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ORIGINAL ARTICLE

Nutritional evaluation, oxidative indexes, and functional properties of Irish potatoes, eggs, and red kidney beans based complementary food

Donald Sévérin Dangang Bossi *, **Marc Bertrand Dandji Saah**, **Bilkissou Njapndounké**, **François Zambou Ngoufack**

University of Dschang, Faculty of Science/Department of Biochemistry, Research Unit of Biochemistry of Medicinal Plants, Food Science and Nutrition, BO. 67 FS UDs, Cameroon. E-mail: donald.dangang@univ-dschang.org / dandjisaah@yahoo.fr / njapndounkebilkissou123@yahoo.com / fzambou@yahoo.fr

ABSTRACT

Background: Protein-energy malnutrition (PEM) remains a serious public health concern in Cameroon. This disorder is frequent in childhood and is primarily caused by a deficiency in energy, protein, and micronutrients. **Aims:** This study aimed to develop novel complementary foods from suitable sources of proteins and minerals such as Irish potatoes (*Solanum tuberosum* L.), red kidney beans (*Phaseolus vulgaris* L.), and egg flours. **Material and Methods:** Different flours were prepared from local raw materials. Four blends (1 to 4) were formulated at different proportions and the nutritional composition, oxidative indexes, urease activity, and techno-functional properties of blends were assessed and compared to the Irish potato flour (control). **Results:** The protein (16.1 to 24.23 %) content was significantly ($p < 0.05$) higher in blends than in the control (10.88 %). Blend 3 (60 % Irish potato, 25% Egg yolk, 15 % Egg white) showed the highest total calorie value (396.69 Kcal/100 g). Magnesium (2084 to 2470 mg/100 g), and iron (10.9 to 14.7 mg/100 g) contents were higher in blends than in the control (2053 and 9.9 mg/100 g respectively). Vitamins C and β-carotene contents in blends were 9.99 – 13.03 and 0.94 – 2.34 mg/ 100 g respectively. The peroxide value ranged from 5.3 to 8.98 meq O_2 /Kg oil. Blend 3 showed the lowest urease activity (0.73 expressed as ΔpH). Concerning the techno-functional properties, the lowest bulk density (0.79 g/cm^3) was obtained in blend 3. Blends 3 and 4 showed the lowest water absorption capacity (2.35 and 2.25 mL/g) and swelling capacity with 5.86 and 5.16 mg/g respectively. **Conclusions:** From our investigation, blend 3 could be used as a base for complementary foods as this blend presents the most nutritive and present the best techno-functional characteristics.

Keywords: Blends, nutritional composition, peroxide value, urease activity, techno-functional properties.

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* **Corresponding author:** Donald Sévérin Dangang Bossi, Tel. (+237) 691 75 97 57. E-mail: donald.dangang@univ-dschang.org

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1 Introduction

According to the World Health Organization (WHO), complementary foods are any food or liquid other than breast milk [1]. During the first six months of human life, breastfeeding provides the ideal food for infants. However, the latter becomes insufficient to meet the nutritional need of the child as he/she grows. Thus, in orders to complete the energy, iron, and other essential nutrients gap, complementary foods are supplemented [2]. In developing countries, most complementary foods are based on local staple foods mainly produced from starch and cereals. Nonetheless, the use of cereals and starchy roots (particularly cassava), as unique ingredients furnish an unbalanced diet as it lacks some macro- and micronutrients to meet the infant's requirements [3]. This situation had led to several cases of malnutrition in children under 59 months, with Cameroon having global acute malnutrition (protein-energy malnutrition) prevalence of 15 % constituting a major public health issue [4]. Protein-energy malnutrition (PEM) is a frequent childhood disorder and is primarily caused by a deficiency of energy, protein, and micronutrients intake. PEM manifests as underweight (low body weight compared with healthy peers), stunting (poor linear growth), wasting (acute weight loss), or edematous malnutrition (kwashiorkor) [5].

Management of most forms of PEM can be carried out in the community setting by improving household food security, promoting appropriate complementary foods, and providing micronutrients [5]. The increasing awareness about the health benefits of natural dietary constituents has led to the development of a range of functional foods [6]. Several developing countries have encouraged families to use, as home-based complementary food, products that can be easily prepared, available, and affordable as a substitute for imported complementary foods aiming to prevent malnutrition in infants and young children [3].

Using local sources is a major goal of sustainable development. Plant and animal foods contain a wide variety of nutrients, some of which are only present in one or the other. For example, plant-based foods provide less complete protein because of lower digestibility and source-specific deficiencies in essential amino acids, compared with animal proteins [7]. Therefore, Irish potato (*Solanum tuberosum*), red kidney beans (*Phaseolus vulgaris*), egg yolk, and egg white can serve as rich and inexpensive sources of proteins and minerals for complementary foods formulation. Irish potato is one of the major staple crops in Cameroon. National production is estimated at around 544,192 tons [8]. Potatoes are an inexpensive source of energy and good-quality protein. In addition, the consumption of potato increased remarkably the dietary intake of vitamins, K, Mn, Cu, and the chemical score of amino acids varied from 54 to 71 [9]. Kidney bean (*Phaseolus vulgaris* L.) is classified third after groundnut and cowpea based on legume consumption in Cameroon [10]. This bean constitutes an excellent source of vegetable protein, carbohydrates, vitamins, dietary fibers, and minerals [11]. Eggs are relatively less expensive and potentially more affordable to low-resource households [12]. Egg protein possesses a biological value of 100 and considered the reference protein. Potatoes are with a relatively high biological value of 90 compared to other key plant sources of protein (e.g., soybean with a biological value of 84 and beans with a biological value of 73) [13]. Common processing techniques of complementary foods namely germination and cooking are used to transform these raw materials. Germination of legumes improves the digestibility and availability of certain nutrients and reducing the anti-nutritional factors. Cooking is a key process to make the food safe by destructing contaminating bacteria, and also to inactivate several heat-labile anti-nutritional factors present in various foods [14]. This study aimed at formulating a nutritious composite flour blend for complementary foods, from local sources commonly used in child nutrition.

2 Subjects and Methods

2.1 Materials and preparation of different flours

Irish potatoes (*Salanum tuberosum* L.), red kidney beans (*Phaseolus vulgaris* L.) and eggs were purchased from Dschang local market (West region-Cameroon). Flours were prepared according to the flow chart shown below (Figure 1).

Each flour was prepared from raw materials by sorting and washing. Red kidney beans were soaked in tap water (1: 3, w/v) at room temperature (≈ 23 °C) for 18 hours. The water was drained off and the grain allowed to sprout. During germination, the wet grains were covered with moist fine cloth and kept in a dark place at ≈ 23 °C for 48 hours. Germination degrades anti-nutritional factors and improves protein and starch digestibility. Beans were cooked, dried in a drying oven (Model No CH-9140A), pulped, crushed in a blender (Kenwood, type FDP 64), and sieved. Potatoes were cooked, peeled, sliced, dried, crushed, and sieved. Eggs were cooked; white egg and egg yolk were separated, sliced, dried, and sieved. The flour samples were kept in sealed plastics and stored until further use at 4 °C.

2.2 Flour blending ratio

A modified method proposed by Aande et al. [15] was used for the formulations. The Irish potato (P), red kidney bean (B), egg yolk (Ey), and egg white (Ew) flours were blended in the ratio as presented in Table 1.

Table 1. Food consumption pattern of the respondents (traditional sauce, meat/meat alternatives, nuts, and legumes)

Blends	Ingredient	Ratio (%)
Control	P	100
1	P-B	70:30
2	P-B-Ey	70:20:10
3	P-Ey-Ew	60:25:15
4	P-B-Ey-Ew	60:10:20:10

P: Irish potato, PB: Irish potato - Red kidney bean, PBEy: Irish potato - Red kidney bean - Egg yolk, PEyEw: Irish potato - Egg yolk - Egg white, PBEyEw: Irish potato - Red kidney bean - Egg yolk - Egg white.

2.3 Determination of proximate composition

Protein, fat, ash, moisture, carbohydrate, and fiber contents were determined using standard methods [16]. For the moisture content, an electric air-dried oven (Plus11 Sanyo Gallenkamp PLC, UK) at 103 °C was utilized to dry 5 g of each sample until a constant weight was obtained. Concerning crude protein, the Kjeldahl method was used and the total amount of crude protein was obtained by multiplying the total nitrogen content by 6.25. For the crude fat content, it was determined using the Soxhlet extraction technique (Gerhardt Soxhlet EV6 AII/16) with hexane as the extraction solvent. Concerning the ash content, 5 g of each sample was incinerated using a muffle furnace (Box-type, FNC-BX1200-16L) at 550 °C for 4 hours. Using the differential weighing of each sample before and after incineration, the ash content of the samples was evaluated. The total carbohydrate content was evaluated by subtracting the percentages of crude fiber, protein, fat, moisture, and ash from 100 and was expressed in percentage. The caloric value was determined using the Atwater's conversion factors of 4.05, 4.03, and 8.93 Kcal for protein, carbohydrate, and fat respectively.

determine the maximal absorbance using a spectrophotometer[18]. The maximum optical density was used to calculate the concentration of total carotenoids in the sample. The total carotenoids content was estimated using equation (1):

$$C = \frac{F \times DO\ max}{196 \times M} \ldots\ldots (1)$$

DO max: optical density for maximum absorption; F: dilution factor; M: samples' mass; C: concentration of total carotenoids.

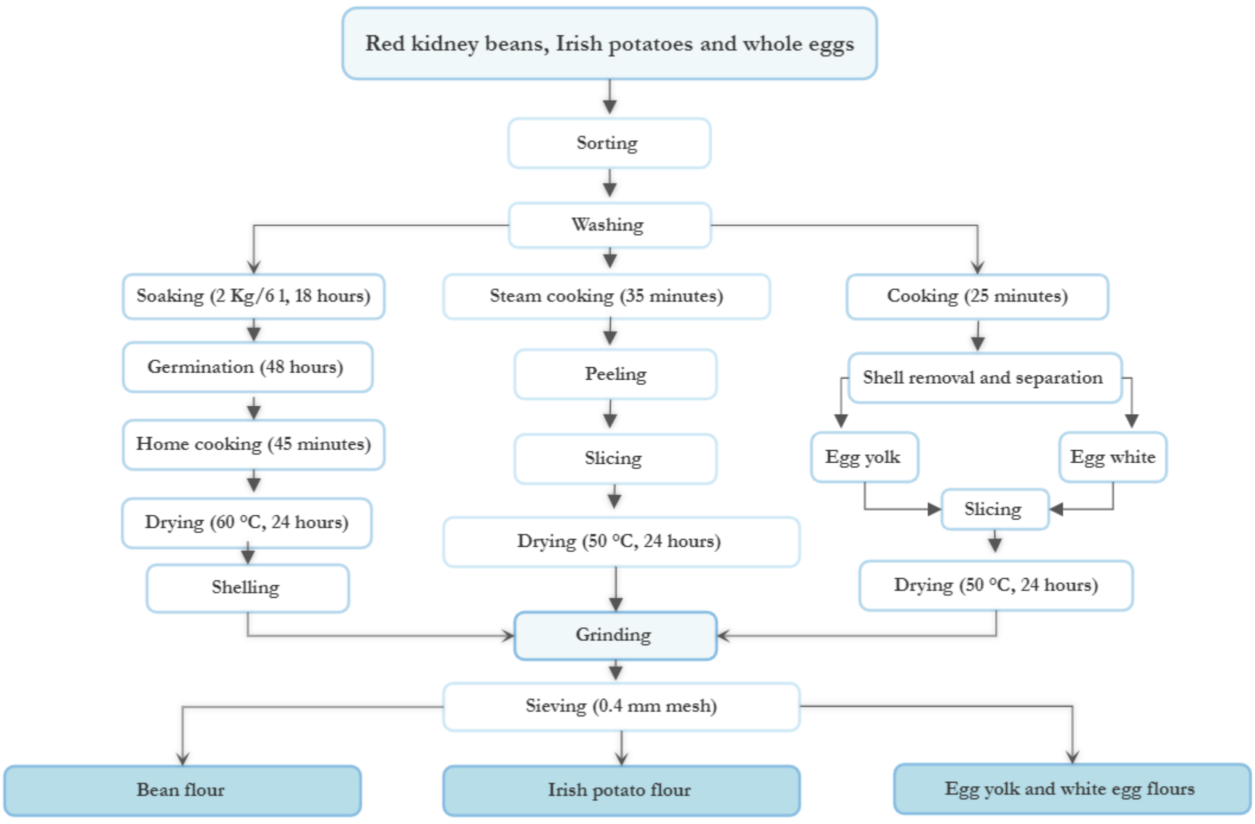

Figure 1. Flow chart for preparation of Bean flour, Irish potato flour, and Egg yolk and egg white flours

2.4 Determination of mineral elements, total carotenoids and vitamin C

Micronutrient contents such as potassium and sodium were assessed by flame spectrophotometry (Flame photometer DW-FP6431) while calcium, magnesium, and iron were analyzed using atomic absorption spectrophotometry [17].

A hexane-acetone mixture in a ratio of 30/70 (v/v) was used to extract the total carotenoids [18]. The optical density of the resulting solution was read between 430 and 450 nm to

The total carotenoids amount (m_{car}) in the diluted solution for the spectrophotometer was calculated based on the equation (2):

$$mcar = C \times V \ldots\ldots (2)$$

m_{car}: total carotenoids amount; C: concentration of total carotenoids; V: volume of the solution

For 100 g of dry matter with a water content (WC), the total carotenoid content TC was quantified by aquation (3):

$$TC = \frac{100 \text{ x mcar}}{100 - WC} \text{ X } 100 \ldots\ldots (3)$$

TC: total carotenoid content; mcar: total carotenoids amount; WC: water content

The vitamin C concentration was measured using a titrimetric assay with 2.6-dichlorophenolindophenol as an indicator [19]. 10 g of each powder was weighed and added to 20 mL of 95 % acetic acid for the extraction. The standard solution of vitamin C (0.01 mg/mL) was placed in a burette and progressively added drop by drop into a beaker containing 1 mL of 2.6-dichlorophenolindophenol until the solution turned pink. The reaction was continued until the content of the beaker became completely discolored. The volume of vitamin C that allowed the discoloration of the solution was noted, and the vitamin C content of the sample was estimated using equation (4):

$$\text{Vit C} = \frac{XV}{PV'} \ldots\ldots (4)$$

X: volume of vitamin C that allowed the discoloration of the solution; V: total volume of extract; V': volume of extract that allowed the discoloration of the solution; P: sample weight.

In relation to dry matter, vitamin C content was calculated using equation (5):

$$\text{Vit C} = \frac{XV/PV'}{100 - H0} \text{ x } 100 \left(\frac{mg}{100} g \text{ DM}\right) \ldots\ldots (5)$$

H0: water content; X: volume of vitamin C that allowed the discoloration of the solution; V: total volume of extract; V': volume of extract that allowed the discoloration of the solution; P: sample weight; DM: dry weight of the sample.

2.5 Determination of oxidative indexes

Peroxide value (PV)

The PV was measured according to the National Standard of China [20]. 1 g of oil sample was mixed with 30 mL chloroform-acetic acid (2:3; v/v). Saturated potassium iodide (0.5 mL) was added and the mixture was allowed to react for 3 min in dark. Thereafter, 50 mL of water and 0.5 mL of 1 % starch solution were added. Finally, the mixture was titrated with sodium thiosulfate solution (0.01 M) until the blue color disappeared. Results were expressed as in milli equivalent per Kg oil (meq/Kg oil).

Acid value (AV)

The AV was measured according to the National Standard of China [21]. 1 g of oil sample was added to ether-isopropyl alcohol (1:1, v/v) and the mixture was then titrated against KOH (0.1 M) using phenolphthalein solution (10 g/L) as an indicator, i.e., when the pink color of the phenolphthalein persisted for at least 30 s. AV was expressed as the milligrams of potassium hydroxide required to neutralize the free fatty acids (FFAs) present in 1 g of the oil sample (mg KOH/g oil).

Evaluation of urease activity

Urease activity was determined according to the AOCS official procedure [22]. 200 mg of blend samples were incubated in 10 mL of phosphate buffered urea solution (30 g of urea in 1 L of phosphate-buffered constituted of 4.45 g of Na_2 HPO_4 and 3.4 g of KH_2 PO_4) at 30 °C for 30 minutes, after which the increase in pH units (expressed as ΔpH) from pH 7.00 was recorded using a pH meter (Suntex TS-2).

2.6 Evaluation of techno-functional properties

The water absorption capacity, oil holding capacity, and bulk density was determined using the method of Huang et al. [23]. Foaming Capacity (FC) and foam stability (FS) were evaluated using the method described by Konak et al. [24]. Swelling capacity was determined according to the method described by Pranoto et al. [25].

2.7 Statistical analysis

Each test was carried out in triplicate. Data obtained were subjected to statistical analysis and the results were presented as mean ± standard deviations. One-way analysis of variance (ANOVA) with SPSS ver. 21.0 (SPSS Inc., Chicago, USA) was used. Comparison of the means and differences between the means were separated by Duncan multiple range test at 95 % (0.05) confidence.

3 Results

3.1 Proximate composition

In our study, changes in proximate composition of different blend formulations were observed and results (Table 2) showed a variation of moisture content of blends between 4.79 and 6.84 %. The values of blends 1, 2, and 3 were significantly ($p < 0.01$) lower than those of the control (6.46 %). Protein content varied from 14.1 to 24.23 %. These values were higher than in the control (10.88 %). The addition of egg white powder (blend 3 and 4) into potato flour induced an increase in protein content more important of bean flour (Blend 1). The fat content ranged between 0.83 and 13.02 %. The highest value of fat content was observed in blend 3 (13.02 %); the addition of egg yolk increased the fat content of this blend. The results also showed that ash content of blends ranged from 5.59 to 7.53 %. There was no

Table 2. Proximate composition of blend samples.

Parameters	Control	Blend 1	Blend 2	Blend 3	Blend 4
Moisture (%)	6.46 ± 0.03^{b}	4.79 ± 0.01^{d}	5.30 ± 0.10^{c}	5.47 ± 0.12^{c}	6.84 ± 0.05^{a}
Ash (%)	6.77 ± 0.04^{a}	5.59 ± 0.03^{b}	6.65 ± 0.31^{a}	6.89 ± 0.07^{a}	7.53 ± 1.39^{a}
Protein (%)	10.88 ± 0.02^{c}	14.10 ± 1.84^{b}	16.33 ± 1.84^{b}	21.03 ± 0.72^{a}	22.23 ± 3.67^{a}
Fat (%)	0.36 ± 0.01^{e}	0.83 ± 0.01^{d}	6.50 ± 0.01^{c}	13.02 ± 0.03^{a}	10.05 ± 0.01^{b}
Carbohydrates (%)	69.02 ± 0.93^{a}	66.58 ± 1.87^{a}	58.14 ± 1.62^{b}	48.45 ± 0.89^{c}	46.91 ± 2.96^{c}
Energy (Kcal/100g)	325.43 ± 0.62^{e}	332.83 ± 0.15^{d}	358.48 ± 0.78^{c}	396.69 ± 0.92^{a}	368.82 ± 2.89
Crude fiber (%)	6.51 ± 0.02^{c}	8.14 ± 0.01^{a}	7.08 ± 0.01^{b}	5.17 ± 0.01^{e}	6.44 ± 0.01^{d}

Values are expressed as means of duplicate samples ± standard deviation (n = 3). Values with same superscripts in the same line are statistically similar while values with different superscripts are different ($p < 0.05$). Control: Irish potato, Blend 1: Irish potato - Red kidney bean, Blend 2: Irish potato - Red kidney bean - Egg yolk, Blend 3: Irish potato - Egg yolk - Egg white, Blend 4: Irish potato - Red kidney bean - Egg yolk - Egg white, Irish potato - Egg yolk - Egg white, PBEyEw: Irish potato - Red kidney bean - Egg yolk - Egg white.

significant difference ($p > 0.05$) in the carbohydrate content of blend 1 and the control flour. The reduction of potato flour in blends 2, 3, and 4 has induced a decrease ($p < 0.05$) in carbohydrate content observed in these blends. The results also showed that the introduction of red kidney bean flour, egg yolk, and egg white resulted in a significant ($p < 0.05$) increase in the calorie values of blends 1 to 4 (332.83 - 396.69 Kcal/100g) compared to the control (325.43 Kcal/100g). Furthermore, the introduction of bean flour to the blends led to a slight increase in crude fiber content.

3.2 Micronutrients

Table 3 summarizes the mineral content, total carotenoids, and vitamin C of each blend. The variation in calcium content in the blends (120 – 126 mg/100 g) was higher than that of the control (100.7 mg/100 g). The potassium content of the blends (121 – 150 mg/100 g) increased significantly ($p < 0.05$), compared to that of the control (124.2 mg/100 g). Whereas sodium content (10 – 12.8 mg/100 g) was significantly lower ($p < 0.05$) than in the control (13.3 mg/100 g). The magnesium content ranged from 2084 to 2470 mg/100 g with the highest amounts obtained in blends 1 and 3. Iron levels (10.9 – 14.7 mg/100 g) in the blends were higher than in the control (9.9 mg/100 g). In general, the addition of bean and egg flour induced an increase in mineral content.

The carotenoid content of the blends ranged from 0.94 to 2.34 mg/100 g. The presence of egg yolk in blend 3 led to the highest carotenoid content. The addition of bean and egg flours has conducted in a decrease in vitamin C content of blends. The vitamin C content of blends (9.99 – 13.03 mg/100 g) was significantly ($p < 0.05$) lower compared to the control (13.76 mg/100 g).

3.3 Oxidative indexes and urease activity of blends

The peroxide value increased significantly ($p < 0.05$) in blends 1 and 2 compared to blends 3, 4, and control (Table 4). This parameter ranged from 5.3 to 8.98 meq O_2/Kg oil in formulated blends. The acid value was also significantly higher ($p < 0.05$) in blends 1 and 2 compared to blends 3, 4, and control. There was a significant difference ($p < 0.05$) in urease

Table 3. Mineral and vitamin contents (mg/100 g dry basis) of blend samples

Minerals and vitamins (mg/100g)	Control	Blend 1	Blend 2	Blend 3	Blend 4
Ca	100.70 ± 0.50^{d}	114 ± 0.20^{c}	126 ± 0.60^{a}	120.50 ± 0.80^{b}	120 ± 0.40^{b}
Mg	2053 ± 1.20^{e}	2470 ± 0.20^{a}	2152 ± 0.40^{c}	2400 ± 0.50^{b}	2084 ± 0.10^{d}
K	124.20 ± 0.80^{d}	150 ± 0.00^{a}	121 ± 0.30^{e}	126 ± 0.70^{c}	128 ± 0.20^{b}
Na	13.30 ± 0.07^{a}	10.00 ± 0.10^{c}	10.00 ± 0.40^{c}	12.00 ± 0.90^{b}	12.80 ± 0.00^{b}
Fe	9.90 ± 0.41^{e}	12.02 ± 0.35^{d}	12.02 ± 0.12^{c}	13.32 ± 0.12^{b}	14.70 ± 0.25^{a}
Total carotenoids	1.50± 0.05	0.94 ± 0.04^{d}	1.10 ± 0.01^{c}	2.34 ± 0.01^{a}	1.52 ± 0.03^{b}
Vitamin C	13.76 ± 0.9^{a}	13.03 ± 1.80^{a}	12.87 ± 0.02^{ab}	9.99 ± 0.41^{c}	11.77 ± 1.13^{b}

Values are expressed as means of duplicate samples ± standard deviation (n = 3). Values with same superscripts in the same line are statistically similar while values with different superscripts are different ($p < 0.05$). Control: Irish potato, Blend 1: Irish potato - Red kidney bean, Blend 2: Irish potato - Red kidney bean - Egg yolk, Blend 3: Irish potato - Egg yolk - Egg white, Blend 4: Irish potato - Red kidney bean - Egg yolk - Egg white.

activity between blends 2, 3, and 4 (0.83 ± 0.05, 0.73 ± 0.09, 0.79 ± 0.04, respectively) and blend 1 and control (0.94 ± 0.04, 0.00 ± 0.00) (Table 4). The addition of bean flour increased the urease activity of blends.

3.4 Techno-functional properties

The bulk densities ranged from 0.79 ± 0.00 to 0.96 ± 0.00 g/cm^3 in the blend flours and 0.95 g/cm^3 in the control (Table 5). The lowest bulk density value was observed in blend 3. The WAC of different blends ranged between 2.25 and 2.50 mL/g. The higher value of WAC was observed in blends 1 (2.50 mL/g) and 2 (2.4 mL/g). There was a significant decrease ($p < 0.05$) in the OAC in blends 1, 2, and 4 (0.75, 0.70, 0.80 mL/g) compared to blend 3 and control (0.90 mL/g). Among the blends, blend 1 had the highest SP (7.31 mg/g), followed by blend 2 (6.20 mg/g). The foaming capacity of blends 2, 3, and 4 (4, 3.5, and 3.9 %, respectively) was significantly ($p < 0.05$) lower than the control (6.00 %). Blend 1 had shown the highest foaming capacity (5 %) compared to others. The highest foam stability was observed in blends 1, 2, and control (2.88, 2.88, and 2.83 %, respectively), and lowest in blends 3 and 4 (1.48 and 1.47 %, respectively). The foam was more stable in blends 3 and 4. From these results, it was observed that the value of the techno-functional properties studied had decreased with the addition of bean flour, egg yolk and egg white flours.

Table 4. Variations of the oxidative indexes and urease activity of blend samples

Parameters	Control	Blend 1	Blend 2	Blend 3	Blend 4
Peroxyde Value (meq O_2 /Kg oil)	4.20 ± 0.04^d	8.98 ± 0.71^a	8.11 ± 0.08^b	6.53 ± 1.04^c	5.30 ± 1.10^c
Acid Value (mg KOH/g oil)	4.08 ± 0.37^d	8.60 ± 0.83^a	7.30 ± 0.60^{ab}	6.72 ±0.82^b	6.09 ± 0.23^{bc}
Urease activity (expressed as ΔpH)	0.00 ± 0.00^c	0.94 ± 0.04^a	0.83 ± 0.05^b	0.73 ± 0.09^b	0.79 ± 0.04^b

Values are expressed as means of duplicate samples ± standard deviation (n = 3). Values with same superscripts in the same line are statistically similar while values with different superscripts are different ($p < 0.05$). Control: Irish potato, Blend 1: Irish potato - Red kidney bean, Blend 2: Irish potato - Red kidney bean - Egg yolk, Blend 3: Irish potato - Egg yolk - Egg white, Blend 4: Irish potato - Red kidney bean - Egg yolk - Egg white.

Table 5. Techno-functional properties of blend samples

Parameters	Control	Blend 1	Blend 2	Blend 3	Blend 4
Density (g/cm^3)	0.95 ± 0.01^a	0.96 ± 0.00^a	0.88 ± 0.01^b	0.79 ± 0.00^d	0.82 ± 0.01^c
Water Absorption Capacity (ml/g)	3.05 ± 0.05^a	2.50 ± 0.00^b	2.40 ± 0.00^c	2.35 ± 0.05^c	2.25 ± 0.05^{cd}
Oil Absorption Capacity (ml/g)	0.90 ± 0.10^a	0.75 ± 0.05^b	0.70 ± 0.10^b	0.90 ± 0.1^a	0.80 ± 0.00^b
Swelling power (mg/g)	7.86 ± 0.05^a	7.31 ±0.26^b	6.20 ± 0.99^{bc}	5.86 ±0.02^c	5.16 ± 0.48^d
Foam capacity (%)	6.00 ± 0.00^a	5.00 ± 1.00^b	4.00 ± 0.00^{bc}	3.50 ± 0.50^c	3.90 ± 0.10^c
Foam stability (%)	3.70 ± 0.00^a	2.88 ± 0.96^b	2.88 ± 0.00^b	1.48 ± 0.48^c	1.47 ± 0.49^c

Values are expressed as means of duplicate samples ± standard deviation (n = 3). Values with same superscripts in the same line are statistically similar while values with different superscripts are different ($p < 0.05$). Control: Irish potato, Blend 1: Irish potato - Red kidney bean, Blend 2: Irish potato - Red kidney bean - Egg yolk, Blend 3: Irish potato - Egg yolk - Egg white, Blend 4: Irish potato - Red kidney bean - Egg yolk - Egg white.

4 Discussion

4.1 Proximate composition

Moisture content is one of the important parameters which influences the shelf life or storage stability of flour. Flours having higher moisture content (14%) are prone to mold growth and infestation by insects [26]. The moisture range obtained was higher than the WHO/FAO recommended value (≤ 5 %) for complementary foods [27]. The high-water content in the formulated blends would be due to the proportion of Irish potato flour which was the main element of our formulas. In fact, the Irish potato was reported to contain about 80 % water. Hence the drying time (24 hours) and temperature (50 °C) may have influenced the flour quality. Interestingly, these results were lower than those reported by Ngume et al. [28] (8.9 g/100 g) on Irish potato mixed with bird meat based complementary food for children (6-23 months) in Tanzania.

The increase in protein may be due to the raw materials used in the formulations such as eggs and beans, which are known as potent sources of protein; egg powders had protein content in the range of 91.13 – 97.03 g/100 g powder [29] and bean flour 23.11 to 27.96 g/100 g [30]. It can also be explained by the techniques used during the preparation of different flours such as cooking. In fact, heat may have released some proteins that were attached to other molecules by breaking the low-energy bond and making them more available [31]. In addition, the germination of beans may have degraded proteins to simple peptides, thus increasing the crude protein [32]. Indeed, protein is the main ingredient on which flour specification and the quality of the product depend. It is important, both in quantity and quality, for the rapid growth and development of a child. The protein content of blends 3 and 4 was significantly ($p < 0.05$) higher as compared to the other blends. In fact, the incorporation of egg powder has led to the highest protein content. The protein content obtained in this study was higher compared to the values of 9.85 – 12.74 % reported by Ukom et al. [33] in complementary made from maize ogi porridge enriched with orange-fleshed sweet potato and African yam bean seed flours. However, it was closer to those obtained (12.576 – 20.97 %) by Aande et al. [15] on Nigerian foods, formulated from pearl millet (*Pennisetum glaucum* (L) R. Br.), potatoes (*Solanum tuberosum* L.) and sesame (*Sesamum indicum* L.) seeds.

Fats are the most concentrated source of energy for infants and young children. The higher level in blend 3 could be due to the higher proportion of egg yolk present in this formulation. In fact, egg yolk is highly rich in fatty acids. Appreciable amounts of fat in this food may have increased the total energy and could be a source of essential fatty acids such as omega-3 which is around 162.33 mg/50 g egg required for the proper development and functioning of the brain and retina; they are the components of myelin sheath of the peripheral nerves, synaptic membrane, and neurotransmitters [26]. With the exception of blend 1, the lipid content of formulated blends was higher compared to those reported by Ukom et al. [33] which were between 3.33 and 3.67 % obtained in maize ogi porridge enriched complementary foods.

Carbohydrates are the major constituent of many complementary foods for older, infants, and young children. The decrease observed in blend 1 may be due to the germination of bean which slightly decreased the total carbohydrate contents; in blends 2, 3, and 4 it may be due to the addition of egg flour to these blends, which has increased the protein content and decreased the carbohydrate one. The carbohydrate levels obtained in these three blends (46.91 to 58.14 %) were lower compared to the WHO/FAO recommendations [27] for complementary foods (≥ 65 g/100 g).

The higher calorie value obtained in blends may be due to the addition of beans and egg in favor of the increase in crude protein and fats and the decrease in crude fiber. These results are identical to those reported by Ukom et al. [33] on maize ogi porridge enriched where the energies ranged from 367.39 to 377.11 Kcal/100g.

However, the crude fiber values of blends were higher than the recommended crude fiber content in complementary food (< 5%) [27]. This may be due to the high fiber content in Irish potatoes. It is known that excess fiber can add the bulk density of food, dilute energy density and potentially interfere with the absorption of essential nutrients.

4.2 Micronutrients

Calcium is an important constituent of bones and teeth; it is responsible for the growth and is actively involved in the regulation of nerve and muscle functions [34]. Potassium is the essential intercellular cation and together with sodium, it plays important role in the regulation of water and electrolyte balance as well as acid-base balance in the body [35]. Diets containing foods rich in potassium and low in sodium may reduce the risk of high blood pressure and stroke [36]. Magnesium plays an essential role in storage, transference, and utilization of energy due to the formation of Mg-ATP, which is a substrate involved in a broad variety of enzymes (e.g., phosphatases and phosphokinases) [14]. The higher iron content in blends may be due to the fact that beans and eggs are good sources of iron, and also due to the germination and cooking of the beans. Indeed, Luo et al. [14] showed that the germination of Vigna radiate increased iron bioavailability. These values were higher than those reported in sweet potato-based complementary food by Adetola et al. [37] which were 8 to 10 mg/100 g. Iron plays an important role for the synthesis of neurotransmitters and myelination and is essential for oxygenation, modulation of cerebral development and to produce energy in the cerebral parenchyma (functional tissue in the brain [38]. Severe iron deficiency during childhood induces cognitive deficits that can persist after 10 years of treatment with iron [38]. In general, it was observed that the addition of bean flour increased the magnesium and potassium content of blends. This may be due to the effect of germination process which improves the bioavailability of minerals [32].

The carotenoid content obtained in the study was lower than those reported by Kassegn et al. [32] in the weaning food flours ofroasted barley, germinated faba bean (*Vicia faba* L.), and carrot powder which ranged from 2.42 to 7.15 mg/100 g. The low vitamin C content in blends may be due to the low vitamin C content of the raw materials used. However, the vitamin C content was higher than those of Bassey et al. [39] (1.54 mg/100 g) reported in complementary food mix formulated from cooked banana, cowpea, and groundnuts.

4.3 Oxidative indexes and urease activity of blends

The PV can be used as an oxidative index for the early stages of lipid oxidation, and higher oxidative stability is usually accompanied by a gradual increase in PV [40]. This parameter was within the standard range (10 meq O_2/Kg) as specified by AFNOR [41]. The AV is an important index to evaluate the quality of oil since it measures the content of free fatty acids formed after the hydrolytic degradation of lipid molecules, and can be used to indicate the degree of rancidity in oil hydrolysis [42]. The increase in the peroxide and acid values may be due to the higher moisture content and the effect of temperature during the flour processing. These findings are similar to those reported by Moustiés et al. [43] on Ready-to-Use Theurapeutic Foods (RUTF) where the peroxide values were < 10 meq O2/Kg lipids.

Urease activity is defined as the micromoles of ammonia released per minute by 1 mL (if liquid extract) or 1 g (if powder in solution) of urease enzyme (i.e., U/ml or U/g). Concerning the blends, the increase in urease activity in blend 1 may be due to the high percentage of beans in that blend. Indeed, raw bean contains in a dry state a urease, but processing of the raw beans such as soaking, germination, and heating treatments reduce this anti-nutrient.

4.4 Techno-functional properties

Bulk density in flour has both nutritional and economic importance in the formulation of infant meals. High nutrient density to low bulk is desired to prepare food with less thickness [33]. Low bulk density would be beneficial in infant food formulation since a small quantity will be required to obtain desired bulkiness. But their ability to limit the calories and nutrient density of food can have a negative effect on the child's growth rate [44]. On the other hand, flours with higher bulk density are more advantageous as they ease the dispersibility of these flours. The higher value of WAC in blend 1 (2.50 mL/g) and 2 (2.4 ml/g) could be due to their high carbohydrate content. The increase in the WAC has been always associated with an increase in amylose leaching and solubility and loss of starch crystalline structure. The flour with high water absorption may have more hydrophilic constituents such as polysaccharides [45]. The WAC of blends was significantly lower than the control (3.05 mL/g). In fact, lower water absorption is desirable for making thinner gruels with high caloric density per unit volume. The higher OAC observed in blend 3 may be due to the nature of protein chains present in this food. In fact, OAC may be the result of the physical entrapment of oil and the binding of fat to the polar chains of proteins [2]. Food with high OAC acts as a flavor retainer and enhances the mouth feel and taste of foods [46]. Therefore, in the current study blends 3 could be potentially used as a complementary food.

The highest SP found in blends 1 and 2 is probably due to higher carbohydrate content. The increase will impact the body, thickening and increase food viscosity. The lowest values were obtained with blends 3 and 4. An appropriate complementary diet produces a gruel or porridge that is neither too thick for the infant to consume nor so thin that energy and nutrient density are reduced [47].

Foam is colloidal of many gas bubbles trapped in a liquid or solid. Proteins in flour are surface active: soluble protein can reduce the surface tension thus the coalescence of the bubbles is obstructed. In foam, small air bubbles are surrounded by thin liquid films [48]. The highest foam capacity of blend 1 may be due to its low-fat content and the nature of amino acid residues on the surface of the protein. The study revealed that flours with high foam capacity could form large bubbles which might be easier to collapse and lowered the foam stability [49]. The addition of bean, egg yolk, and egg white flours has led to a decrease in bulk density and swelling power which are useful in the formulation of complementary foods.

5 Conclusions

The purpose of the present study was to formulate a nutritious composite flour blend for complementary foods, from local sources usually integrated in child nutrition, some observations have been raised: The addition of bean and egg flours resulted in a decrease in carbohydrate content and an increase in protein and mineral contents which could be useful to fight against protein-energy malnutrition in children. The presence of an average total carotenoid range of these blends could promote growth, boost the immune system and protect against vision damage in children. The peroxide value was within the standard (10 meq O_2/Kg) specified by AFNOR. Blend 3 presented the highest total energy with the lowest bulk density, lowest crude fiber, and highest oil absorption capacity, which can enhance the mouth feel and taste. This blend also possesses good water absorption capacity and low swelling power. Subject to analysis of the amino acid composition, sensory and microbiology analyzes, blend 3 could be a potential formulation for complementary foods.

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