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Evaluation of the Nutritional Properties and Anti-Nutritional Factors of Weaning Flours Made from *Zea mays* (Poaceae) Seeds, *Citrullus lanatus* (Cucurbitaceae) Seeds, and *Moringa oleifera* (Moringaceae) Leaves

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Abstract

Introduction: Traditional complementary foods in Africa, which are based solely on cereals, are unable to meet the nutritional needs of infants during weaning. The use of protein-rich plant resources in combination with these cereals appears to be necessary. The objective of this study is to develop a high-quality nutritional weaning flour for infants from corn kernels, *Citrullus lanatus*, and *Moringa oleifera* leaves. **Methodology:** An MbCMo flour containing 75% raw yellow corn, 15% defatted *Citrullus lanatus*, 10% Moringa oleifera, an MfCMo flour containing 80% fermented yellow corn, 15% defatted *Citrullus lanatus*, and 5% *Moringa oleifera*, and MgCMo flour containing 75% germinated yellow corn, 15% defatted *Citrullus lanatus*, and 10% *Moringa oleifera*. A commercial industrial flour was used as a control. These three formulated feeds and the control were analyzed for their overall composition, mineral content, and antinutritional factors using standard methods. **Results:** Biochemical analyses of the three formulated feeds revealed water contents ranging from 2.5 to 5.4 g/100 gDM, lipids from 3.35 to 4.23 ± 0.01 g/100 gDM, proteins from 17.55 to 18.64 g/100 gDM, ash 2.38 to 3.38 g/100 gDM, fiber 1.54 to 3.13%, carbohydrates 70.63 to 75.17 g/100 gDM, and energy value 395.15 to 401.03 Kcal/100 gDM. These values are similar to the control and to the recommendations defined by the World Food Program. With regard to minerals, the formulations contained appreciable amounts, while antinutritional factors and mineral phytate molar ratios (Ca, Zn, Fe) were below critical levels. **Conclusion:** Overall, the formulated samples and the control sample comply with the standards defined by the WFP for infant nutrition.

Keywords

Weaning Flour, Corn, *Cirtullus lanatus* Squash Seeds, *Moringa oleifera*, Nutritional Quality

1. Introduction

Nutritional problems in children, particularly protein-energy malnutrition, generally arise during the weaning period. This malnutrition is partly due to the high cost of enriched, nutritious complementary foods available on the market in developing countries, making them inaccessible to low-income mothers [1]. On the other hand, the use of porridges made solely from cereals (corn) unfortunately does not meet the nutritional needs of children due to their low protein content, low energy density, and high volume [2]. Given this situation, the search for new local plant resources that can improve the poor nutritional quality of porridges appears to be essential. *Citrullus lanatus* squash seeds contain high levels of protein (29% - 40%) [3], as well as essential amino acids such as valine, lysine, and methionine, which are very important for children's nutrition [4]. The leaves of *Moringa oleifera* are rich in minerals and protein (25% and 39%) and also contain all ten essential amino acids and essential fatty acids [5]**.** A mixture of *Citrullus lanatus* and *Moringa oleifera* powder with a cereal (*Zea mays*) could be used to formulate a food of good nutritional quality for weaning children. It is in this context that this work is being carried out with a view to improving the safety and nutritional status of children by developing a high-quality nutritional weaning flour for infants from *Citrullus lanatus* seeds and *Moringa oleifera* leaves.

2. Materials and Methods

2.1. Plant Material

The plant material consists of yellow corn kernels (*Zea mays*) and *Citrullus lanatus* squash seeds purchased at the Adjamé market in the District of Abidjan, while the *Moringa oleifera* (Moringaceae) leaves were harvested at Félix Houphouët-Boigny University in Abidjan, Côte d'Ivoire.

2.2. Production of Raw, Sprouted, and Fermented Yellow Corn Flour

The corn kernels were sorted to remove stones, foreign materials, insects, and damaged kernels. The raw yellow corn kernels were washed with double-distilled water and dried in an oven at 60˚C for 20 hours before being ground and stored in a jar [6]. To obtain sprouted flour, the corn kernels were soaked in distilled water for 24 hours and spread out on a cloth for 3 days on a workbench. The sprouted grains were dried in an oven at 65˚C for 72 hours and left to cool in a desiccator for 30 minutes, then sorted again, degerminated, and finally ground using a blender [7]. As for the fermented flour, the corn kernels were soaked in distilled water at room temperature ( ) for 3 days. The kernels were then carefully washed, drained, wet-milled, sieved, and dried in an oven at 60˚C for 20 hours. The resulting flour was oven-dried and re-ground in a blender, sifted, and stored in a jar [8].

2.3. Production of *Moringa oleifera* Powder

The leaves were sorted, washed, and dried. The powder obtained was immediately packaged in a jar and left at room temperature [9].

2.4. Production of *Citrullus lanatus* Flour

The squash seeds were sorted to remove impurities. The defatted flour was obtained using the method described by Kouakou *et al*. [10].

2.5. Formulation of Compound Food Flours

The mixture of different ingredients (raw, sprouted, and fermented corn), *Citrullus lanatus* delipidated and *Moringa oleifera* was based on the complementary nature of each flour's composition in order to obtain a composite flour with a high protein and energy value close to that recommended by the WFD [11] and the industrial instant phosphate control flour (TMN), intended for children aged 6 months and older. Thus, a composite flour called MbCMo was formulated containing 75% raw yellow corn, 15% *Citrullus lanatus* delipidated, 10% Moringa oleifera, a composite flour MfCMo containing 80% fermented yellow corn, 15% defatted *Citrullus lanatus*, and 5% *Moringa oleifera*; and a composite flour called MgCMo containing 75% germinated yellow corn, 15% defatted *Citrullus lanatus*, and 10% *Moringa oleifera*. Table 1

Table 1. Diet formulations.

Ingredients	Diet		
	MbCMo	MgCMo	MfCMo
Corn crude %	75		
Sprouted corn %		75	
Fermented corn (%)			80
Squash %	15	15	15
Moringa oleifera %	10	10	5

MbCMo: dietfoodbased on raw corn, *Citrullus lanatus* delipidated, Moringa oleifera; MgCMo: dietfoodbased on germinated corn, *Citrullus lanatus* defatted; MfCMo: dietfoodbased on fermented corn, *Citrullus lanatus* defatted, Moringa oleifera.

2.6. Analysis of the Chemical Composition of Compound Flours

The titratable acidity, pH, protein, lipid, and fiber content of the compound flours were determined using the AOAC method [12]. The moisture and ash content of the compound flours were determined using the AOAC method [13]. The carbohydrate content and energy values were determined using the method recommended by the FAO [14].

2.7. Analysis of the Composition and Mineral Content of Weaning Flours

Potassium (K), calcium (Ca), sodium (Na), magnesium (Mg), phosphorus (P), iron (Fe), zinc (Zn), and copper (Cu) were measured by atomic absorption spectrophotometry according to the digestion method of Singleton *et al.* [15] using strong acids.

2.8. Determination of Secondary Metabolites in Weaning Flours

The analysis of secondary metabolites (polyphenols, flavonoids, and tannins) in formulated complementary foods was performed using the respective methods described by Singleton *et al.* [15], Meda *et al.* [16], and Bainbridge *et al.* [17].

2.9. Determination of Antinutritional Factors and Molar Ratios in Weaning Flours

Phytates were quantified using the method of Latta & Eskin [18] and oxalates using the AOAC method [19]. The phytate/iron (Phy/Fe) molar ratio and the phytate/zinc (Phy/Zn) molar ratio were calculated using the formula of Harland [20].

2.10. Statistical Analysis

The results were expressed as mean ± standard deviation and subjected to one-way analysis of variance (ANOVA 1) using R software version 4.4.3. Differences between means were assessed using Tukey's test. Differences were considered statistically significant when $P < 0.05$.

3. Results

3.1. Chemical Composition of Weaning Flours

Composite flours compared to the control have a lower pH ranging from 5.32 ± 0.01% for the MgCMo diet to 5.42% ± 0.27% for the MbCMo diet and higher acidity ranging from 1.2 meq/100g for MbCMo to 2 meq/100 g for MgCMo ($P \leq 0.05$). In terms of moisture content, the composite flours had a r content ranging from 2.5 ± 0.1 g/100 gDM (MgCMo) to 5.4 g/100 gDM (MbCMo). The lipid content of the control diet (4.45 ± 0.01 g/100 gDM) was higher ($P < 0.05$) compared to the MbCMo (4.23 ± 0.01g/100 gDM), MfCMo (3.35 ± 0.01 g/100 gDM) and MfCMo (3.85 ± 0.02 g/100 gDM) diets. In terms of protein content, they are all different from each other ($P < 0.05$). The protein content of the formulated flours varies between 17.55 ± 0.02 g/100 gDM for MfCMo and 18.64 ± 0.01 g/100 gDM for MbCMo. The processed flours MbCMo (3.38 ± 0.01 g/100 gDM) and MgCMo (3.01 ± 0.02 g/100 gDM) have a higher mineral content than the control (2.6 g/100 gDM) and MfCMo flour (2.38 ± 0.03 g/100 gDM). A different observation was made with regard to fiber content. The control flour had the highest content, at 3.3 ± 0.01 g/100 gDM. The fiber content of MbCMo, MfCMo, and MgCMo flours was 3.13 ± 0.01 g/100 gDM, 1.54 ± 0.02 g/100 gDM, and 2.26 ± 0.02 g/100 gDM, respectively ($P < 0.05$). The carbohydrate content of the composite flours and the control ranged from 70.63 ± 0.05 g/100 gDM to 75.17 ± 0.03 g/100 gDM ($P < 0.05$). MfCMo flour contained 75.17 ± 0.03 g/100 gDM, which was higher than the other feed flours. Finally, the energy value of the composite flours ranged from 395.15 ± 0.04 kcal/100 gDM to 401.03 ± 0.30 kcal/100 gDM. The MfCMo composite flour (401.03 ± 0.30 Kcal/100 gDM) has the highest value ($P < 0.05$). Compared to the control (404.05 ± 0.01kcal/100 gDM), the processed flours have lower energy contents ($P < 0.05$) (Table 2).

Table 2. Biochemical composition of compound flours.

Parameters	TMN	MbCMo	MfCMo	MgCMo
pH	6.09 ± 0.01^{a}	5.42 ± 0.27^{b}	5.33 ± 0.01^{b}	5.32 ± 0.01^{b}
Acidity (meq/100 g)	0.6 ± 0.00^{d}	1.2 ± 0.00^{c}	1.4 ± 0.00^{b}	2 ± 0.00^{a}
Moisture (g/100 gDM)	4.1 ± 0.3^{b}	5.4 ± 0.03^{a}	4.9 ± 0.3^{ab}	2.5 ± 0.1^{c}
Lipids (g/100 gDM)	4.45 ± 0.01^{a}	4.23 ± 0.01^{b}	3.35 ± 0.01^{d}	3.85 ± 0.02^{c}
Protein (g/100 gDM)	18.2 ± 0.03^{b}	18.64 ± 0.01^{a}	17.55 ± 0.01^{d}	17.74 ± 0.02^{c}
Ash (g/100 gDM)	2.6 ± 0.02^{c}	3.38 ± 0.01a	2.38 ± 0.03^{d}	3.01 ± 0.02^{b}
Fiber (g/100 gDM)	3.3 ± 0.01^{a}	3.13 ± 0.01^{b}	1.54 ± 0.02^{d}	2.26 ± 0.02^{c}
Total carbohydrates (g/100 gDM)	72.8 ± 0.01^{c}	70.63 ± 0.05^{d}	75.17 ± 0.03^{a}	73.14 ± 0.01^{b}
Energy values (kcal/100 gDM)	404.05 ± 0.01^{a}	395.15 ± 0.04^{d}	401.03 ± 0.30^{b}	398.17 ± 0.07^{c}

Each value is the mean ± standard deviation results obtained in triplicate. a, b,c ,d.means followed by different letters on the same lineare significantly different ($P < 0.05$).

3.2. Mineral Composition of Prepared Weaning Flours and the Control

The sodium content of the compound feeds ranged from 12 mg/100 g for the MbCMo diet to 33.1 mg/100 g for the MfCMo diet, which was lower than that of the control (161 mg/100 g) ($P < 0.05$). The magnesium content ranged from 388 mg/100 gDM to 442.8 mg/100 gDM. There were no significant differences ($P > 0.05$) between the test flours or between the test flours and the control. As for potassium, the MgCMo diet (675.2 mg/100 gDM) had a high level, followed by MbCMo (673.7 mg/100 gDM), which was higher than the control in this study, except for the MfCMo diet (589.98 mg/100 gDM) ($P < 0.05$). Next, the calcium value varies between 192.2 mg/100 gDM and 378.5 mg/100 g. The MfCMo diet recorded the lowest value (192.2 mg/100 g), while the highest value was observed in the MbCMo diet, with a content of 378.5 mg/100 g. However, the different calcium contents of the formulations are lower than the control (471 ± 0.04 mg/100 g) ($P < 0.05$). Unlike calcium, the iron content in the three formulations (MbCMo 9.7 ± 0.02 mg/100 g, MfCMo 9.59 ± 0.01 mg/100 g and MgCMo 10.61 ± 0.02 mg/100 g) was higher ($P < 0.05$) than that of the control diet (7.5 mg/100 g). The zinc (6.3 ± 0.01 mg/100 gDM) and copper (2.4 ± 0.01 mg/100 gDM) values of the control batch were higher ($P < 0.05$) than those of the other weaning feeds. The MbCMo test diet had the highest copper and zinc values (1.34 mg/100 g and 4.96 mg/100 g) compared to the other two test diets, and the MfCMo diet had the lowest zinc content (4.91 mg/100 g) (Table 3).

Table 3. Mineral content of compound flours and control.

Parameters (mg/100 gDM)	Diet			
	TMN	MbCMo	MfCMo	MgCMo
Sodium	162 ± 0.01[a]	12 ± 0.02[d]	33.1 ± 0.03[b]	30.6 ± 0.01[c]
Magnesium	401 ± 0.03[a]	442.8 ± 0.03[a]	405.2 ± 0.05[a]	388 ± 0.03[a]
Potassium	660 ± 0.02[c]	673.7 ± 0.01[b]	589.9 ± 0.02[d]	675.2 ± 0.02[a]
Calcium	471 ± 0.04[a]	378.5 ± 0.02[b]	192.2 ± 0.01[d]	349.8 ± 0.02[c]
Iron	7.5 ± 0.03[d]	9.7 ± 0.01[b]	9.59 ± 0.04[c]	10.61 ± 0.02[a]
Copper	2.4 ± 0.01[a]	1.34 ± 0.02[b]	1.31 ± 0.01[c]	1.25 ± 0.03[d]
Zinc	6.31 ± 0.01[a]	4.96 ± 0.01[b]	4.91 ± 0.05[c]	4.96 ± 0.02[b]

Each value is the mean ± standard deviation results obtained in triplicate. a, b, c ,d on the same line. Means followed by letter sdifferent (are significantly different (P) < 0.05).

3.3. Secondary Metabolite Composition of Weaning Flours and the Control

The MfCMo composite flour contains the highest levels of polyphenols (0.84 mg/100 gDM), flavonoids (0.64 ± 0.01 mg/100 gDM) and tannins (0.55 ± 0.01 mg/100 gDM). The flavonoid content of MbCMo meal (0.35 ± 0.02 mg/100 gDM) and MgCMo meal (0.28 ± 0.01 mg/100 gDM) is similar. Similarly, there was no significant difference between the tannin content of MbCMo flour (0.31 ± 0.01 mg/100 gDM) and that of the control (0.35 ± 0.01 mg/100 gDM) (Table 4).

3.4. Antinutritional Factor Composition of Weaning Flours and the Control

The antinutritional content and molar ratios of weaning flours and the control are shown in Table 5. The oxalate content of compound flours, ranging from 0.42 ± 0.01 for MbCMo to 1.14 ± 0.01 for MgCMo, is lower than that of the control (2.58 ± 0.01). Similarly, the oxalate content of the control (0.54 ± 0.01) is higher than the levels of the three compound feeds, ranging from 0.35 ± 0.02 for MgCMo to 0.43 ± 0.01 for MfCMo (P < 0.05). The molar ratio of the formulations differs between them and from the control (P < 0.05).

Table 4. Secondary metabolite composition of weaning flours and control.

Parameters	TMN	MbCMo	MgCMo	MfCMo
Polyphenols	0.76 ± 0.01^{b}	0.55 ± 0.01^{c}	0.36 ± 0.02^{d}	0.84 ± 0.01^{a}
Flavonoids	0.44 ± 0.02^{b}	0.35 ± 0.02^{c}	0.28 ± 0.01^{c}	0.64 ± 0.01^{a}
Tannins	0.35 ± 0.01^{b}	0.31 ± 0.01^{b}	0.26 ± 0.01^{c}	0.55 ± 0.01^{a}

Each value is the mean ± standard deviation results obtained in triplicate. a, b, c, d on the same line. Means followed by different letters (are significantly different (P) < 0.05).

Table 5. Antinutritional factors in weaning flours and the control.

Parameters	TMN	MbCMo	MgCMo	MfCMo
Oxalates	2.58 ± 0.01^{a}	0.42 ± 0.01^{d}	1.14 ± 0.01^{b}	0.64 ± 0.01^{c}
Phytates	0.54 ± 0.01^{a}	0.42 ± 0.02^{c}	0.35 ± 0.02^{d}	0.43 ± 0.01^{b}
Phytate/Iron	0.006 ± 0.01^{a}	0.004 ± 0.01^{b}	0.003 ± 0.01^{c}	0.004 ± 0.01^{b}
Phytate/Calcium	$6.95.10^{-5}$ ± 0.01^{b}	$6.66.10^{-5}$ ± 0.02^{c}	$6.09.10^{-5}$ ± 0.01^{d}	$1.35.10^{-4}$ ± 0.01^{a}
Phytate/Zinc	0.008 ± 0.02^{b}	0.008 ± 0.01^{a}	0.007 ± 0.01^{c}	0.008 ± 0.01^{b}

Each value is the mean ± standard deviation results obtained in triplicate. a, b, c ,d on the same line. Means followed by different letters (are significantly different (P) < 0.05).

The phytate/iron molar ratio ranges from 0.003 ± 0.01 for MgCMo to 0.004 ± 0.01 for MfCMo and MbCMo. The phytate/iron ratios of MbCMo and MfCMo flours show no significant difference and are higher than that of MgCMo but lower than the control (0.006 ± 0.01). Regarding the molar ratio of phytate to calcium, MfCMo flour has the highest content, $1.35.10^{-4}$ ± 0.01, which is higher (P < 0.05) than the MbCMo and MgCMo formulations and the control. In terms of the molar ratio of phytate to zinc, there is no significant difference between the control and MgCMo (P > 0.05), and both have higher values than the MgCMo diet (0.007 ± 0.01).

4. Discussion

The composite flours used all have an acidic pH (5.32 to 5.42) comparable to the pH value (5.49) reported by Sankhon *et al*. [21] in Guinea-Conakry and that obtained in Côte d'Ivoire between 6.23 and 6.31 by Sika *et al*. [22]. According to Soro *et al*. [23], any flour with an acidic pH is better protected from attacks by microorganisms.

The moisture content of the compound flours in this study remains below the 5% threshold recommended by the World Food Programme [11], except for the

MbCMo diet (5.4 g/100 Ms). However, it remains below the Egyptian standard, which states that the recommended water content for weaning foods should not exceed 7%. The low water content of complementary food flours would be beneficial for their preservation. According to D'Souza *et al*. [24], the preservation of food and food products depends on their water content, as this regulates the activity of microorganisms. The protein content of the MbCMo complementary food (18.64 g/100 gDM) was higher than that of the MfCMo (17.5 g/100 gDM) and MgCMo (17.74 g/100 gDM) flours. Based on the standards set by the Codex Alimentarius, the protein content of weaning foods should be between 14.52 g/100 g and 37.76 g/100 g to facilitate maximum amino acid supplementation in the diet and growth [25] [26]. The high protein content in these flours is due to both *Moringa oleifera* and *Citrullus lanatus* powder, which are known for their high protein content. The digestive tract of infants does not properly digest foods with high fiber content [26]. As a result, the composite flours used in this study have a fiber content of less than 5%, meeting the standards set for weaning foods [11].

The mineral content of a food corresponds to its ash content [27]. The various test diets developed and the control diet had values above 2%, as recommended by the WFD [11]. The carbohydrate content of the compound flours was within the recommended standards set by the Codex Alimentarius, between 60% and 75% [28], and also in line with the results obtained by Sika *et al*. [22], which were around (69.73% - 76.48%). This result reflects the high carbohydrate content of the diets, showing that they could be a source of energy for infants.

In addition, the lipid content of the processed flours (3.35% to 4.2%) complies with the requirement of less than 10% [26]. This low lipid content appears to be beneficial. It increases quality, as it promotes better preservation of the flours. These results are comparable to those of the different diets obtained in the work of Tiencheu *et al*. [25], which ranged from 3.15 to 4.49.

The energy content of the diets designed was higher than the results obtained by Ijarotimi [29] for various diets based on corn, defatted peanuts, and ginger, ranging from 371.49 kcal/100 g to 394.53 kcal/100 g. In addition, among the complementary flours produced, the energy value of the MfCMo diet complies with the recommended standard of 400 kcal/100 gDM [11], while the other two have values close to the recommended level.

Calcium, magnesium, and phosphorus contribute positively to bone and tooth formation and growth. The various magnesium contents found were higher than the values obtained in fermented and malted weaning porridges enriched with pumpkin seed flour (*Cucurbita pepo*) by Okoro *et al*. [26]. Although the calcium content of the diets was lower than the control, it was within the range recommended by the WFD [11], *i.e.*, 260 - 400 mg/100 g, except for the MfCMo formulation (192 mg/100 g). These values were compared with the research conducted by Okoro *et al*. [26] on instant multigrain weaning foods enriched with pumpkin seeds (*Cucurbita pepo*), which ranged from 195.93 to 199.50 mg/100 g. Iron deficiency can have a negative impact on the growth of newborns during the weaning phase [30]. The formulated complementary foods contain more iron than the control. Similarly, these iron values (9.59 to 10.61 mg/100 g) are higher than the iron values (0.3 to 5.8 mg/100 g) of weaning foods made from puffed corn, African carob, and bambara groundnuts by Ijarotimi & Keshinro [8]. The zinc content in the complementary foods developed by was lower than that of the control, but still within the range of 3 mg/100 g to 8.40 mg/100 g specified by the WFD [11].

The presence of phytochemicals in flours is beneficial for infants from a nutritional standpoint. According to Zhang *et al.* [31], a low intake of phytochemicals is desirable for controlling the onset of obesity and associated diseases. The antinutritional concentrations in these diets were comparatively lower than critical levels, as reported by Ijarotimi [29] (1.65 mg/100 g and 3.65 mg/100 g) to (9.48 mg/100 g and 31.31 mg/100 g) respectively for oxalate and phytate from three compounds of yellow corn (raw, sprouted, and fermented), defatted peanuts, and ginger, indicating good availability of minerals in these diets that can be absorbed into the bloodstream [26]. The molar ratios (phytate/iron; phytate/calcium; phytate/zinc) of the different diets developed were below the critical thresholds of 0.15, 0.24, and 15 [32], suggesting better bioavailability of iron, calcium, and zinc in the bloodstream for the benefit of infants.

This study was limited to the physicochemical characterization and evaluation of the antinutritional factors of the developed flours. However, the absence of microbiological analyses does not allow for full assurance of the safety of the formulated food products. In addition, no in vivo biological evaluation was performed to assess the bioavailability of nutrients and the nutritional efficacy of the composite flours. Finally, no sensory acceptability test was performed on the composite flours.

5. Conclusion

In summary, the composite flours developed have acceptable nutritional qualities that comply with the recommended standards for weaning foods. As a result, these formulations could potentially be used to prevent nutritional problems, especially protein-energy malnutrition in children during weaning. Nevertheless, in order to better promote these food products, further studies are needed to evaluate the microbiological quality of the composite flours, determine their nutritional efficacy in vivo, and assess their sensory acceptability.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Kafuti, G., Fundu, T. and Sindic, M. (2015) Amino Acid and Fatty Acid Composition of a Complementary Food Based on Local Food Resources: The Case of Vamine in DR Congo. *International Journal of Biological and Chemical Sciences*, **9**, 1624-1629. https://doi.org/10.4314/ijbcs.v9i3.41

[2] Stoecker, B.J., Abebe, Y., Hinds, M.J. and Gates, G.E. (2006) Nutritive Value and Sensory Acceptability of Corn- and Kocho- Based Foods Supplemented with Legumes for Infant Feeding in Southern Ethiopia. *African Journal of Food*, *Agriculture*, *Nutrition and Development*, **6**, 1684-5376. https://doi.org/10.4314/ajfand.v6i1.19172

[3] Loukou, A.L., Gnakri, D., Dje, Y., Ippre, A.V., Malice, M., Baudoin, J.P. and BI, I.A. (2007) Macronutrient Composition of Three Cucurbits Species Cultivated for Seed Consumption in Cote d'Ivoire. *African Journal of Biotechnology*, **6**, 29-533.

[4] Achu, M.B., Fokou, E., Tchiégang, C., Fotso, M., and Tchouanguep, F. M. (2005) Nutritive Value of Some Cucurbitaceae Oil Seeds from Different Regions in Cameroon. *African Journal of Biotechnology*, **4**, 1329-1334.

[5] Manzo, M.L., Halidou, D.M., Hallarou, M., Illo, A., Rabani, A., Donnen, P., and Dramaix, M. (2016) Composition of *Moringa oleifera* Dry Leaf Powder in Three Regions of Niger. *African Journal of Food*, *Agriculture Nutrition and Development*, **16**, 11436-11442.

[6] Mankambou, J.G., Fagbohoun, J.B., Ya, K.C., Blei, S.K., and Kouame, L.P. (2021) Evaluation of Minerals, Vitamins, and Functional Properties of Flours from Sprouted Yellow Corn Seeds (*Zea mays* L.) from Daloa (Ivory Coast). *International Journal of Food Science and Nutrition Engineering*, **11**, 35-42.

[7] Andre, G.D., Angele Kou, K.A.A., Albarin, G.G., Kouakou, B. and Dago, G. (2009) Rheological and Nutritional Characteristic of Weaning Mush Prepared from Mixed Flours of Taro [*Colocasia esculenta* (L) Schott], Pigeon Pea (*Cajanus cajan*) and Malted Maize (*Zea mays*). *Pakistan Journal of Nutrition*, **8**, 1032-1035. https://doi.org/10.3923/pjn.2009.1032.1035

[8] Ijarotimi, O.S. and Keshinro, O.O. (2012) Formulation and Nutritional Quality of Infant Formula Produced from Germinated Popcorn, Bambara Groundnut and African Locust Bean Flour. *Journal of Microbiology*, *Biotechnology and Food Sciences*, **1**, 1358-1388.

[9] Houndji, B., Ouetchehou, R., Londji, S., Eamouzou, K., Yehouenou, B. and Ahohuendo, C. (2013) Microbiological and Physicochemical Characterizations of *Moringa oleifera* (Lam.) Leaf Powder, a Traditional Leaf Vegetable in Benin. *International Journal of Biological and Chemical Sciences*, **7**, 75-85. https://doi.org/10.4314/ijbcs.v7i1.7

[10] Kouakou, E.K.V., Méité, A., Bouafou, K.G.M., Kouamé, K.G., and Kati, C.B. (2016) Nutritional Performance of Soybean/Corn and Pistachio/Rice Diets in the Rehabilitation of Undernourished Rats. *Asian Journal of Applied Science*, **4**, 2321-0893.

[11] World Food Program (2017) World Food Program (WFP) Strategic Plan for 2017-2021. Second Regular Session of the Executive Board, 52.

[12] AOAC (1990) Official Methods of Analysis of the Association of Analytical Chemists. 15th Edition, 684-1230.

[13] AOAC (1995) Official Methods of Analysis of the Association of Analytical Chemists. 16th Edition, 463-464.

[14] FAO (2002) Food Energy-Methods of Analysis and Conversion Factor. FAO Edition, 97 p.

[15] Singleton, V.L., Orthofer, R. and Lamuela-Raventós, R.M. (1999) Analysis of Total Phenols and Other Oxidation Substrates and Antioxidants by Means of Folin-Ciocalteu Reagent. In: *Methods in Enzymology*, Elsevier, 152-178. https://doi.org/10.1016/s0076-6879(99)99017-1

[16] Meda, A., Lamien, C.E., Romito, M., Millogo, J. and Nacoulma, O.G. (2005) Determination of the Total Phenolic, Flavonoid and Proline Contents in Burkina Fasan

Honey, as Well as Their Radical Scavenging Activity. *Food Chemistry*, **91**, 571-577. https://doi.org/10.1016/j.foodchem.2004.10.006

[17] Bainbridge, Z., Tomlins, K., Welling, K. and Westby, A. (1996) Analysis of Condensed Tannins Using Acidified Vanillin. *Journal of the Science of Food and Agriculture*, **29**, 77-79.

[18] Latta, M. and Eskin, M. (1980) A Simple and Rapid Colorimetric Method for Phytate Determination. *Journal of Agricultural and Food Chemistry*, **28**, 1313-1315. https://doi.org/10.1021/jf60232a049

[19] AOAC (1999) Official Methods of Analysis of the Association of Analytical Chemists. 15th Edition, Virginia, 217 p.

[20] Harland, B.F., Smikle-Williams, S. and Oberleas, D. (2004) High Performance Liquid Chromatography Analysis of Phytate (IP6) in Selected Foods. *Journal of Food Composition and Analysis*, **17**, 227-233. https://doi.org/10.1016/j.jfca.2003.08.005

[21] Sankhon, A., Loua, T., Balde M.A., Conde, S., Sylla M.M., Keita, S.O. and Kourouma K. (2024) Formulation of an Enriched Infant Flour Based on Milk and Local Ingredients in the Guinea-Conakry Region. *Sciences et Technique*, **47**, 1011-6028.

[22] Sika, A.E., Kadji, B.R.L., Dje, K.M., Kone, M.F.T., Dabonne, S. and Koffi-Nevry, A.R. (2019) Nutritional, Microbiological, and Organoleptic Quality of Flours Made from Corn (*Zea mays*) and Safou (*Dacryodes edulis*) Produced in Côte d'Ivoire. *International Journal of Biological and Chemical Sciences*, **13**, 325-337. https://doi.org/10.4314/ijbcs.v13i1.26

[23] Soro, S., Konan, G., Koffi, E., Elleingand, E. and N'guessan, D. (2013) Formulation of Infant Foods Based on Yam Flour Enriched with Soy. *African Journal of Food, Agriculture, Nutrition and Development*, **13**, 8313-8339. https://doi.org/10.18697/ajfand.60.12655

[24] D'Souza, A.A., Kumari, D. and Banerjee, R. (2017) Nanocomposite Biosensors for Point-of-Care—Evaluation of Food Quality and Safety. In: Grumezescu, A.M., Ed., *Nanobiosensors*, Elsevier, 629-676. https://doi.org/10.1016/b978-0-12-804301-1.00015-1

[25] Tiencheu, B., Aduni, U.A., Bertrand, T.F., Noel, T., Eurydice, F., Tiepma, N. and Hilaire, M. (2016) Formulation and Nutritional Evaluation of Instant Weaning Foods Processed from Maize (*Zea mays*), Pawpaw (*Carica papaya*), Red Beans (*Phaseolus vulgaris*) and Mackerel Fish Meal (*Scomber scombrus*). *American Journal of Food Science and Technology*, **4**, 149-159.

[26] Elechi, J.O.G., Smah, A.C., Sule, J.I., Rimamcwe, N., Eunice, A., Eno-Obong, S., *et al.* (2023) Healthy Food Design and Early Childhood Nutrition: Nutritional and Food Safety Assessment of Fermented and Malted Multi-Grains Instant Weaning Porridge Fortified with Defatted Pumpkin (*Cucurbita pepo*) Seed Flour. *European Food Science and Engineering*, **4**, 61-74. https://doi.org/10.55147/efse.1383047

[27] Ngaha Damndja, W., Ngangoum, E.S., Saidou, C. and Mohamadou, S. (2023) Formulation of Three Infant Foods from Plantain Flour Fortified with Sesame (*Sesamum indicum*), Soya Bean (Glycine Max) and Cashew Nut (*Anacardium occidentale* L.). *Food Chemistry Advances*, **3**, Article 100313. https://doi.org/10.1016/j.focha.2023.100313

[28] Marcel, M.R., Chacha, J.S. and Ofoedu, C.E. (2021) Nutritional Evaluation of Complementary Porridge Formulated from Orange-Fleshed Sweet Potato, Amaranth Grain, Pumpkin Seed, and Soybean Flours. *Food Science & Nutrition*, **10**, 536-553. https://doi.org/10.1002/fsn3.2675

[29] Ijarotimi, O.S. (2022) Nutritional Quality, Functional Property and Acceptability of

Maize (*Zea mays*) Based Complementary Foods Enriched with Defatted Groundnut (*Arachis hypogea* L.) and Ginger (Zinger Officinale Roscoe) Powder in Wistar Rats. *Food Production*, *Processing and Nutrition*, **4**, Article No. 13. https://doi.org/10.1186/s43014-022-00091-3

[30] Laryea, D., Wireko-Manu, F.D. and Oduro, I. (2018) Formulation and Characterization of Sweetpotato-Based Complementary Food. *Cogent Food & Agriculture*, **4**, Article 1517426. https://doi.org/10.1080/23311932.2018.1517426

[31] Zhang, G., Xu, Z., Gao, Y., Huang, X., Zou, Y. and Yang, T. (2015) Effects of Germination on the Nutritional Properties, Phenolic Profiles, and Antioxidant Activities of Buckwheat. *Journal of Food Science*, **80**, 1111-1119. https://doi.org/10.1111/1750-3841.12830

[32] Gémède, H.F. (2020) Nutritional and Anti-Nutritional Evaluation of Complementary Foods Based on Corn, Peas, and Four-Anchovies. *Food Science and Nutrition*, **8**, 2156-2164.