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Infant food formulations based on cereals (millet, maize) and caterpillar powder (*Imbrasia oyemensis*): Nutritional composition and sensory evaluation

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Abstract

Malnutrition is a real public health problem, particularly in low-income households. Therefore, the objective of this work is to improve nutritional quality of complementary foods based on maize and millet flours intended for children during diversification period of low-income households. Thus, biochemical and phytochemical composition of ten cereal-based formulations (maize and millet) incorporated or not with *Imbrasia oyemensis* caterpillar powder were studied using standard and conventional methods. In addition, these formulations were subjected to a hedonic test by a panel of fifty people. It was found that incorporation of *Imbrasia oyemensis* powder improved contents of protein (11.97±0.03-16.4±0.03%), lipids (7.65±0.49-11.08±0.20%), ash (2.07±0.05-3.20±0.05%) and energy value (402.97±13.9- 483.63±35.71 kcal/100g) of maize (FMa0) and millet (FMi0) based flours. In addition, these formulations showed excellent contents of total polyphenols (160.19±2.80-256.16±0.00 mg/100g), flavonoids (10.95±0.07-25.64±0.15mg/100g) and tannins (109.45±0.68- 225.54±0.90 mg/100g). In addition, anti-nutritional contents such as phytates (97.24±0.08-128.60±0.08 mg/100g) and oxalates (215.81±1.67-370.65±9.29 mg/100g) are below the acceptable limit in human food. Thus, these incorporated formulations of *Imbrasia oyemensis* caterpillar powder were highly appreciated by panelists. Incorporation of *Imbrasia oyemensis* powder in maize and millet-based supplementary foods constitutes a cheaper and healthier alternative in children diet during diversification period of low-income households in Côte d'Ivoire.

Keywords: Flours; Cereals; Nutrient composition; Supplementary foods; *Imbrasia oyemensis*

1. Introduction

Malnutrition remains to this day a real public health problem, especially in developing countries like Côte d'Ivoire [1, 2]. According to recent FAO study in 2014, malnutrition is responsible for 33% of child mortality in Côte d'Ivoire [1]. This situation would be explained by the fact that during the diversification period, which is between 6 and 24 months, breast milk becomes insufficient quantitatively and qualitatively to cover the needs of the child. Thus, it is important to diversify the child's diet to supplement the intake of breast milk. However, the complementary foods given to children during the diversification period are for the most part, local cereal-based dishes that are poor and non-diversified [3,4]. As a result, a cheaper alternative for populations in developing countries is the use of new non-conventional sources of protein to substitute or complement existing ones [5]. Moreover, it has been recognized that valorization resources is

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one of the main ways to meet the protein needs for this African population and thus help fight malnutrition [6, 7]. These resources are rich in protein amino acids essential for children [8]. In addition, they contain a high content of linolenic acid, a precursor of Omega 3 [7, 9, 10]. Among these non-conventional resources, there is the *Imbrasia oyemensis* caterpillar which is available and easily accessible in the Ivorian forest zone [11, 12]. Moreover, it represents an excellent source of protein (53.57-57.77%), lipids (19.43-23.79%), minerals (2.17 - 2.61%) and energy [13, 11]. Also, the daily consumption of 50g of dried caterpillars (*Imbrasia oyemensis*) is sufficient to cover the child's riboflavin and pantothenic acid and niacin needs [12].

Thus, the use of these caterpillars in the child's diet during the diversification period constitutes a nutritional and dietary asset in the fight against child malnutrition. Therefore, the objective of this study is to improve the nutritional quality of maize and millet meal-based complementary foods for children during the diversification period in low-income households.

2. Material and methods

2.1. Material

The material used in this study consists of maize (*Zea mays*) and millet (*Pennisetum glaucum* L.) grains used as carbohydrates main sources. Cereals (maize and millet) were purchased at Abobo market (Abidjan, Côte d'Ivoire). Dried caterpillars (*Imbrasia oyemensis*), main source of essential nutrients for children, were purchased at Biankouma market (West, Côte d'Ivoire) (Figure 1).

Figure 1 Caterpillars *Imbrasia oyemensis*

2.2. Methods

2.2.1. Production of fermented maize and millet flours

Fermented maize and millet flours were obtained from cleaned and washed grains, then put to ferment in hermetically sealed bowls. Fermentation time was 48 hours. Grains were rinsed and left to dry for 3 days in an oven at a temperature (70°C). Fermented grains were ground using a Moulinex and sieved. Flours obtained were stored in hermetically sealed boxes.

2.2.2. Production of Sprouted maize and millet flours

Sprouted corn flour

Sprouted corn flour was obtained from corn kernels that were washed and then sprouted on a support of moist white cotton cloth, watered regularly. Sprouted time was five (5) days. Grains were then dried for 3 days in an oven at a temperature (45°C). Grains were degermed and then ground. Maize flour obtained was stored in hermetically sealed boxes.

Sprouted millet flour

Sprouted millet flour was obtained from washed millet grains then sprouted on a support of damp white cotton cloth, watered regularly. Sprouted time was four (4) days. Grains were then dried for 3 days in an oven at a temperature

(45°C). Grains were degermed then crushed using a Moulinex and sieved. Millet flour obtained was stored in hermetically sealed boxes.

2.2.3. Production of Imbrasia oyemensis caterpillar powder

Two (2) kilograms of dried *Imbrasia oyemensis* caterpillars, sorted and cleared of all kinds of waste, were ground in a blender and sieved to obtain *Imbrasia oyemensis* powder. The powder was put in hermetically sealed boxes and stored at room temperature.

2.2.4. Formulation of composite flours based on maize and millet incorporated in the powder of the caterpillar Imbrasia oyemensis

The composite flours based on maize and millet flours incorporated with *Imbrasia oyemensis* powder were formulated in the proportions recorded in Table 1.

Table 1 Formulation of composite flours based on maize and millet flour incorporated with *Imbrasia oyemensis* powder

Ingredients (%)	**Corn based formulations**				
	FMa0	**FMa17.5**	**FMa20**	**FMa22. 5**	**FMa25**
Fermented corn flour	90	72.5	70	67.5	65
Sprouted corn flour	10	10	10	10	10
Imbrasia oyemensis raw powder	0	17.50	20	22.5	25
	Millet based formulations				
	FMi0	**FMi17, 5**	**FMi20**	**FMi22, 5**	**FMi25**
Fermented millet flours	90	72.5	70	67.5	65
Sprouted millet flours	10	10	10	10	10
Imbrasia oyemensis raw powder	0	17.50	20	22.5	25

Code: FMa0 designated controlled corn flour without incorporation of raw flour from Imbrasia oyemensis. Codes FMa17.5; FMa20; FMa22.5 and FMa25 designated composite corn test flours with respectively 17.5%; 20%; 22.5% and 25% incorporation of Imbrasia oyemensis powder

2.2.5. Nutritive composition determination of composite flours

Dry matter, protein, lipid, ash and total carbohydrate contents of the composite flours were determined according to [14] methods. Crude fibers content was evaluated according to the method described by [15]. Calculation energy was done according to the relation given by [16].

2.2.6. Determination of phytochemical contents of composite flours

Vitamin C content of the samples was determined according to method described by [17]. Polyphenol, flavonoid and tannin contents were determined according to method described by [18, 19, 20]**.**The oxalate content of the samples was done according to the method described by [21] and the phytate content by the method described by [22].

2.2.7. Sensory analysis of balls based on composite flours

Hedonic sensory evaluation of slurries was carried out according to the standards NF ISO 5492 and V 09-001 [23]. Analyses were carried out on a seven-point hedonic scale using a panel of 50 tasters. Different descriptors evaluated are color, aroma, texture, taste and general acceptability [24].

2.3. Statistical analysis

The collected data were first filled in on the Excel spreadsheet. Then, their statistical processing was done using STATISTICA software (version 7.1). Statistically significant differences between the results were highlighted by a one-factor analysis of variance (ANOVA) followed by Duncan's test. Statistical significance was defined at the 5% level.

3. Results

3.1. Biochemical composition and energy value of formulations

The nutritive composition of the different formulations incorporated to the *Imbrasia oyemensis* powder shows a significant difference at the 5% threshold (Table 2).

Indeed, dry matter content of formulations decreased with incorporation rate of *Imbrasia oyemensis* powder in composite flours based on maize and millet. These contents ranged from 91.62±0.03% (FMa0) to 88.81±0.21% (FMa25) and from 92.66±0.05% (FMi0) to 89.7±0.02% (FMi22, 5) for maize and millet-based formulations respectively. Similarly, fibers content of maize and millet formulations decreased significantly (p<0.05) with the incorporation of *Imbrasia oyemensis* powder. These values ranged from 7.84±1.58% (FMa0) to 4.67±0.49% (FMa25) and from 7.24±0.4% (FMi0) to 4.35±0.48% (FMi22.5), while those of total carbohydrates ranged from 71.43±0.74% (FMa0) to 52.34±0.49% (FMa25) and from 73.30±0.32% (FMi0) to 56.58±0.87% (FMi22.5) for maize and millet formulations respectively.

However, protein content increased significantly (p <0.05) from 9.33±0.03% (FMa0) to 16.40±0.03% (FMa25) and from 9.07±0.03% (FMi0) to 15.41± 0.03% (FMi22.5), respectively, with the incorporation of *Imbrasia oyemensis* powder into the maize and millet formulations. In addition, lipids content increased significantly (p<0.05) with the incorporation of *Imbrasia oyemensis* powder in maize and millet formulations from 6.00±0.11% (FMa0) to 10.57±0.32% (FMa25) and from 7.59±0.24% (FMi0) to 11.08±0.20% (FMi22.5) respectively. Similarly, ash content increased from 1.99 ± 0.05% (FMa0) to 2.25 ± 0.06% (FMa25) and from 2.93 ± 0.14% (FMi0) to 3.20 ± 0.05% (FMi22, 5) with the incorporation of *Imbrasia oyemensis* powder in maize and millet-based formulations. In addition, energy value of formulations increased with incorporation of increasing levels of *Imbrasia oyemensis* powder. These values varied significantly (p<0.05) from 396.93±0.44 kcal/100g (FMa0) to 483.63±5.71 kcal/100g (FMa25) and from 400.58±2.82 kcal/100g (FMi0) to 449.68±4.92 kcal/100g (FMi22.5) in maize and millet formulations respectively.

3.2. Phytochemical and vitamin C content of formulations

Table 2 Biochemical composition and energy values of composite flours based on maize and millet incorporated into caterpillar powder *Imbrasia oyemensis*

Flours	Dry matter (%)	Protein (%)	Carbohydrates Total (%)	Lipids (%)	Ash (%)	Fibers Crude (%)	Energy value (kcal/100g)
Corn based formulations							
FMa0	91.62±0.03[a]	9.33±0.03[a]	71.43±0.74[d]	6.00 ± 0.11[a]	1.99±0.05[a]	7.84±1.58[a]	396.93±0.44[a]
(FMa17.5)	90.37±0.21[a]	12.7±0.03[b]	63.06±0.31[b]	7.91±0.15[b]	2.07±0.05[a]	7.06±0.09[a]	426.28±2.86[a]
(FMa 20)	90.31±0.24[b]	13.5±0.03[c]	61.54±1.13[c]	7.69 ± 0.17[b]	2.17±0.05[a]	6.17±0.86[a]	423.15±1.34[a]
(FMa 22.5)	89.49±0.16[b]	14.4±0.03[c]	60.27±0.35[b]	7.94 ± 0.21[b]	2.51±0.18[b]	5.28±0.40[a]	451.53±17.79[a]
(FMa 25)	88.81±0.21[b]	16.4±0.03[d]	52.34±0.49[a]	10.57±0.32[c]	2.25±0.06[a]	4.67±0.49[a]	483.63±35.71[a]
Millet based formulations							
FMi0	92.66±0.05[a]	9.07±0.03[a]	73.3±0.32[e]	7.59 ± 0.24[a]	2.93±0.14[b]	7.24±0.4[bc]	400.58±2.82[a]
FMi 15	92.24±0.83[a]	11.97±0.03[b]	66.48±0.16[c]	7.65±0.49[b]	2.27±0.11[a]	6.73±1.56[a]	402.97±13.9[a]
(FMi 17.5)	91.24±0.02[a]	12.30±0.03[c]	64.7±0.29[d]	7.00±0.22[d]	2.86±0.19[b]	5.39±0.11[d]	408.80±22.64[a]
(FMi 20)	90.28±0.33[a]	14.08±0.03[d]	61.53±0.49[b]	9.19±0.23[c]	3.20±0.09[b]	5.21±0.63[d]	409.15±7.21[a]
(FMi 22.5)	89.75±0.02[a]	15.41±0.03[e]	56.58±0.87[a]	11.08±0.20[e]	3.20±0.05[b]	4.35±0.48[b]	449.68±34.92[a]

Means with different letters in same row are significantly different at 5% threshold according to Duncan's test depending on parameters studied; FMa0: simple corn flour = Mix of fermented corn (90%) and sprouted corn (10%). FMa 17.5: Mix of fermented corn (72.5%) and sprouted corn (10%) + Imbrasia oyemensis (17.5%). FMa 20: Mix of fermented corn (70%), sprouted corn (10%) and Imbrasia oyemensis (20%); FMa 22,5 : Mix of fermented corn (67.5%), sprouted corn (10%) and Imbrasia oyemensis (22.5%) FMa 25: Mix of fermented corn (65%) , sprouted corn (10%) and Imbrasia oyemensis (25%) FMi0: simple millet flour = Mix of fermented millet (90%) and sprouted millet (10%). FMi 15: Mix of fermented millet (75%), sprouted millet (10%) and Imbrasia oyemensis (15%). FMi 17.5: Mix of fermented millet (72.5%) , sprouted millet (10%) and Imbrasia oyemensis (17.5%) FMi 20: Mix of fermented millet (70%), sprouted millet (10%) and Imbrasia oyemensis (20%). FMi 22.5: Mix of fermented millet (67.5%), sprouted millet (10%) and Imbrasia oyemensis (22.5%).

Vitamin C and phytochemicals contents (total polyphenols, flavonoids, tannins, oxalates and phytates) showed a significant difference at 5% threshold (Table 3). Moreover, these contents decreased with the increasing level of *Imbrasia oyemensis* powder in composite flours based on corn and millet. Indeed, results showed that vitamin C contents varied significantly (p <0.05) from 9.85±0.88 mg/100g (FMa0) to 6.47±0.0 mg/100g (FMa25) and from 10.59±0.87 mg/ 100g (FMi0) to 6.22±0.0mg/100g (FMi22.5) respectively for maize and millet based formulations. In addition, total polyphenol contents ranged from 225.21±0.70 mg/ 100g (FMa0) to 160.19±2.80 mg/100g (FMa25) and 256.16±0.00 mg/100g (FMi0) to 189.35±0.70 mg/ 100g (FMi22, 5) for corn and millet formulations respectively. Flavonoid contents ranged from 25.64±0.15 mg/100g (FMa0) to 10.95±0.07 mg/100g (FMa25) and from 21.42±3.35 mg/100g (FMi0) to 12.52±0.07 mg/100g (FMi22.5) in maize and millet formulations respectively. In addition, tannin contents increased from 173.15±0.90 mg/100g (FMa0) to 109.45±0.68 mg/100g (FMa25) and from 225.54±0.90 mg/100g (FMi0) to 130.74±0.68 mg/100g (FMi22, 5) in maize and millet formulations respectively. Oxalate contents varied significantly (p<0.05) from 370.65±9.29 mg/100g (FMa0) to 215.81±1.67 mg/100g (FMa25) and from 367.58±14.33 mg/100g (FMi0) to 223.87±5.38 mg/ 100g (FMi22.5) in corn and millet formulations, respectively. Similarly, phytate contents ranged from 128.60±0.08 mg/100g (FMa0) to 97.24±0.08 mg/100g (FMa25) and from 123.15±0.08 mg/100g (FMi0) to 106.60 ± 0.17 mg/100g (FMi22.5).Flavonoid contents during incorporation with maize and millet varied significantly (p <0.05) from 25.64±0.15 (FMa0) to 10.95±0.07 (FMa25) and from 21.42±3.35 (FMi0) to 12.52±0.07 (FMi22.5) respectively (Table 4).

Table 3 Phenolic and vitamin C contents in maize and millet flours supplemented with *Imbrasia oyemensis* powder

Flours	Vitamin C	Total polyphenol	Flavonoids	Tannins	Oxalates	Phytates
Corn based formulations						
FMa0	9.85±0.88^{ab}	225.21±0.70^{a}	25.64 ± 0.15^{a}	173.15±0.90^{b}	370.65±9.29^{a}	128.60 ± 0.08^{d}
FMa17.5	8.60±0.88^{a}	219.40±2.80^{b}	18.58 ±0.07^{b}	152.95±0.68^{c}	327.67±8.31^{e}	113.03±0.25^{a}
FMa 20	7.36±0.88^{c}	202.24±0.00^{c}	16.13 ± 0.07^{c}	143.27±0.22^{c}	294.62±6.31^{b}	107.15 ± 0.25^{c}
FMa 22.5	7.07±0.87^{bc}	199.38±1.40^{b}	14.62 ± 0.00^{b}	120.00±0.22^{d}	250.90±6.43^{c}	102.03 ± 0.08^{e}
FMa 25	6.47±0.00^{abc}	160.19±2.80^{d}	10.95 ± 0/07^{e}	109.45±0.68^{a}	215.81±1.67^{d}	97.24 ± 0.08^{d}
Millet based formulations						
FMi0	10.59±0.87^{a}	256.16±0.00^{a}	21.42 ± 3.35^{ab}	225.54±0.90^{b}	367.58±14.33^{c}	123.15 ± 0.08^{b}
FMi 15	9.34±0.87^{a}	238.00±0.00^{c}	19.06 ± 0.23^{b}	194.21±0.22^{c}	352.23±3.65^{bc}	114.78 ± 0.17^{c}
FMi 17.5	8.76±0.87^{b}	219.57±0.70^{b}	18.16±0.00^{a}	184.43 ±0.00^{a}	339.75±10.97^{b}	110.15±0.25^{d}
FMi 20	8.20 ±0.88^{a}	210.28±2.10^{e}	13.91±0.23^{c}	144.66±0.45^{d}	297.00±9.35^{a}	112.00±0.34^{a}
FMi 22.5	6.22±0.00^{ab}	189.35±0.70^{d}	12.52±0.07^{b}	130.74±0.68^{b}	223.87±5.38^{bc}	106.60±0.17^{d}

Means with different letters in same row are significantly different at 5% threshold according to Duncan's test depending on parameters studied; FMa0: simple corn flour = Mix of fermented corn (90%) and sprouted corn (10%). FMa 17.5: Mix of fermented corn (72.5%) and sprouted corn (10%) + Imbrasia oyemensis (17.5%). FMa 20: Mix of fermented corn (70%), sprouted corn (10%) and Imbrasia oyemensis (20%); FMa 22,5 : Mix of fermented corn (67.5%), sprouted corn (10%) and Imbrasia oyemensis (22.5%) FMa 25: Mix of fermented corn (65%) , sprouted corn (10%) and Imbrasia oyemensis (25%) FMi0: simple millet flour = Mix of fermented millet (90%) and sprouted millet (10%). FMi 15: Mix of fermented millet (75%), sprouted millet (10%) and Imbrasia oyemensis (15%). FMi 17.5: Mix of fermented millet (72.5%) , sprouted millet (10%) and Imbrasia oyemensis (17.5%) FMi 20: Mix of fermented millet (70%), sprouted millet (10%) and Imbrasia oyemensis (20%). FMi 22.5: Mix of fermented millet (67.5%), sprouted millet (10%) and Imbrasia oyemensis (22.5%).

3.3. Sensory characteristics and acceptability of slurries based on composite maize and millet flours incorporated with caterpillar powder

Sensory analysis of slurries showed that panelists were attracted to the slurries from formulations enriched with *Imbrasia oyemensis* powder (Table 4). According to panelists, difference in color, texture and taste of porridges from maize-based formulations are noticeable from contents of incorporation of *Imbrasia oyemensis* powder of 17.5% (BFMa17.5), 22.5% (BFMa22.5) and 25% (BFMa25) respectively. With the exception of these descriptors, no difference was observed between the other descriptors, regardless of type of balls subjected to their evaluation.

Table 4 Sensory evaluation of slurries based on composite maize and millet flours incorporated into *Imbrasia oyemensis powder*

Descriptors	Color	Aroma	Texture	Taste	General acceptability
Slurries of corn based formulations					
BFMa0	6.90^{b} ± 0.79	6.35^{a}±0.71	6.30^{a} ±0.34	5.20^{a} ±0.70	6.15^{a} ±0.41
(BFMa17.5)	6.10^{ab} ±0.25	6.25^{a} ± 0.34	6.40^{a} ±0.30	5.45^{a} ±0.14	5.85^{a} ±0.33
BFMa20	5.25^{a}± 0.15	6.75^{a} ± 0.12	6.25^{a} ±0.19	5.75^{a} ±0.25	5.80^{a} ±0.31
(BFMa22.5)	5.84 ^{a}±0.23	6.85^{a} ± 0.17	5.15^{ab} ±0.16	5.90^{a} ±0.16	5.80^{a} ±0.42
(BFMa25)	5.20^{a} ±0.20	6.90^{a} ±0.23	5.05^{b} ±0.21	6.65^{b} ±0.18	5.75^{a} ±0.23
Slurries of millet based formulations					
BFMi0	5.85^{a}± 0.89	5.25^{a} ± 0.86	5.90^{a} ± 0.64	4.90^{a} ± 0.63	5.40^{a} ± 0.54
BFMi15	5.70^{a}± 0.78	5.85^{a} ± 0.65	5.60^{a} ± 0.37	5.10^{a} ± 0.60	5.20^{a} ± 0.76
(BFMi17.5)	5.60^{a}± 0.45	5.75^{a} ± 0.81	5.60^{a} ± 0.53	5.15^{a} ± 0.12	5.65^{a} ± 0.32
BFMi20	5.50^{a}± 0.91	5.55^{a} ± 0.72	5.45^{a} ± 0.43	5.25^{a} ± 0.53	5.55^{a} ± 0.54
(BFMi22.5)	5.60^{a} ± 0.36	5.75^{a} ± 0.93	5.45^{a} ± 0.51	5.32^{a} ± 0.21	5.60^{a} ± 0.34

Means with different letters in same row are significantly different at 5% threshold according to Duncan's test depending on the parameter studied.

BFMa0: simple corn flour = Mix of fermented corn (90%) and sprouted corn (10%) BFMa 17.5: Mix of fermented corn (72.5%), sprouted corn (10%) and Imbrasia oyemensis (17.5%) BFMa 20: Mix of fermented corn (70%), sprouted corn (10%) and Imbrasia oyemensis (20%) BFMa 22,5 : Mix of fermented corn (67.5%), sprouted corn (10%) and Imbrasia oyemensis (22.5%) BFMa 25: Mix of fermented corn (65%), sprouted corn (10%) and Imbrasia oyemensis (25%) ; BFMi0: simple millet flour = Mix of fermented millet (90%) + sprouted millet (10%). BFMi 15: fermented millet (75%), sprouted millet (10%) and Imbrasia oyemensis (15%). BFMi 17.5: fermented millet (72.5%), sprouted millet (10%) and Imbrasia oyemensis (17.5%) BFMi 20: fermented millet (70%), sprouted millet (10%) and Imbrasia oyemensis (20%). BFMi 22.5: Mix of fermented millet (67.5%), sprouted millet (10%) and Imbrasia oyemensis (22.5%).

4. Discussion

Dry matter content of formulations is an indicator of its nutritional value. Also, it provides information on moisture content of formulations [4]. Thus, these high dry matter contents showed that formulations based on composite flours of maize and millet incorporated or not with *Imbrasia oyemensis* powder had moisture contents below 10%. According to [25], moisture content of less than 10% is desirable in flours because it reduces microbial load and thus extends shelf life of formulated feed during storage [26].

Incorporation is a technique to improve nutritive and nutritional values of supplementary feeds [27,4] . Increase in protein, lipids and ash contents of flours formulated with incorporation of increasing contents of *Imbrasia oyemensis* powder could be explained by its high content of these nutrients compared to those of cereals [11, 4] . Indeed, *Imbrasia oyemensis* powder is an excellent source of protein (53.57-57.77%), lipids (19.43-23.79%) and minerals (2.17-2.61%) [11, 12]. Moreover, with exception of FMa0 and Fmi0 flours, formulations studied had protein contents in line with the range (1-21%) set by FAO for supplementary feeds [28]. Therefore, increasing lipids content of these formulations would provide child with enough energy and promote absorption of fat-soluble minerals and vitamins [29]. In addition, lipids contents are below the 8% recommended by [28] in complementary foods. Thus, lipid contents would be important to combat conditions such as anemia and rickets, and participate in some metabolic activities observed in children during diversification period [30].

Decrease in crude fibers content in formulations would be explained by its low presence in organisms of animal origin [9, 10]. However, [28] recommends low crude fibers content (≤ 5%) in infant food. Thus, FMa 22.5, FMa 25, FMi 17.5, FMi 20, and FMi 22.5 had levels consistent with this recommendation. Indeed, low contents of crude fibers would be a major asset for digestion and prevention of constipation in children [31] . On the other hand, lower carbohydrate contents of formulations enriched with *Imbrasia oyemensis* powder. This would be explained by the fact that *Imbrasia oyemensis* powder that is the source of fortification contains a low amount of carbohydrates [11, 12]. However, total carbohydrate contents of formulations are in line with content (68%) recommended by Codex [32].

Feeds energy are produced by proteins, lipids and carbohydrates [4]. Almost all formulations fortified with *Imbrasia oyemensis* powder record energy values in line with 400 Kcal/100g recommended by [32] in diversification diet of child. Indeed, due to small size of their stomach (30 to 40g/kg of body weight or 150 to 200 ml). Thus, [33] recommend that foods given to infants and children should be energy-dense because low-energy foods tend to limit total energy intake and the use of other nutrients. Therefore, these formulations enriched with *Imbrasia oyemensis* powder are a good source of energy for child.

Vitamin C is necessary for collagen formation, the main protein of connective tissue. It also helps prevent anemia by enhancing absorption of iron needed for red blood cell formation [34]. [35] recommended contents of 20 mg/100g in child's diet. However, values recorded at formulation content are far below this recommendation. Thus, consumption of vitamin C-rich fresh fruits and/or vegetables by child after a meal with formulated flours would be recommended to bridge carbohydrate gap [4] .

Phenolic compounds (total polyphenols, flavonoids and tannins) are excellent sources of antioxidant activity. In addition, they would provide better preservation of foodstuffs by preventing lipid oxidation [36]. Decrease of these compounds with incorporation of increasing contents of *Imbrasia oyemensis* powder would be due to their vegetable and not animal origin. However, total polyphenols values recorded at content of the formulations studied are higher than those obtained by [37] (50.55 to 115.62 mg/100 g DM) during formulation of soy-enriched yam-based infant flours. Thus, consumption of *Imbrasia oyemensis* powder fortified formulations would be a less expensive alternative in management of metabolic diseases in children.

Phytates and oxalates contents that may reduce the bioavailability of vitamins, proteins and minerals [4]. However, values recorded in formulations studied are below the tolerable limits of 4-5 g total oxalates/day and 250 to 500 mg/100 g respectively for oxalates and phytates in human food [38, 39]. On the other hand, oxalate contents of formulations are lower than [40] obtained in infant flours preparation based on cereals enriched with soybeans, egg yolks and crayfish, which were 780 mg/100g. Therefore, presence of these contents in formulations studied could not affect these foods qualities.

Organoleptic quality of slurries was also a factor to be taken into account in the valuation of the supplementary feeds. High acceptability of formulated flours would be due to the fact that the *Imbrasia oyemensis* powder would not have modified the taste, aroma and color of the formulations. Indeed, color of *Imbrasia oyemensis* powder is close to that of cereal flours. Moreover, high lipid content of formulations would justify their high acceptability. Indeed, lipids improve the taste, smell, and aroma of foods [41].

5. Conclusion

Flours formulated from cereals (maize or millet) enriched with *Imbrasia oyemensis* powder had a high protein, lipid and ash contents and a high energy value. Moreover, phytochemical composition study showed that formulated flours are an excellent source of polyphenols, flavonoids and tannins. Also, oxalates and phytates contents are below doses that could induce intoxication in infants. In addition, these formulations were considered very acceptable by panelists. Thus, flours consumption made from cereals (corn and millet) incorporated into *Imbrasia oyemensis* powder would be a good alternative in diet of weaning-age children and reduce use of synthetic antioxidants.

Compliance with ethical standards

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This work was carried out in collaboration among all authors. Author AO collected the data and wrote the first draft of the manuscript. Authors CKY and DK performed the manuscript writing. Author KWD designed the study, performed the statistical analysis and wrote the protocol. Author JBF managed the analyses of the study. Authors GSEE and DYN managed the literature searches and supervised the study. All authors read and approved the final manuscript

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