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Nutritional Qualities, Physical and Organoleptic Characteristics of Cookies Resulting from the Substitution of Wheat Flour by Caterpillar Powder *(Imbrasia Oyemensis)*

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Abstract The present work aims to study the nutritional properties of cookies, resulting from the substitution of wheat flour by caterpillar powder *(Imbrasia oyemensis)*. The different substitution rates were 0%, 5%, 10%, 15% and 20%. The physicochemical composition of the cookies was determined by standard methods (AOAC). A significant improvement ($p<0.05$) in the protein (10.1 ± 0.3 to 17.5 ± 0.6%), fat (15.1 ± 0.4 to 18.2 ± 0.1%), ash (0.57 ± 0.1 to 1.66 ± 0.8%), and fiber (0.1 ± 0.06 to 1.2 ± 0.05%) content of the cookies was observed with the substitution level. On the other hand, there was a significant decrease ($p<0.05$) in carbohydrate content (68.93 to 60.7 %) and a significant increase ($p<0.05$) in energy values (453.4 to 476.6 Kcal). At the level of the physical parameters of the cookies, it is noted on the one hand a decrease of the diameter (6.8 ± 0.05 to 6.2 ± 0.02 cm), of the spread ratio (12.84 ± 0.76 to 8.12 ± 0.43) and on the other hand an increase of the thickness (0.53 ± 0.03 to 0.76 ± 0.2 cm) and of the weight (20.37 ± 0.4 to 21.03 ± 0.3 g), as the level of substitution increases. The descriptive parameters of the cookies (color, texture, crispness, flavor, aroma, sweet taste) were also influenced with the substitution level. The hedonic test indicates that the 100% wheat cookie (BFB) was the most preferred by tasters, followed by BFC5 and BFC10. The substitution of wheat flour by caterpillar *(Imbrasia oyemensis)* powder has improved the nutritional properties of the cookies compared to cookies made only with wheat flour. These cookies could therefore be an alternative in the fight against protein-energy malnutrition.

Keywords: *cookies, caterpillar (Imbrasia oyemensis), wheat flour, substitution, protein-energy malnutrition*

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1. Introduction

Hunger and malnutrition remain widespread scourges in the world today. If in developed countries it is overnutrition that predominates with its corollaries of metabolic and cardiovascular diseases [1], in developing countries it is rather deficiency malnutrition that prevails. Protein-energy malnutrition ranks first among nutritional disorders and is a serious challenge for food security [2]. In order to sustainably solve the issue of malnutrition, which remains an obstacle to development [3,4], food fortification is another option.

Protein fortification is the incorporation of protein-rich food resources into a widely consumed staple food to improve its nutritional balance. Because of their organoleptic characteristics, cookies are appreciated by most people, especially children and adolescents. This admiring trend seems to make cookies a promising avenue for protein fortification, which is one of the strategies to fight protein-energy malnutrition.

Work carried out in this field has consisted in the fortification of cookies with date fruits and chickpea seeds. Thus, the work of [5] in Saudi Arabia and [6] in Egypt showed that cookies fortified respectively, with date flour at the rate of 20% and chickpea flour at the rate of 15% have higher nutritional values than those cookies made only with wheat flour.

Like legumes, caterpillars are a good source of protein and contain important nutritional potential. Indeed, the work of [7] reveals that these caterpillars contain more than 9 amino acids and 8 essential fatty acids, 55 % protein, and 476 Kcal as energy value per 100 g of insect dry matter. However, very few studies have been carried out, until now, on composite cookies resulting from the fortification of wheat flour with caterpillar powder *(Imbrasia oyemensis)*.

Can the incorporation of caterpillar powder *(Imbrasia oyemensis)* into wheat flour improve the nutritional properties of composite cookies?

In order to respond to this, the present work was undertaken with the general objective of reducing protein-energy malnutrition through the manufacture of cookies based on wheat flour and caterpillar powder *(Imbrasia oyemensis)*.

This work will result in:

- the determination of the global chemical composition of the cookies

- the determination of the physical and organoleptic characteristics of the cookies.

2. Material and Methods

2.1. Material

2.1.1. Biological Material

The biological material consists of dried caterpillars of *Imbrasia oyemensis* and Type 45 wheat flour. Dried caterpillars *(Imbrasia oyemensis)* were purchased in the markets of the towns of Bouaflé and Zénoula (central-west Ivory Cost).

2.1.2. Food Products

The commercial food products used in the formulation of the cookies were: wheat flour type 45, baking powder, sugar, butter, vanilla and tap water.

2.2. Methods

2.2.1. Production of the Caterpillar Powder *(Imbrasia Oyemensis)*

Two (2) kg of dried caterpillars *(Imbrasia oyemensis)* were sorted and then cleared of any kind of waste. They were then placed in an oven at 65°C for 72 hours, then ground with a blender to obtain the caterpillar powder. The powder obtained was put in covered jars and stored in the refrigerator at 4°C.

2.2.2. Formulation and Production Process of the Cookies

The recipe for preparation of control (100% wheat flour) cookies (BFB) and composite cookies where wheat flour is substituted by 5% (BFC5), 10% (BFC10), 15% (BFC15) and 20% (BFC20) of caterpillar *(Imbrasia oyemensis)* powder are made according to the method described by [5]. The raw material wheat flour and caterpillar *(Imbrasia oyemensis)* is rigorously controlled. It is then stored under conditions (at room temperature) that preserve its qualities. For each cookie recipe, a rigorous weighing of the ingredients was carried out (Table 1).

To produce the cookies, the ingredients were fed into the mixer in a specific order. The sugar and then the butter were introduced and whipped to obtain a cream. Vanilla was added to the cream. The caterpillar powder *(Imbrasia Oyemensis)* previously sifted and added to the wheat flour and mixed with the yeast was introduced last.

The whole is kneaded for 5 to 20 minutes. After kneading and resting, the dough is then shaped into individual portions. The cooking, which is done with wet heat, takes place at 200°C during 15 to 20 minutes in an electric oven. Once out of the oven, the cookie is left at room temperature to cool and then packed in polyethylene bags and stored at room temperature.

Table 1. Recipe for normal and composite cookies

Cookies Ingredients	**Normal cookies BFB**	**Composite cookies**			
		5 % BFC5	10 % BFC10	15 % BFC15	20 % BFC20
Wheat flour	100 %	95 %	90 %	85 %	80 %
Caterpillar power *(Imbrasia oyemensis)*	_	5 %	10 %	15 %	20 %
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
Levure (g)	1.25	1.25	1.25	1.25	1.25
Water	**As needed**				

Wheat flour substituted by 5 %, 10 %, 15 % and 2 0% of caterpillar powder (Imbrasia oyemensis).

2.2.3. Determination of the Global Chemical Composition of Cookies

Moisture content was determined by drying at 105°C for 24 h according to the method AOAC [8].

The protein content was determined according to the method AOAC [8] using Kjeldahl.

Fat content was determined by the soxhlet method AOAC [8].

The carbohydrate content was calculated by the difference method AOAC [8].

The ash content was determined by incineration in a muffle furnace at 550°C for 12 h AOAC [8].

The determination of the crude fiber content is performed according to the AOAC method [8].

The total energy value is determined by calculation according to the AOAC method [8].

The pH and titratable acidity are determined according to the AOAC method [8].

2.2.4. Determination of the Physical Parameters of the Cookies

The physical parameters of the cookies are determined by the diameter (cm), thickness (cm), weight (g), and spread ratio [9].

- The weight, expressed in grams, is measured with an electronic scale

- The diameter and thickness, expressed in centimeters, are measured with a caliper.

- The spread ratio is calculated by the ratio of the diameter by the thickness according to the following formula:

$$\textbf{Spreadratio} = \frac{\text{Diameter}(\text{cm})}{\text{Thickness}(\text{cm})}$$

2.2.5. Sensory Analysis of the Cookies

2.2.5.1. Sampling and Description of Samples

The samples are composed of five (5) elements: cookies with 100% wheat flour (BFB); cookies with caterpillar powder *(Imbrasia oyemensis)* where wheat flour is substituted at the rate of 5 % (BFC5), 10 % (BFC10), 15 % (BFC15), 20 % (BFC20) respectively.

2.2.5.2. Method of Sensory Analysis

The sensory analyses were performed on the cookie samples. The methods of sensory analysis are based on the choice of the panel, the coding of the samples and the realization of the test. In total, two types of tests were carried out. These are: the descriptive test and the hedonic test.

a-Descriptive test

a.1-Principle

The method consists of evaluating and quantifying the descriptors (color, texture, crispness, flavor, aroma, sweet taste) according to a category scale. The different cookies produced were presented to a panel of judges recruited and trained in the analysis methodology. These cookies were coded with three numbers and presented simultaneously in a randomized order [10].

a.2-Panel selection and training

After informed consent, fifteen (15) people (Men and Women) from the University Félix Houphouët-Boigny were recruited based on their knowledge of the cookie. Their availability, their sensitivity to stimuli and their ability to hold coherent arguments were also criteria that contributed to the recruitment. The people recruited were trained in the methodology for analyzing and assessing the selected qualitative characteristics. The training took place during three (3) sessions during which, the attributes or descriptors of the cookies were identified, defined, tested as well as their intensity quantified on a linear scale (10 cm). These sensory criteria were evaluated on a ten-point rating scale, ranging from one (when the assessed qualitative characteristic is extremely absent) to ten (when the assessed qualitative characteristic is extremely present).

a.3-Conducting the tasting tests

Cookies produced from caterpillar *(Imbrasia oyemensis)* powder (caterpillar/wheat) as well as cookies made with 100% wheat flour (control) were presented to a panel of 15 trained panelists. During the actual evaluation, cookie samples were served on disposable plates of the same coded appearance (three digits) and presented simultaneously in a randomized order. Each taster was given a glass of water to rinse the mouth between samples.

b-Hedonic test (Acceptability test)

Cookies made with caterpillar powder *(Imbrasia oyemensis)*, composite flours and 100% wheat flour (control) were evaluated on the acceptability of color, texture, taste and aroma.

The cookie samples were judged by 60 untrained individuals (male and female) recruited from among the students and staff of the University Félix Houphouët-Boigny. Panelists were recruited on the basis of their availability and knowledge of cookies. The acceptability of each sample was assessed on a nine-point hedonic scale, ranging from 1 (extremely unpleasant) to 9 (extremely pleasant) [10].

2.2.6. Statistical Analysis

The software used for statistical analysis was GRAPH PAD Prism 7.0. The sensory profile of the cookies was carried out using Excel 2007 software. A significance level ($p<0.05$) is chosen for the significance of all statistical analyses.

3. Results

3.1. Global Chemical Composition of the Cookies

The chemical composition of the different cookies according to the incorporation rate shows that the moisture content of the 100% wheat flour cookies is 6.3 ± 0.1 g/100g. That of the composite cookies (*Imbrasia oyemensis* caterpillar/wheat flour powder) varied from 2.2 ± 0.11 to 5.1 ± 0.05 g/100g and were statistically lower ($p<0.05$) than that of the BFB cookies.

The substitution of wheat flour by caterpillar *(Imbrasia oyemensis)* powder, significantly ($p<0.05$), improves the protein content of the composite cookies (12.3 ± 0.7 to 17.5 ± 0.6 g/100g) compared to the BFB cookie, which has the lowest protein content (10.1 ± 0.3 g/100g).

The fat content of the composite cookies varied from 16.4 ± 0,6 to 18.2 ± 0.1 g/100g. With the exception of the BFC5 cookie, the fat content of the composite cookies is significantly ($p<0.05$) higher than that of the BFB cookies is 15.1 ± 0.4 g/100g.

The carbohydrate content of the cookies is 68.93 ± 0.04 g/100g, 66.44 ± 0.1 g/100g, 64.58 ± 0.12 g/100g, 62.7 ± 0.03 g/100g and 60.7± 0.2g/100g respectively for BFB, BFC5, BFC10, BFC15 and BFC20 cookies.

Incorporation of *Imbrasia oyemensis* caterpillar powder into wheat flour at all levels resulted in a significant ($p<0.05$) decrease in total carbohydrate content of the cookies.

The ash content of the composite cookies ranged from 0.76 ± 0.03 to 1.66 ± 0.8 g/100g and was significantly ($p<0.05$) higher than that of the BFB cookies (0.57 ± 0.1 g/100g) except for the BFC5 cookie.

The fiber content of the BFB cookies was 0.1 ± 0.06 g/100g. The incorporation of caterpillar powder *(Imbrasa oyemensis)* into wheat flour resulted in a significant increase ($p<0.05$) in the fiber content of the composite cookies, which varied from 1.05 ± 0.017 to 1.2 ± 0.05 g/100g.

The energy value of the composite cookies varied from 464.3 ± 0.7 to 476.6 ± 1.1 Kcal/100g and was significantly ($p<0.05$) higher than that of the BFB cookies, which had an energy value of 453.4 ± 1.2 kcal/100g. All cookies are slightly acidic with pH ranging from 6.32 ± 0.01 to 6.87 ± 0.1. (Table 2).

3.2. Physical Properties of Cookies

The physical characteristics of the cookies which are weight, diameter, thickness and spead ratio (spreading ratio) are presented by Table 3.

The weight of the composite cookies varied from 20.48 ± 0.3 to 21.03 ± 0.3 g. With the exception of the BFC5 cookie, the substitution of wheat flour by caterpillar

(Imbrasia oyemensis) powder resulted in a significant increase (p<0.05) in the weight of the cookies compared to the 100% wheat flour (BFB) cookies, which had a weight of 20.37 ± 0.4 g.

The diameter of the composite cookies ranged from 6.2 ± 0.02 to 6.5 ± 0.03 cm and was significantly (p<0.05) smaller than that of the BFB cookies which was 6.8 ± 0.05 cm.

The thickness of the BFB cookies was 0.53 ± 0.03 cm. The incorporation of caterpillar powder *(Imbrasia oyemensis)* into wheat flour resulted in a significant increase (p<0.05) in the thickness of the composite cookies, which varied from 0.63 ± 0.3 to 0.76 ± 0.2 cm.

The spread ratio of BFB cookies is 12.84 ± 0.76 and is significantly higher than those of composite cookies which are 10.2 ± 0.44; 9.14 ± 0.08; 8.64 ± 0.4 and 8.12 ± 0.43 respectively for BFC5, BFC10, BFC15 and BFC20 cookies.

3.3. Sensory Analysis of the Cookies

3.3.1. Descriptive Test

Substitution of wheat flour by caterpillar powder *(Imbrasia oyemensis)* resulted in a significant variation (p<0.05) in the intensity of the descriptors (color, texture, flavor, aroma, sweet taste) except for crispness.

The sensory profiles from the descriptive tests indicate that the score for the descriptor "Brown color" of the 100% wheat flour BFB cookies is 1.72. Those of the composite cookies (*Imbrasia Oyemensis* caterpillar powder/wheat flour) are between 4.24 and 8.4.

The score of the descriptor "Texture (firmness)" of the composite cookies ranges from 4.48 to 7.33. The highest intensity is recorded by cookie BFC20 and is significantly (p<0.05) higher than that of cookies BFC5 and BFC10. The intensity of the descriptor "Texture (firmness)" of BFB cookies is 3.72 and is significantly lower (p<0.05) than that of composite cookies.

The crispness scores of the cookies are 4.83; 6.53; 6.96; 7.56 and 7.74 for BFB, BFC5, BFC10, BFC15 and BFC20 cookies respectively.

For the descriptor "Sweet taste", the BFB cookies have an intensity of 7.26. The intensity of this descriptor varies from 3.2 to 5.7 for the composite cookies. It is observed that the perception of this sweet taste in the cookies decreases significantly (p<0.05) with the substitution rate of wheat flour by caterpillar powder *(Imbrasia oyemensis).*

The 100% wheat flour (BFB) and composite cookies differ in flavor and aroma. The BFB cookies have the intensity of the descriptor "flavor" and "aroma" of 1.9 and 1.5 respectively. The composite cookies have the intensity of the descriptor "flavor" that varies from 3.9 to 8.13 and from 2.96 to 6.83 for the descriptor "aroma".

The descriptor "flavor" is significantly perceived by the panelists from 5% of substitution. As for the descriptor "aroma", it is significantly perceived by the panelists from 10% of substitution (Figure 1).

3.3.2. Hedonic Characteristics

The result of the hedonic test indicates the level of acceptability of the color, texture, taste, aroma, and general acceptability of the cookies.

The level of acceptability of color (8.6 ± 0.74), texture (7.51 ± 0.63), taste (8.4 ± 1.2), aroma (7.82 ± 1.05) and overall acceptability (8.36 ± 0, 85) of the 100% wheat flour (BFB) cookies were significantly higher (p<0.05) than those of the composite cookies except for the BFC5 cookies (cookie based on 5% caterpillar powder *(Imbrasia oyemensis)* and 95% wheat flour).

The hedonic test of the composite cookies (*Imbrasia oyemensis* caterpillar powder/wheat flour) indicates that the acceptability level of color (8.2 ± 0.52), texture (7.34 ± 0.92), taste (8.27 ± 1.4), aroma (7.35 ± 1.02) and overall acceptability (8.12 ± 1.02) of the BFC5 cookies are significantly (p<0.05) higher than those of the BFC10, BFC15 and BFC20 cookies.

The level of acceptability of color, texture, taste, aroma, and general acceptability of BFB and BFC5 cookies are not significantly (p>0.05) different and are the highest. These cookies are therefore the most appreciated.

The BFC10 cookie has an overall acceptability level of 7.42 ± 1.1 higher than 5. This cookie is therefore considered acceptable by the panelists.

However, a significant reduction (p<0.05) in overall acceptability was observed due to the substitution of wheat flour by *Imbrasia oyemensis* caterpillar powder. The overall acceptability level of BFC15 and BFC20 cookies are 4.53 ± 0.66 and 3.38 ± 0.78, respectively, which are below 5. Thus, the cookies BFC15 and BFC20 were not rated by the panelists with respect to sensory quality. (Table 4).

Table 2. Chemical composition of the cookies

Parameters \ Cookies	BFB	BFC5	BFC10	BFC15	BFC20
Moisture (g/100g)	6.3 ± 0.1[a]	5.1 ± 0.05[b]	4.06 ± 0.6[c]	2.73 ± 0.1[d]	2.2 ± 0.11[d]
Protein (g/100g)	10.1 ± 0.3[a]	12.3 ± 0.7[b]	13.32 ± 0.8[b]	16.4 ± 0.2[c]	17,5 ± 0.6[c]
Fat (g/100g)	15.1 ± 0.4[a]	16.4 ± 0,6[ab]	17.07± 0.3[bc]	17.5 ± 0.2[bc]	18.2 ± 0.1[c]
Carbohydrate (g/100g)	68.93±0.04[a]	66.44 ± 0.1[b]	64.58 ± 0.12[c]	62.7 ± 0.03[d]	60.7± 0.2[e]
Ash (g/100g)	0.57 ± 0.1[a]	0.76 ± 0.03[a]	1.1 ± 0.05[b]	1.4 ± 0.05[c]	1.66 ± 0.8[d]
Fiber (g/100g)	0.1 ± 0.06[a]	1.05 ± 0.017[b]	1.1 ± 0.01[b]	1.14 ± 0.08[b]	1.2 ± 0.05[b]
Energy value (kcal)	453.4 ± 1.2[a]	464.3 ± 0.7[b]	466.6 ± 0.3[b]	473.5 ± 0.6[c]	476.6 ± 1.1[c]
Ph	6.87 ± 0.1[a]	6.66 ± 0.02[b]	6.65 ± 0.1[b]	6.33 ± 0.4[c]	6.32 ± 0.01[c]

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 of the same line topped by the same letter.

Table 3. Physical properties of cookies

Parameters \ Cookies	BFB	BFC5	BFC10	BFC15	BFC20
Weight (g)	20.37 ± 0.4^{a}	20.48 ± 0.3^{ab}	20.52 ± 0.5^{b}	20.92 ± 0.2^{c}	21.03 ± 0.3^{c}
Diameter (Cm)	6.8 ± 0.05^{a}	6.5 ± 0.03^{b}	6.4 ± 0.04^{b}	6.3 ± 0.03^{bc}	6.2 ± 0.02^{c}
Thickness (Cm)	0.53 ± 0.03^{a}	0.63 ± 0.3^{ab}	0.7 ± 0.1^{b}	0.73 ± 0.3^{b}	0.76 ± 0.2^{b}
Spread ratio	12.84 ± 0.76^{a}	10.2 ± 0.44^{b}	9.14 ± 0.08^{b}	8.64 ± 0.4^{c}	8.12 ± 0.43^{c}

Each value is the mean ± standard deviation of three determinations.
a, b, c: there is no significant difference (p> 0,05) between two values of the same line topped by the same letter.

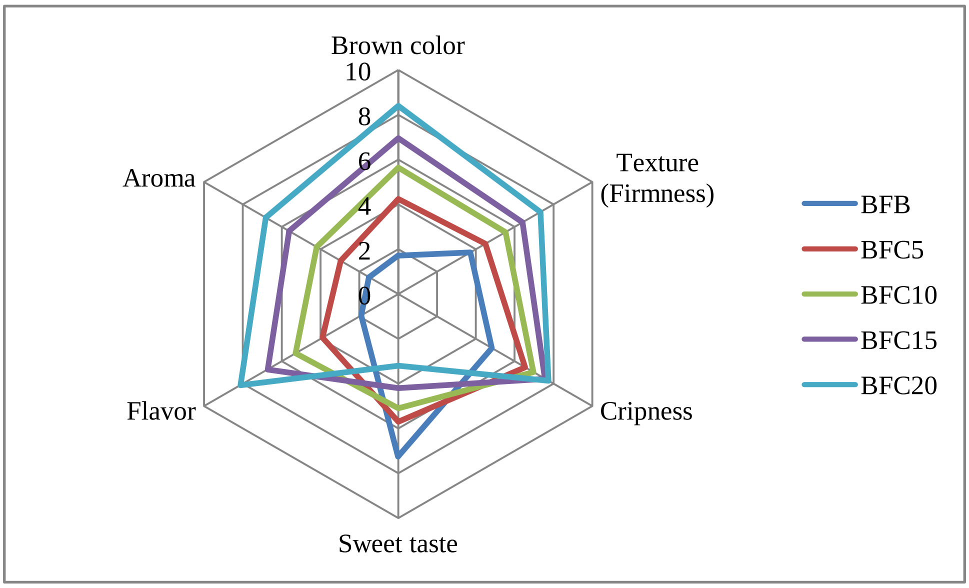

Figure 1. Sensory profile of wheat flour and composite flour cookies (*Imbrasia oyemensis* caterpillar/wheat flour powder)

Table 4. Hedonic analysis of wheat flour cookies and composite cookies (*Imbrasia oyemensis*/wheat)

Samples	Sensory characteristics				
	Color	Texture	Taste	Aroma	Global Acceptability
BFB	8.6 ± 0.74^{a}	7.51 ± 0.63^{a}	8.4 ± 1.2^{a}	7.82 ± 1.05^{a}	8.36 ± 0.85^{a}
BFC5	8.2 ± 0.52^{a}	7.34 ± 0.92^{a}	8.27 ± 1.4^{a}	7.35 ± 1.02^{a}	8.12 ± 1.02^{a}
BFC10	6.73 ± 0.95^{b}	6.23 ± 0.77^{b}	7.18 ± 1.35^{b}	6.52 ± 1.04^{b}	7.42 ± 1.1^{b}
BFC15	5.1 ± 1.03^{c}	5.62 ± 0.57^{c}	4.27 ± 1.26^{c}	4.48 ± 0.25^{c}	4.53 ± 0.66^{c}
BFC20	4.2 ± 1.02^{d}	5.31 ± 1.1^{c}	3.41 ± 0.98^{d}	4.34 ± 0.41^{c}	3.38 ± 0.78^{c}

Each value is the average of scores ± standard deviation of sixty tasters
a, b, c, d: there is no significant difference (p> 0,05) between two values of the same column topped by the same letter.

4. Discussion

Protein-energy malnutrition is a serious problem that threatens developing countries. Food fortification would be, however, a promising alternative in order to respond effectively and sustainably to this scourge. This part of the work aims to study the nutritional qualities, physical and organoleptic characteristics of the cookies resulting from the substitution of wheat flour by caterpillar powder *(Imbrasia oyemensis)*. The different substitution rates are 0%, 5%, 10%, 15% and 20%.

The present study reveals an increase in the protein and fat content of the cookies with the level of incorporation of caterpillar *(Imbrasia oyemensis)* powder. The protein and fat contents of the cookies varied from 10.1 ± 0.3 to 17.5 ± 0.6 g/100g and 15.1 ± 0.4 to 18.2 ± 0.1 g/100g, respectively. This result could be explained by the fact that caterpillar powder *(Imbrasia oyemensis)* is a good source of protein (52.12 g/100g) and contains a significant amount of fat (20.58 g/100g). These results are different to those of [11] on caterpillar *(Rhynchophorus phoenicis)* powder fortified cookies which obtained 9.63 ± 0.08 g/100g and 34 ± 0.2 g/100g as protein and fat content respectively. This difference may be due to the type of caterpillar species used and the incorporation rate. In addition, [12] in their study indicate an increase in the protein and fat content of wheat-based cookies enriched with soy flour. Caterpillar powder *(Imbrasia oyemensis)*, rich in lysine, an essential amino acid, present in very low proportion in wheat flour, improves the protein quality of composite cookies.

These analyses show that the 100% wheat flour cookie (BFB) is mainly rich in carbohydrates (68.93 ± 0.04%). This chemical profile is in agreement with the results of analyses carried out by [13] on BFB cookies (100% wheat flour) (67.77%) and confirms, moreover, the priority energy function attributed to this food.

The results indicate that the fiber content of the cookies increases with increasing amount of chenille powder (0.1 ± 0.06 to 1.2 ± 0.05 g/100g). These results are consistent with those reported [6] who obtained an increase in the fiber content of cookies with the level of date flour substitution (0.79 ± 0.01 to 1.21 ± 0.04 g/100). Dietary fiber is considered essential for optimal digestive health, and also confers various functional benefits [14].

The physical properties of the cookies are important to manufacturers and consumers. The incorporation of caterpillar powder *(Imbrasia oyemensis)* resulted in a reduction in the diameter of the cookies from 6.8 to 6.2 cm. The decreasing trend in diameter is proportional to the increasing level of substitution of wheat flour by chenille powder. This significant decrease in the diameter of the cookies can be explained according to [15] to the increase in fiber content, which in this study is due to the addition of caterpillar powder *(Imbrasia oyemensis)*, which is rich in fiber (3.2%) against 0.12% for wheat flour. This result could also be explained by the fact that the caterpillar powder is less soluble, thus retaining its undissolved nature longer during cooking, which would restrict the flow of the paste. These results are in agreement with those of [6], who show a decrease in the diameter of the cookies (5.56 to 5.32 cm) with increasing the level of incorporation of date flour, which is a good source of dietary fiber.

Cookie thickness was positively affected, increasing as the level of substitution increased. These results are consistent with those observed by [16], who observed an increase in cookie thickness with increasing levels of Mothbean flour incorporation. Cookie thickness increases with increasing amount of fiber and crude protein [17].

The present study reveals a reduction in the spread ratio of cookies from 12.84 ± 0.76 to 8.12 ± 0.43 according to the increase in the incorporation rate of caterpillar *(Imbrasia oyemensis)* powder. High protein flours other than wheat or any other ingredient that absorbs water during dough mixing will reduce the spread ratio. Indeed, the water available in such a system would be insufficient to dissolve the sugar during cooking, increasing the viscosity and resulting in a lower spreading ratio [18].

The physical properties of the cookies indicate that the increase in cookie weight is proportional to the increase in the rate of incorporation of caterpillar *(Imbrasia oyemensis)* powder (20.37 ± 0.4 to 21.03 ± 0.3 g). This increase in cookie weight could be explained by the high fat and protein content of the caterpillar *(Imbrasia oyemensis)* powder. These results are consistent with those of [13] who obtained an increase in the weight of cookies (16.49 to 21.99 g) from the substitution of wheat flour with corn flour.

Color plays a major role in consumer perception and acceptability. The results of the descriptive test indicate that, increasing the substitution rate leads to a significant increase ($p<0.05$) in the intensity of the descriptor "brown color" of the cookies. This variation in cookie color may be related to the Maillard Reaction between sugar and amino acids during the baking process, causing the cookies to darken in color. [19] in their studies on the nutritional and sensory quality of soy-based cookies showed that browning could result from the Maillard reaction or from caramelization. While [20] reported a direct relationship between fiber content and browning. Therefore, the high fiber content of the cookies due to the presence of the caterpillar powder may also have caused some browning effects. In addition, the color of the caterpillar powder *(Imbrasia oyemensis)* was brown and may have been a contributing factor.

The importance of texture in consumer acceptability is highly recognized. [21] reported that hardness is most important in the evaluation of pastry and/or bakery products, due to its close association with human perception and freshness. The hardness of the cookies increases with the level of substitution. This increase in hardness may be due to the high fiber content of the caterpillar *(Imbrasia oyemensis)* powder. [22] suggest that high fiber content contributes to increased cookie hardness compared to the control formula. These results are in agreement with the work of [6], who indicate an increase in cookie hardness with the level of date flour incorporation.

Flavor is a difficult characteristic to perceive and describe because the sensitivity of the taste buds differs when moving from one person to another. The score of the descriptor "flavor" of cookies increases with the level of substitution (1.9 ± 0.22 to 8.13 ± 0.2). This result is explained by the increase in the content of caterpillar powder *(Imbrasia oyemensis)* and thus the increase in its aroma and taste contained in the cookies.

The present study reveals an increase in the intensity of the descriptor "crispness" of the cookies with the incorporation rate. This result could be explained by the fact that composite flours form aggregates with an increased number of hydrophilic sites found in oligisaccharides, polysaccharides, and proteins that increase competition for limited free water in the cookie dough [23].

The hedonic test indicates that the brown color of the cookies due to the substitution of wheat flour by caterpillar powder *(Imbrasia Oyemensis)* reduces the appreciation of the cookies. These results are in agreement with those of [17] who showed that browning of cookies due to substitution of wheat flour with bambara pea flour (Vigna subterranean L.) reduces the color acceptability of the cookies.

Cookies BFC15 (Biscuits made with 15% *Imbrasia Oyemensis* caterpillar powder and 85% wheat) and BFC20 (Biscuits made with 20% *Imbrasia Oyemensis* caterpillar powder and 80% wheat) do not seem to be appreciated by the panelists in terms of sensory quality. This choice could be explained by the fact that from 15 % of incorporation, the cookies are affected by a higher intensity of flavour and a darker color after cooking. This observation can be enhanced by the addition of some optional ingredients such as milk, egg, flavoring and sweeteners. [24], report that cookies with more than 15% incorporation of defatted wheat germ had low overall acceptability by panelists.

The BFB cookie was the most appreciated by the panelists with a score of 8.36 ± 0.85, followed by BFC 5 and BFC 10 with 8.12 ± 1.02 and 7.42 ± 1.1 respectively. The preference for the BFB cookie may be due to the dietary habits of the consumers regarding wheat flour. Many criteria are attributed to wheat flour, which are; high consumption, product stability, technical and financial feasibility.

5. Conclusion

The substitution of wheat flour by caterpillar powder *(Imbrasia oyemensis)* improved the nutritional quality of the cookies compared to cookies made only with wheat flour. An increase in protein, lipid, fiber and ash content was observed as the substitution rate increased. Conversely, the decrease in total carbohydrate was proportional to the increase in substitution level (0-20 %). The physical parameters of the cookies such as diameter, thickness, weight and spread ratio were also influenced by the level of substitution. In terms of sensory analysis, the 100% wheat cookie (BFB) was the most preferred by the tasters, followed by BFC 5 and BFC 10. However, caterpillar powder *(Imbrasia oyemensis)* can be incorporated up to 10 % in the formulation of cookies without affecting their sensory quality. This study shows that these cookies can be used in the fight against protein-energy malnutrition. Nevertheless, further studies on nutritional parameters and glycemic power in rats are needed.

List of Abbreviations

-BFB: 100% wheat flour cookie

-BFC5: Cookies made with 5 % caterpillar powder *(Imbrasia oyemensis)* and 95 % wheat flour

-BFC10: Biscuits made with 10 % caterpillar powder *(Imbrasia oyemensis)* and 90 % wheat flour

-BFC15: Cookies made from 15 % caterpillar powder (*Imbrasia oyemensis)* and 85 % wheat flour

-BFC20: Biscuits made with 20 % caterpillar powder *(Imbrasia oyemensis)* and 80 % wheat flour

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