reduction in moisture content of around 65%. In contrast to moisture content,

Terminalia catappa almond flour boosted protein content by 90% as the level of flour incorporation increased. Protein levels measured in BFB and BFTC40 cookies are 10.07 ± 0.02 and 19.20 ± 0.01 g/100 g, respectively.

The incorporation of *Terminalia catappa* almond flour had no significant impact ($p > 0.05$) on the fat and fiber content of the cookies, with the exception of BFTC30, for which there was a significant increase ($p< 0.05$) in these parameters. As for ash content, there was a significant increase ($p< 0.05$) with the level of incorporation up to 151.51 %. Ash contents ranged from 0.66 ± 0.02 for the control cookie to 1.66 ± 0.80 g/100 g for BFTC40.

The energy value was significantly improved ($p< 0.05$) with the progressive addition of *Terminalia catappa* flour, up to 13.29 %. These values ranged from 450.2 ± 0.01 for BFB to 510 ± 0.01 for BFTC40.

In terms of pH, cookie levels varied very little, remaining below 7 despite the increase in *Terminalia catappa* almond flour substitution. Cookie pH values ranged from 6.28 ± 0.01 for the control cookie to 5.22 ± 0.07 for the BFTC40 cookie. A significant decrease in pH value was observed as the substitution rate increased.

BFB : Cookie made with 100% wheat flour; BFTC10 : Cookies made with 10 % *Terminalia catappa* almond flour and 90 % wheat flour BFTC20 : Cookies made with 20 % *Terminalia catappa* almond flour and 80 % wheat flour; BFTC30 : Cookies made with 30 % *Terminalia catappa* almond flour and 70 % wheat flour BFTC40 : Cookies made with 40 % Terminalia catappa almond flour and 60 % wheat flour

Figure 1 Different types of experimental cookies according to incorporation rate

Table 2 Physico-chemical composition of cookies

Parameters studied	**Formulated cookies**				
	BFB	BFTC10	BFTC20	BFTC30	BFTC40
Humidity (g/100g) MS	6.27 ± 0.32^{a}	4.42 ± 0.19^{b}	3.41 ± 0.13^{b}	2.65 ± 0.31^{b}	2.19 ± 0.67^{b}
Protein (g/100g)	10.07 ±0.02^{a}	15.63 ± 0.01^{b}	16.57 ± 0.01^{c}	18.41 ± 0.02^{d}	19.20 ± 0.01^{e}
Fats and oils (g/100g)	14.30 ± 0.10^{a}	19.20 ± 0.60^{a}	22.70 ± 0.90^{a}	24.30 ± 0.50^{b}	27.40 ± 0.20^{a}
Ash (g/100g)	0.66 ± 0.02^{a}	1.00 ± 0.01^{b}	1.17 ± 0.17^{b}	1.66 ± 0.02^{b}	1.66 ± 0.80^{b}

Fibers (g/100g)	1.12 ± 0.01[a]	1.27 ± 0.02[a]	1.37 ± 0.02[a]	1.44 ± 0.02[b]	1.56 ± 0.01[c]
Total carbohydrates (g/100g)	70.31 ± 0.01[a]	62.31 ± 0.02[b]	56.71 ± 0.02[c]	53.03 ± 0.01[d]	46.64 ± 0.03[e]
Energy value (Kcal)	450.2 ± 0.01[a]	484.6 ± 0.01[b]	497.4 ± 0.01[c]	504.5 ± 0.01[d]	510 ± 0.01[e]
pH	6.28 ± 0.01[a]	6.14 ± 0.01[b]	5.73 ± 0.02[c]	5,44 ± 0.02[d]	5.22 ± 0.07[e]

Each value is the mean ± standard deviation of three determinations; a, b, c, d and e in superscript: there is no significant difference (p< 0.05) between two values on the same line surmounted by the same letter.

3.2. Physical properties of cookies

The physical characteristics of the cookies are shown in Table III. In the present study, physical parameters such as diameter, thickness, spread ratio, and mass were evaluated. The results of the analysis revealed that all the formulated cookies have the same diameter, thickness, and mass. However, there was a significant difference (p<0.05) between the formulated cookies in terms of spread ratio. The differences observed relate to the decrease in the spread ratio as the substitution rate increases. Indeed, cookies formulated BFB, BFTC10, BFTC20, BFTC30, and BFTC40 have spread ratios estimated at 10.10 ± 0.01; 9.15 ± 0.01; 8.61 ± 0.01; 8.14 ± 0.01 and 7.76 ± 0.01 respectively.

Table 3 Physical properties of cookies

Parameters	**Cookies**				
	BFB	BFTC10	BFTC20	BFTC30	BFTC40
Diameter (cm)	6.77 ± 0.20[a]	6.68 ± 0.07[a]	6.63 ± 0.06[a]	6.51 ± 0.02[a]	6.44 ± 0.08[a]
Thickness (cm)	0.67 ± 0.03[a]	0.73 ± 0.03[a]	0.77 ± 0.03[a]	0.80 ± 0.01[a]	0.83 ± 0.03[a]
Spread ratio	10.10 ± 0.01[a]	9.15 ± 0.01[b]	8.61± 0.01[c]	8.14 ± 0.01[d]	7.76 ± 0.01[e]
Mass (g)	21.88 ± 0.15[a]	22.12 ± 0.16[a]	22.78 ± 0.26[a]	23.24 ± 0.51[a]	23.41 ± 0.14[a]

Each value is the mean ± standard deviation of three determinations; a, b, c, d, e: there is no significant difference (p > 0.05) between two values on the same line surmounted by the same letter.

Table 4 Hedonic characteristics of wheat flour cookies and composite cookies (*Terminalia catappa* almond / wheat)

Biscuits	**Sensory characteristics**				
	Color	Texture	Goût	Arôme	General acceptability
BFB	7.45 ± 0.21[a]	7.51 ± 0.26[a]	8.01 ± 0.14[a]	8.52 ± 0.13[a]	8.30 ± 0.17[a]
BFTC10	7.39 ± 0.19[a]	7.25 ± 0.23[a]	7.97 ± 0.14[a]	8.34 ± 0.14[a]	7.43 ± 0.17[b]
BFTC20	7.06 ± 0.20[a]	6.43 ± 0.22[b]	6.92 ± 0.23[b]	7.03 ± 0.29[b]	6.63 ± 0.20[b]
BFTC30	6.62 ± 0.21[a]	5.87 ± 0.26[c]	4.66 ± 0.32[c]	4.89 ± 0.30[c]	4.97 ± 0.26[c]
BFTC40	4.43 ± 0.30[b]	5.17 ± 0.31[d]	3.82 ± 0.27[c]	4.80 ± 0.26[c]	4.66 ± 0.26[c]

Each value is the average score ± standard deviation of sixty tasters; a, b and c superscript: there is no significant difference (p > 0.05) between two values in the same column surmounted by the same letter.

3.3. Sensory (organoleptic) analysis of cookies

3.3.1. Descriptive test

The sensory profiles of the different cookies are shown in Figure 2. Descriptive test results showed that the sensory criteria influencing cookie acceptability were color, texture, flavor, aroma, sweetness and crispness. A significant decrease (p < 0.05) in cookie sweetness was observed with the substitution of wheat flour by *Terminalia catappa* almond flour. The intensity of the "texture (firmness)" descriptor for BFB cookies was significantly lower (p<0.05) than for composite cookies. The crispness scores of the composite cookies were statistically (p < 0.05) higher than those of the BFB cookies. As for the "aroma" descriptor, it was significantly perceived by panelists from 10% substitution upwards.

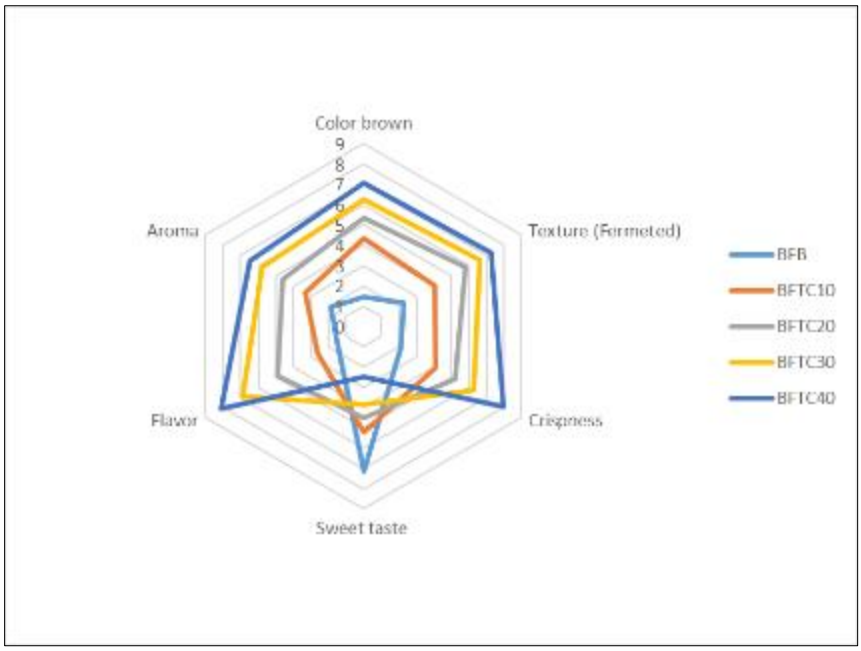

Figure 2 Sensory profile of wheat flour and composite flour cookies (*Terminalia catappa* almond flour / wheat

3.3.2. Hedonic test

The test results showed that Terminalia catappa-based fortified cookies had lower acceptability levels than the control cookie (Table IV). The 10 %-substituted cookies were the most popular of the composite cookies. There was a significant difference ($p<0.05$) between the fortified cookies and the control cookie in terms of general acceptability. Cookies substituted at 20 %, 30 % and 40 % showed moderate acceptability in the order of substitution.

4. Discussion

Increasing the substitution of *Terminalia catappa* kernel flour for wheat flour significantly ($P < 0.05$) increased the protein, lipid, and ash content, as well as the energy value, of the cookies. These increases are in line with the results of Javaria et al., (2023), who showed *Lens culinaris* and *Avena sativa* flour increased the protein, lipid, and ash contents of cookies. Protein content is 90% higher in the BFTC40 cookie than in the control diet (BFB). According to Toundoufedouno et al. (2024), replacing wheat flour with *Vicia narbonensis* seed flour increases the protein content of composite cookies. The higher protein content of fortified cookies is mainly due to the high protein content of *Terminalia catappa* flour. According to Aboudou et al. (2017), the flour of these almonds contains between 18.39 and 40.9% protein. Thanks to their high protein content, BFTC40-fortified cookies could be a good protein rehabilitation food.

The fat content of all composite cookies increased with the substitution rate of *Terminalia catappa*-amade flour. This result is similar to those of Diallo et al. (2015), who found an increase in fat content in bakery products fortified with Voandzou flour (*Vigna subterranea L. verdc*). This increase is thought to be due to the fact that *Terminalia catappa* almonds have a high lipid content. The increased fat content of cookies could justify their energy value. Moreover, the energy value of formulated cookies increases with fat content. The data showed a significant reduction ($P<0.05$) in cookie moisture content from 6.27 (control) to 2.19% (BFTC40). These results are corroborated by those of Islam et al. (2012), who observed a slight decrease in moisture content in cookies made from brown rice. A low moisture content promotes good preservation of food products (Tiendrebeogo, 2021). A rise in fiber content was observed, from 1.12 ± 0.01 g/100 g for the control cookie to 1.56 ± 0.01 g/100 g for BFTC40. These results concur with those of Badje et al. (2019), who reported that the use of composite flours increases the fiber content of bakery products. These fiber contents are in line with the recommended value (≤ 5) (FAO/OMS, 2004). As a result, formulated cookies could not induce diarrhea or constipation in the malnourished. For ash content, a significant increase ($p<0.05$) was observed compared with the control. The more the cookies were enriched with *Terminalia catappa* almond flour, the higher the ash content. These results are in line with the findings of Obichili et al. (2019), who showed an increase in the mineral content of cookies following the addition of *Moringa oleifera* leaf powder. A similar trend has been observed in almost all studies dealing with the incorporation of plant-derived powders in cookies (Songré-Ouattara et al., 2017).

In the cookie industry, the physical properties of cookies play a very important role. Replacing wheat flour with *Terminalia catappa* almond flour has led to a reduction in cookie diameter. These results are in line with those of Sakr et al. (2017), who showed a decrease in cookie diameter following the level of incorporation of the fruit of *Phoenix dactylifera*. Changes in cookie diameter are due to the softening and loosening of the dough during kneading (Amina 2018). Cookie thickness increased with the level of substitution. The same observations were made on cookies fortified with *Silybum marianum* powder Menasra, (2020). The increase in thickness is linked to the kneading time and the level of incorporation of *Terminalia catappa* almond flour. The addition of *Terminalia catappa* almond flour increases the mass of the cookies, depending on the level of incorporation. These results are in line with those of Giva et al. (2010), who substituted wheat flour for corn flour. The high protein and fat content of *Terminalia catappa* almond flour could explain this increase in cookie weight. As the level of substitution increased, the cookie spread ratio decreased significantly. These results are in agreement with those of Darimont et al. (2022), who indicate that the reduction in cookie spread ratio can be attributed to the fact that a higher protein content presents a greater water-binding capacity, thus limiting cookie spread.

The level of incorporation of *Terminalia catappa* almond flour modifies the color of the formulated cookies. Brightness decreases considerably with the rate of incorporation. This variation in color and brightness is thought to be due to the Maillard reaction during baking Diallo et al., (2015). Cookie hardness increases with the level of *Terminalia catappa* almond flour enrichment. According to Sakr et al. (2017), date flour increases the hardness of formulated cookies. The high fiber content increases the hardness of the cookies (Becker et al., 2014). Flavor and crispness are characteristics that depend on the panelists' individual sensitivities. They can in no way represent the opinion of a very large population. However, they can be used to judge the general acceptability of a food product. According to the panelists, the BFB cookie was the most popular. It was followed by BFTC10 and BFTC20, respectively. The preference for the BFB cookie could be due to consumers eating habits with regard to wheat flour. The non-preference of BFTC30 and BFTC40 cookies is due to the pronounced taste of *Terminalia catappa* almond flour.

Abbreviations

- PAS: Specialized food product
- CSB : Corn Soya Blended
- PNN : National Nutrition Program
- AOAC : *Official Methods of Analysis*
- BFB : Cookie made with 100% wheat flour
- BFTC10 : Cookies made with 10 % *Terminalia catappa* almond flour and 90 % wheat flour BFTC20 : Cookies made with 20 % *Terminalia catappa* almond flour and 80 % wheat flour
- BFTC30 : Cookies made with 30 % *Terminalia catappa* almond flour and 70 % wheat flour BFTC40 : Cookies made with 40 % Terminalia catappa almond flour and 60 % wheat flour

5. Conclusion

The incorporation of *Terminalia catappa* flour into wheat flour has improved the nutritional quality of the cookies. Protein, lipid, fiber and ash content increased as the incorporation rate increased. Cookie physical parameters such as diameter, thickness, mass and spread ratio were also influenced by the level of enrichment. The BFB cookie is the most popular. It is followed by BFTC10 and BFTC20. Considering all these nutritional properties, cookies enriched with up to 20% *Terminalia catappa* almond flour could be an option for combating protein-energy malnutrition.

Compliance with ethical standards

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Disclosure of conflict of interest

The author declares no conflict of interest.

Statement of ethical approval

A tasting panel was conducted by both men and women.

Statement of informed consent

Informed consent was obtained from all individual participants included in this panel.

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