

# Enhancing the Nutritional Value of Weaning Foods: Formulation of a Roasted-Corn Flour Enriched with Egg Powder

Mamy Eklou<sup>1\*</sup>, Komlan Tekando<sup>2</sup>, Gott'liebe Mawuena Goka<sup>1</sup>,  
Simplice Damintoti Karou<sup>1</sup>, Elolo Osseyi<sup>3</sup>, Kokou Tona<sup>2</sup>

<sup>1</sup>Laboratory of Microbiology and Quality Control of Foodstuffs (LAMICODA), University of Lome, Lome, Togo

<sup>2</sup>Regional Center of Excellence in Avian Sciences (CERSA), University of Lome, Lome, Togo

<sup>3</sup>Higher School of Biological and Food Technology (ESTBA), University of Lome, Lome, Togo

\*Corresponding author: [eklouenyae@gmail.com](mailto:eklouenyae@gmail.com)

Received December 18, 2025; Revised January 20, 2026; Accepted January 27, 2026

**Abstract** The inclusion of eggs in the diets of non-exclusively breastfed children can improve nutritional quality during the weaning period. However, the egg's high moisture content and the usual method of incorporating it into infant food pose significant risks of food poisoning. This study aimed to formulate an enriched complementary infant flour based on roasted corn flour and egg powder incorporated at 10%, 15%, 20%, 25%, and 30%. Physicochemical analysis were completed in reference to AFNOR standards: NFV03-707, NFV03-760, NF EN ISO 3188-1994. Microbiological analysis were conducted in reference to AFNOR (XP V 059, NF V08-057-1 and -2, NF V08-060), ISO 4833 and ISO 6579/A1 norms. Results showed a progressive increase in protein (10.72–25.84 g/100 g DM), lipid (2.61–24.04 g/100 g DM), and energy contents (389.62–491.31 kcal/100 g DM) with increasing egg powder incorporation. These macronutrient levels correspond to World Health Organization (WHO) recommendations for complementary foods for children aged 6–23 months, particularly for energy density and protein adequacy. Among the formulations, the 20% egg powder flour (FTO 20) showed the most balanced mineral profile relative to WHO criteria. The results of microbiological analyses comparing control flour and flours treated with egg powder show that germ concentration quantities are below the poisoning levels. *Salmonella* sp was not present in the corn flour mixed with egg powder (25g). In this mixed food powder, compared to respective control values of 103CFU/g, 105CFU/g and 102 CFU/g, the concentration proportions of yeast and mold, total aerobic mesophilic flora, and *Staphylococcus aureus* were less than 100 CFU/g. Thermotolerant coliforms are less than 10 CFU/g (the control value). Further research is recommended to assess micronutrient fortification, shelf stability, and digestibility for full WHO compliance.

**Keywords:** infant flour, egg powder, corn, nutrition, processing

**Cite This Article:** Mamy Eklou, Komlan Tekando, Gott'liebe Mawuena Goka, Simplicite Damintoti Karou, Elolo Osseyi, and Kokou Tona, "Enhancing the Nutritional Value of Weaning Foods: Formulation of a Roasted-Corn Flour Enriched with Egg Powder." *American Journal of Food and Nutrition*, vol. 14, no. 1 (2026): 38-46. doi: 10.12691/ajfn-14-1-5.

## 1. Introduction

The nutritional needs of children from birth to 6 months of age are all covered by breast milk [1]. Beyond this age, breast milk is no longer sufficient to fully cover energy and protein requirements. During this period, new food in liquid or semi-liquid forms must be introduced to supplement the mother's milk. This period is known as weaning and lasts 6 to 24 months.

In Togo, in 2021, the mortality rate of children under five years old was estimated at 47%. This rate is expected to decrease to 39% in 2025 and to 28% in 2030. [2]. The main causes of these under-five deaths are associated in one case out of three with malnutrition [3,4].

Over the past five years, Togo has succeeded in achieving food self-sufficiency for the main staples [5]. However, the population's diet, particularly that of children, is insufficient in both diversity and quality [6]. This situation is primarily due to the limited availability of appropriately formulated quality foods rich in vitamins and micronutrients [7,8]. There is also a lack of knowledge about meal composition and proper food preparation, as well as about the specific nutritional needs of young children [9].

As a result, complementary foods are produced to correct this dietary deficit [10]. These foods are essentially composed of cereals, legumes, fruit and vegetables [11]. They are often prepared in the form of enriched flours for infant nutrition. Ukom, et al. [12] and Damndja, et al. [13] formulated infant foods based on yam, sorghum, corn,

plantain and soya bean flours enriched with soy.

In human nutrition, eggs are considered to be a complete food with high nutritional value. They are a source of protein, minerals, and vitamins. [14]. In general, eggs are recommended as part of a child's diet. They are certainly a food that is permanently available throughout the world. However, they remain relatively expensive and beyond the budget of most households in developing countries. [15]. Furthermore, fresh raw eggs have a limited shelf life of 6 weeks [16]. Converting them into powder could enhance convenience, simplify storage and increase accessibility over time and distance [17]. Incorporating egg powder into infant flours can enhance their nutritional value, making this complete food more accessible to children in all households, including those with limited resources [18]. Dewi, et al. [19] demonstrated that introducing eggs into the diets of weaning children can significantly improve their nutrition. However, the processes involved in mixing egg powder with infant foods carry risks of poisoning due to their high moisture content, which is conducive to microbial contamination. [20]. Thus, processing fresh eggs into egg powder will reduce or eliminate this bottleneck. In order to improve the quality of infant foods during weaning, the research contributes, on the one hand, to the transformation of liquid eggs into powder. Based on this transformation, this work will determine the appropriate incorporation rates of egg powder into corn flour in order to obtain an enriched food powder intended for infant consumption. This will make a significant contribution to reduce child malnutrition in Africa.

## 2. Materials and Methods

### 2.1. Materials

#### 2.1.1. Biological Material

The biological material used comprises the rust-shelled egg (Figure 1), Obatampa corn (Figure 2), and commercial complementary infant flour (Figure 3). Fresh eggs were purchased from the experimental poultry science unit of the University of Lomé and stored in a refrigerator at 4°C, before being processed into powder. White corn was purchased at the “Cacavéli market” (on the outskirts of Lomé) and processed into flour. Commercial complementary infant flours were collected from pharmacies in Lomé. Twelve (12) second-age flours (6 months and older) were randomly selected for the research study.



Figure 1. Eggs in shell



Figure 2. Corn kernels



Figure 3. Infant flours

Source: Photos taken while conducting the research

### 2.2. Methods

#### 2.2.1. Processing of Whole Eggs Into Powder

Egg powder was obtained by vacuum evaporation at 50°C for 2 hours. Mini Rotary Evaporator (RE-201D, 2L Manual) was used. Prior to evaporation, the eggs were washed, disinfected with bleach, dried at room temperature and broken. The content was homogenized with a spatula and submitted to vacuum evaporation ( $P < 100$  mbar). Figure 4 illustrates the steps involved in egg powder production.

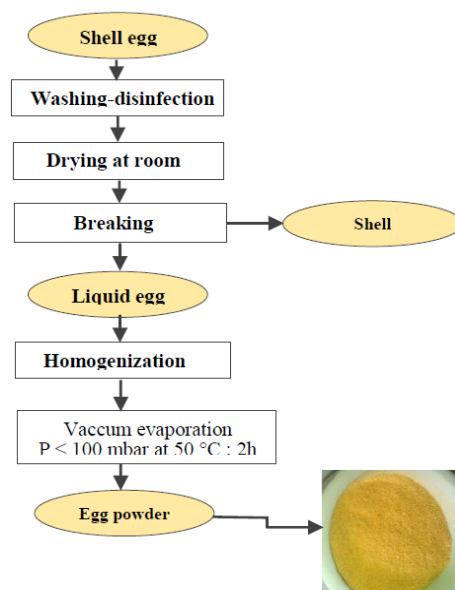


Figure 4. Egg powder production diagram

### 2.2.2. Incorporating Egg Powder Into Corn Flour

Egg powder was incorporated into roasted corn flour at rates of 0% (control), 10%, 15%, 20%, 25%, and 30% (selected at random). The mixture was made manually (Figure 5).

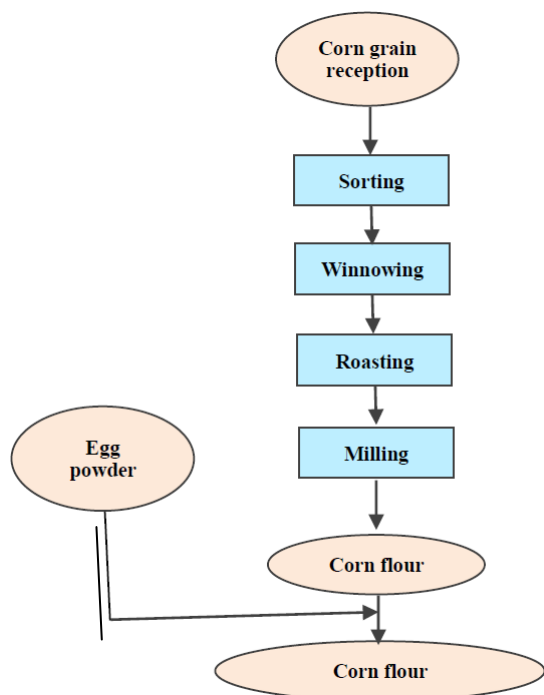


Figure 5. Formulation diagram for enriched infant formula flour

The various formulations comprised roasted corn flour without egg powder (**FT**); roasted corn flour with 10% egg powder added (**FTO 10**); roasted corn flour with 15% egg powder added (**FTO 15**); roasted corn flour with 20% egg powder added (**FTO 20**); roasted corn flour with 25% egg powder added (**FTO 25**) and roasted corn flour with 30% egg powder (**FTO 30**).

### 2.2.3. Collection of Commercial Complementary Infant Flour

Table 1. Some commercial complementary infant flours and their ingredients bought in Lomé pharmacies

| N° | Flour code | Raw materials and ingredients                           |
|----|------------|---------------------------------------------------------|
| 1  | SMA        | Corn, tapioca, soya, milk powder, vitamins and minerals |
| 2  | FDE        | Corn, millet, soybean, rice, sorghum                    |
| 3  | FIT        | Corn, rice, soybean, sorghum, millet                    |
| 4  | VIT        | Corn, rice, soybean                                     |
| 5  | NUT        | Corn, soybean, sorghum, millet and monkey bread         |
| 6  | NUTR       | Corn, rice, soybean                                     |
| 7  | BRO        | Corn, rice, soybeans, fonio, sorghum                    |
| 8  | VITA       | Corn, rice, soybean, fonio, wheat                       |
| 9  | MAP        | Corn, soy, vitamin, fruit and mineral salts             |
| 10 | VITP       | Corn, sorghum, soybean, plantain                        |
| 11 | FAN        | Corn, rice, soybean, fonio                              |
| 12 | FOR        | Corn, rice, soybean                                     |

A representative sample of the commercial complementary infant flours most commonly used was taken from randomly selected pharmacies in Greater Lomé. Twelve flour samples were selected after a

preliminary investigation and purchased for the study. The raw materials and ingredients making up these flours are summarized in Table 1.

### 2.2.4. Physico-chemical Analysis

The physico-chemical parameters determined on egg-treated and commercial complementary flours are moisture, protein, fat, ash, total carbohydrates, energy and certain minerals such as iron, zinc, magnesium, calcium, sodium and potassium.

#### Moisture

The moisture content of the flours studied was determined in accordance with AFNOR standard NFV03-707, June 1989 (AFNOR, 1991), by drying a 5 g test sample at 103°C to constant mass. The flour sample was oven-dried (Memmert) during 4 hours. The difference in weight gave the moisture content.

#### Ash

Ash content was determined by incinerating a 5 g test sample at 550°C, in accordance with AFNOR standard NFV03-760, December 1981 (AFNOR, 1991). Incineration was carried out in a muffle furnace (Nabertherm P330). Mineralization continued for 6 hours, until total combustion of the organic matter has taken place and a whitish residue has appeared.

#### Protein content

Total protein content was determined by calculating total nitrogen using the Kjeldahl method in accordance with NF EN ISO 3188-1994.

The total nitrogen content "NT" in g per 100 g of dry product was given by the following formula:

$$NT = 1,4 * V * N * \frac{1}{PE} * \frac{100}{(100 - H)}$$

V: volume in ml of titrating H<sub>2</sub>SO<sub>4</sub>;

N: normality of titrating H<sub>2</sub>SO<sub>4</sub>;

Pe: test sample mass in grams;

H: sample water content in % of wet mass

**Protein content** = NT × 6.25

#### Total lipids

Extraction was performed using hexane in a Soxhlet extractor (TALC). After evaporation of the solvent, the capsule was dried in an oven at 103°C for 30 min. The difference in weight gave the lipid content "L" per 100g of dry sample, expressed by the following formula:

$$L = m * \frac{100}{PE} * \frac{100}{(100 - H)}$$

m: mass in g of lipid residue;

Pe: mass in g of test sample;

H: sample water content in % of wet mass.

#### Total carbohydrates

The total carbohydrate content "G" in g per 100 g of dry product is calculated by difference:

$$G = 100 - (H + C + P + L)$$

H: moisture content (in % of dry product); C: ash content (in % of dry product);

P: total protein content (in % of dry product); L: total lipid content (in % of dry product).

#### Energy value

Energy values were calculated using Atwater's specific coefficients for proteins, lipids and carbohydrates [21].

### Minerals

After dry mineralization in a muffle furnace (Nabertherm P330), the ash obtained was put into solution (distilled water) and filtered using Watman paper. The filtrate obtained (100 ml) was assayed by Atomic Absorption Spectrometry (Agilent 200 serie AA) (iron, zinc, calcium, magnesium) and flame photometry (JENWAY, sodium and potassium).

### 2.2.5. Microbiological Analysis

Microbiological analyses were carried out on flours treated with egg powder (FTO 10, FTO 15, FTO 20, FTO 25 and FTO 30) and control flour (FT). Microorganisms tested included Total Aerobic Mesophilic Flora (TAMF), Yeasts and Moulds, Salmonella, Staphylococcus aureus and Thermotolerant Coliforms. The microorganism tested, normative references, and incubation conditions for these germs are shown in Table 2.

Table 2. Microorganisms' analysis conditions and standards

| Microorganism                         | References                  | Incubation conditions                                                                                                                 |
|---------------------------------------|-----------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| Total Aerobic Mesophilic Flora (TAMF) | ISO 4833                    | Inoculation and enumeration on solid Plate Count Agar (PCA)                                                                           |
| Yeasts and Molds                      | AFNOR :XP V 059             | 0.1 ml aliquots of decimal dilutions seeding on Oxytetracycline glucose medium (OGA)                                                  |
| Salmonella sp                         | ISO 6579/A1                 | sterile plastic bag and 225 ml of Buffered Peptone Water (BPW)                                                                        |
| Staphylococcus aureus                 | AFNOR : NF V08-057-1 and -2 | buffered peptone water (BPW) for a stock suspension. Aliquots of 0.1ml from each 10 <sup>-2</sup> to 10 <sup>0</sup> decimal dilution |
| Thermotolerant Coliforms              | AFNOR : NF V08-060          | VRBL agar solid medium and 10 <sup>-2</sup> and 10 <sup>-1</sup> dilutions                                                            |

### 2.2.6. Sensory Evaluation

Preliminary tests with untrained tasters led to the selection of 50 g of flour cooked in 225 ml of drinking water. This quantity took account of the slurry's fluidity. Cooking took 8 min at 110°C. The porridges were cooled to around 40°C at room temperature in the preparation room before being served.

The method consisted in evaluating and quantifying the appropriate descriptors (colour, odor, taste, texture and acceptability) according to a category scale. The porridge, made from roasted corn flour enriched with 20% egg powder, was presented to a panel of 25 mothers who were recruited and trained for the research purposes. The pleasure perceived by each panelist was marked on a 9-

point hedonic scale. Scores ranging from 9 (extremely pleasant) to 1 (extremely unpleasant) were assigned to the different modalities of the scale.

### 2.2.7. Statistical Analysis of Data

The results of the physico-chemical analyses were entered using Microsoft Excel spreadsheet software. Mean values ( $\pm$  standard deviation) of physicochemical characteristics were obtained over three trials. Differences among values were evaluated by oneway analysis of variance using Fisher's least significant difference (LSD). Differences were considered to be significant at  $P < 0.05$ .

## 3. Results

### 3.1. Description of Egg Powder

Whole egg powder obtained by vacuum evaporation was yellowish in color and had a neutral odor. This coloration comes from the yolk of the egg. The imperceptibility of the egg odor may be explained by the process of water evaporation. This process removes most of the odor molecules from the egg and reduces the initial intensity of its scent to a level below the threshold of human perception. The evaporation yield of liquid whole egg was 20%, i.e. 12 g of egg powder for a 60 g shell egg.

#### 3.1.1. Nutritional Value of Whole Egg Powder

##### Physico-chemical characteristics

The physico-chemical characteristics of whole egg powder (WOP) are presented in Table 3.

Moisture, protein, lipid, ash and carbohydrate contents in g/100g and energy in Kcal/100g DM were respectively  $5.39 \pm 0.30$ ,  $51.64 \pm 3.03$ ,  $30.55 \pm 0.42$ ,  $3.61 \pm 0.46$ ,  $16.18 \pm 4.22$  and  $546.31 \pm 0.93$ . These results indicate that egg powder has a low moisture content, which should enable it to have a long shelf life. It was also low in carbohydrates, but very rich in proteins and lipids.

##### Mineral content

The mineral elements determined in the Oven-Dried Base/Blend/Composition (OCB) were iron, zinc, calcium, magnesium, sodium and potassium. Their contents are shown in Table 4.

The results showed that the contents of iron, zinc, calcium, magnesium, sodium and potassium in mg/100g DM were  $8.60 \pm 0.50$ ,  $3.37 \pm 0.04$ ,  $287.98 \pm 9.19$ ,  $56.06 \pm 0.37$ ,  $673.96 \pm 3.50$  and  $648.52 \pm 1.75$  respectively. These results indicate that egg powder contains high levels of sodium, potassium, iron and calcium, and low levels of zinc and magnesium.

Table 3. Physico-chemical characteristics of whole egg powder

|     | Moisture<br>MOISTURE (% dry basis) | Protein<br>(%DM) | Fat<br>(%DM)     | Ash<br>(% DM)   | Carbohydrates<br>(% DM) | Energy<br>(Kcal/100g) |
|-----|------------------------------------|------------------|------------------|-----------------|-------------------------|-----------------------|
| WOP | $5.39 \pm 0.30$                    | $51.64 \pm 3.03$ | $30.55 \pm 0.42$ | $3.61 \pm 0.46$ | $16.18 \pm 4.22$        | $546.31 \pm 0.93$     |

DM: dry matter

Table 4. Mineral content of egg powder (mg/100g DM)

|                               | Iron            | Zinc            | Calcium           | Magnesium        | Sodium            | Potassium         |
|-------------------------------|-----------------|-----------------|-------------------|------------------|-------------------|-------------------|
| Powdered Oven-Dried Egg (POE) | $8.60 \pm 0.50$ | $3.37 \pm 0.04$ | $287.98 \pm 9.19$ | $56.06 \pm 0.37$ | $673.96 \pm 3.50$ | $648.52 \pm 1.75$ |



## 3.2. Nutritional Value of Infant Flours Studied

### 3.2.1. Physico-chemical Characteristics of Infant Flours Studied

The physico-chemical composition of commercial complementary infant flours and flours processed at different rates of incorporation of egg powder is presented in Table 5.

According to the results in Table 5, the moisture content of commercial infant flours ranged from  $2.32 \pm 0.23$  to  $7.75 \pm 0.66$  g/100g DM for VITA and MAP flours respectively. Experimental flours (FT, FTO 10, 15, 20, 25, 30) also had a moisture content of less than 12%, which would ensure good shelf life.

The difference was not significant ( $P > 0.05$ ) for both types of flour. The protein contents of commercial complementary flours ranged from  $6.29 \pm 0.94$  g/100g DM for MAP flour to  $15.71 \pm 1.22$  g/100g DM for FOR flour. But those of flours treated with egg powder increased proportionally ( $15.50 \pm 1.43$ ;  $20.16 \pm 0.39$ ;  $22.36 \pm 0.20$ ;  $24.61 \pm 0.55$  and  $25.84 \pm 0.09$  g/100g DM) as the incorporation rate of egg powder increased (FTO 10, FTO 15, FTO 20, FTO 25 and FTO 30 respectively). The protein content of FT flour ( $10.72 \pm 0.56$  g/100g DM) was lower than that of flours treated with egg powder. Only the FOR flour of the market complied with the recommendations ( $15.3$ - $36.46$  g/100g DM), but all the flours treated with egg powder complied.

The lipid content of commercial complementary flours ranged from  $7.59 \pm 3.51$  g/100g DM (FOR) to  $21.79 \pm 0.08$  g/100g DM (MAP). The lipid content of FT flour ( $2.61 \pm 0.38$  g/100g DM) was lower than that of flours

treated with egg powder with the latter showing higher values ( $9.82 \pm 3.24$ ;  $15.14 \pm 2.52$ ;  $17.25 \pm 1.88$ ;  $19.17 \pm 3.50$  and  $24.07 \pm 1.14$  g/100g DM), increasing with incorporation rates (10%, 15%, 20%, 25% and 30% respectively) and indicating a lipid-rich egg intake.

The ash content of commercial flours ranged from  $1.45 \pm 0.07$  g/100g DM (FIT) to  $2.65 \pm 0.05$  g/100g MS (VIT). The ash content of FT flour ( $1.59 \pm 0.27$  g/100g DM) was lower than that of egg-treated flours. However, these levels did not differ significantly ( $P > 0.05$ ) as the incorporation rate of egg powder increased. The mineral content of egg powder would be as low as that of corn flour (FT) and commercial complementary flours.

The total carbohydrate contents of the flours varied between  $61.83 \pm 2.16$  g/100g DM (MAP) and  $79.44 \pm 2.15$  g/100g DM (FIT). As the incorporation rate of egg powder increased from 0% (FT) to 30% (FTO 30), the total carbohydrate content decreased from  $80.80 \pm 0.04$  g/100g DM to  $42.82 \pm 0.60$  g/100g DM, indicating that egg powder composition in carbohydrates is low compared to corn flour.

The energy of commercial complementary flours ranged from  $409.72 \pm 9.44$  Kcal/100g DM for FDE flour to  $468.71 \pm 13.12$  Kcal/100g DM for MAP flour, but that of experimental flours increased ( $389.62 \pm 0.97$ ;  $424.31 \pm 15.97$ ;  $450.03 \pm 12.81$ ;  $457.79 \pm 12.88$ ;  $467.45 \pm 14.78$  and  $491.31 \pm 8.24$  g/100g DM) in proportion to the incorporation rates of egg powder. According to these results, the flours studied had almost the same energy values, which would be due to the fact that these flours have a high amount of carbohydrates (commercial complementary flours), proteins and lipids (egg flours), which are energy components.

Table 5. Physico-chemical characteristics of commercial complementary and experimental infant flours

|                                 | Moisture <sup>(a)</sup><br>(% DM) | Protein <sup>(b)</sup><br>(% DM) | Fat <sup>(b)</sup><br>(% DM) | Ash <sup>(a)</sup><br>(% DM) | Carbohydrate <sup>(b)</sup><br>(% DM) | Energy <sup>(b)</sup><br>(Kcal/100g DM) |
|---------------------------------|-----------------------------------|----------------------------------|------------------------------|------------------------------|---------------------------------------|-----------------------------------------|
| RDA*                            | < 12                              | 15.3-36.46                       | 20-21.54                     |                              |                                       |                                         |
| Commercial complementary flours |                                   |                                  |                              |                              |                                       |                                         |
| SMA                             | <b>6.39±0.52</b>                  | 8.40±1.35                        | 11.39±0.11                   | 2.48± 0.09                   | 71.31±1.04                            | 421.47±10.55                            |
| FDE                             | <b>5.88±0.15</b>                  | 9.28±1.43                        | 8.34±0.40                    | 2.11± 0.03                   | 74.37±0.92                            | 409.72±9.44                             |
| FIT                             | <b>3.58±0.16</b>                  | 6.80±0.62                        | 8.72±0.19                    | 1.45± 0.07                   | 79.44±2.15                            | 423.48±12.79                            |
| VIT                             | <b>2.51±0.17</b>                  | 10.14±0.97                       | 15.46±0.57                   | 2.65± 0.05                   | 69.22±1.02                            | 456.67±13.09                            |
| NUT                             | <b>5.55±0.25</b>                  | 9.44±0.67                        | 8.04±0.64                    | 1.70± 0.08                   | 75.25±1.34                            | 411.21±13.80                            |
| NUTR                            | <b>3.68±0.43</b>                  | 9.44±0.15                        | <b>17.61±0.73</b>            | 1.71± 0.40                   | 67.54±0.67                            | 466.51±9.85                             |
| BRO                             | <b>4.95±0.35</b>                  | 10.12±1.41                       | 14.47±0.11                   | 2.57± 0.11                   | 67.87±1.03                            | 442.27±10.75                            |
| VITA                            | <b>2.32±0.23</b>                  | 8.04±0.08                        | 9.19±0.13                    | 1.93± 0.03                   | 78.50±3.04                            | 428.94±13.65                            |
| MAP                             | <b>7.75±0.66</b>                  | 6.29±0.94                        | <b>21.79±0.08</b>            | 2.31± 0.04                   | 61.83±2.16                            | 468.71±13.12                            |
| VITP                            | <b>5.05±0.69</b>                  | 8.72±0.52                        | 10.19±0.24                   | 2.18± 0.24                   | 73.85±1.13                            | 422.05±8.76                             |
| FAN                             | <b>4.87±0.13</b>                  | 7.58±2.24                        | 10.58±2.66                   | 2.49± 0.04                   | 74.46±0.09                            | 423.48±33.26                            |
| FOR                             | <b>3.1 ± 0.43</b>                 | <b>15.71±1.22</b>                | 7.59± 3.51                   | 2.55± 0.81                   | 71.02±1.25                            | 415.33±41.47                            |
| Experimental flours             |                                   |                                  |                              |                              |                                       |                                         |
| FT                              | <b>4.26 ± 0.50</b>                | 10.72±0.56                       | 2.61± 0.38                   | 1.59± 0.27                   | 80.80±0.04                            | 389.62±0.97                             |
| FTO 10                          | <b>4.14 ± 0.05</b>                | <b>15.50±1.43</b>                | 9.82± 3.24                   | 2.06± 0.12                   | 68.46±1.87                            | 424.31±15.97                            |
| FTO 15                          | <b>4.43 ± 0.26</b>                | <b>20.16±0.39</b>                | 15.14±2.52                   | 1.98±0.31                    | 58.27±2.87                            | 450.03±12.81                            |
| FTO 20                          | <b>4.84 ± 0.68</b>                | <b>22.36±0.20</b>                | <b>17.25±1.88</b>            | 2.28± 0.18                   | 53.26±1.21                            | 457.79±12.88                            |
| FTO 25                          | <b>4.57 ± 0.91</b>                | <b>24.61±0.55</b>                | <b>19.17±3.50</b>            | 2.53± 0.24                   | 49.10±3.62                            | 467.45± 14.78                           |
| FTO 30                          | <b>5.15 ± 0.53</b>                | <b>25.84±0.09</b>                | 24.07±1.14                   | 2.10± 0.09                   | 42.82±0.60                            | 491.31± 8.24                            |

\* RDA: Recommended Daily Allowance (children under 2)

Values in the table, marked in bold, are in line with recommendations.

((a)): No significant difference at the 0.05 risk level ((b)): Significant difference at the 0.05 risk level

### 3.2.2. Mineral Content of Infant Flours Studied

The mineral content of the experimental and the commercial complementary flours is shown in Table 6. This mainly concerns the importance of Iron, Zinc, Calcium, Magnesium, Sodium, and Potassium in the categories of experimental flours compared to those acquired from traders.

Table 6. Mineral content of commercial complementary flours and experimental flours in mg/100Kcal

|                                 | Iron <sup>(a)</sup> | Zinc <sup>(b)</sup> | Calcium <sup>(b)</sup> | Magnesium <sup>(a)</sup> | Sodium <sup>(b)</sup> | Potassium <sup>(b)</sup> |
|---------------------------------|---------------------|---------------------|------------------------|--------------------------|-----------------------|--------------------------|
| RDA*                            | > 4 mg              | > 0.8 mg            | > 125 mg               | > 19 mg                  | > 74 mg               | > 129 mg                 |
| commercial complementary flours |                     |                     |                        |                          |                       |                          |
| SMA                             | 0.40±0.11           | 0.63±0.02           | 1.93±0.12              | 15.13±2.05               | 45.82±2.34            | <b>149.02±5.17</b>       |
| FDE                             | 0.88±0.02           | <b>0.76±0.15</b>    | 2.48±0.06              | <b>25.61±3.52</b>        | 18.71±1.35            | <b>172.37±10.10</b>      |
| FIT                             | 0.80±0.03           | 0.53±0.01           | 0.47±0.04              | <b>21.07±2.20</b>        | 26.19±2.80            | <b>127.82±12.30</b>      |
| VIT                             | 1.06±0.05           | <b>0.78±0.05</b>    | 2.50±0.32              | <b>25.32±3.10</b>        | 10.79±1.17            | <b>188.87±11.30</b>      |
| NUT                             | 0.32±0.07           | 0.07±0.01           | 1.72±0.05              | 15.69±2.35               | 11.98±1.23            | <b>133.74±6.28</b>       |
| NUTR                            | 0.77±0.03           | 0.66±0.02           | 2.53±0.23              | <b>23.45±2.30</b>        | 6.16±1.86             | <b>173.72±4.32</b>       |
| BRO                             | 0.94±0.10           | 0.66±0.10           | 2.51±0.52              | <b>24.46±3.10</b>        | 12.69±0.62            | <b>171.46±10.64</b>      |
| VITA                            | 0.61±0.17           | <b>0.72±0.11</b>    | 2.86±0.81              | <b>21.30±2.24</b>        | 6.70±1.08             | <b>168.69±7.26</b>       |
| MAP                             | 0.52±0.06           | 0.64±0.06           | 3.49±0.36              | <b>15.93±3.12</b>        | 25.13±3.50            | <b>128.45±9.73</b>       |
| VITP                            | 0.56±0.05           | 0.63±0.05           | 2.79±0.52              | <b>21.28±2.04</b>        | 10.06±1.94            | <b>169.39±7.65</b>       |
| FAN                             | 0.96±0.08           | <b>1.70±0.13</b>    | 3.41±1.03              | <b>23.79±0.14</b>        | 6.79±1.22             | <b>187.27±12.66</b>      |
| FOR                             | 0.52±0.09           | 0.70±0.01           | 2.92±0.31              | <b>17.79±2.56</b>        | 10.22±2.11            | <b>142.87±6.47</b>       |
| Experimental flours             |                     |                     |                        |                          |                       |                          |
| FT                              | 0.60± 0.31          | 0.43± 0.11          | 8.35±3.57              | <b>24.95±1.72</b>        | 3.86 ±1.12            | 118.87±3.42              |
| FTO 10                          | 1.06± 0.51          | 0.46± 0.06          | 13.69±13.25            | <b>22.28±0.20</b>        | 27.76±0.47            | 111.20±2.15              |
| FTO 15                          | 0.97± 0.64          | 0.45± 0.02          | 14.76±14.46            | <b>21.39±1.13</b>        | 36.82±0.35            | 114.49±1.65              |
| FTO 20                          | 1.21± 0.72          | 0.48± 0.01          | 31.78±11.07            | <b>37.86±2.93</b>        | <b>70.61±2.52</b>     | <b>173.23±2.23</b>       |
| FTO 25                          | 0.94± 1.09          | 0.48± 0.10          | 16.00±0.45             | <b>19.45±0.37</b>        | 51.75±3.40            | 106.78±3.21              |
| FTO 30                          | 1.07± 0.64          | 0.48± 0.16          | 22.25±10.46            | <b>20.47±0.75</b>        | 57.43±1.28            | 110.17±2.01              |

\* RDA: Recommended Daily Allowance (children under 2)

Values in the Table marked in bold are in line with recommendations.

((a)): No significant difference at the 0.05 risk level ((b)): Significant difference at the 0.05 risk level

In Table 6, the iron content of commercial complementary flours ranged from 0.32±0.07 mg/100 Kcal (NUT flour) to 1.06±0.05 mg/100 Kcal (VIT flour). Experimental flours ranged from 0.60±0.31 (FT) to 1.21±0.72 mg/100 Kcal (FTO 20). Furthermore, the iron content of these categories of flour was below the recommended level (4 mg/100 Kcal), with no significant difference ( $P > 0.05$ ). This indicates that the components making up commercial complementary flours are low in iron and that these flours could be enriched with vegetables or fortified with iron.

Zinc levels in commercial complementary flours ranged from 0.07±0.01 mg/100 Kcal (NUT flour) to 1.70±0.13 mg/100 Kcal (FAN flour) and in experimental flours from 0.43±0.11 (FT) to 0.48±0.16 mg/100 Kcal (FTO 30). It appears that FDE, VIT, VITA and FAN flours have values in line with recommendations (0.8 mg/100 Kcal), probably due to the use of certain zinc-rich ingredients in their formulations. Flours treated with egg powder on the other hand did not comply indicating that egg is not rich in zinc and leading to a significant difference ( $P < 0.05$ ) between the two types of flour.

Calcium levels in commercial complementary flours ranged from 0.47±0.04 mg/100 Kcal (FIT flour) to 3.49±0.36 mg/100 Kcal (MAP flour) and in experimental flours from 8.35±3.57 (FT) to 31.78±11.07 mg/100 Kcal (FTO 20). All flours showed values not in line with recommendations (125 mg/100 Kcal). These flours are

therefore low in calcium, as they are essentially made from cereals and pulses, which are low in this element. However, egg flours were slightly richer in calcium than commercial complementary flours, indicating a significant difference ( $P < 0.05$ ) between them.

The magnesium content of commercial complementary flours ranged from 15.13±2.05 mg/100 Kcal (SMA flour) to 25.61±3.52 mg/100 Kcal (FDE flour) and was not significantly different ( $P > 0.05$ ) from that of experimental flours ranging from 19.45±0.37 (FTO 25) to 37.86±2.93 mg/100 Kcal (FTO 20). Commercial complementary and experimental flours were in line with recommendations (19 mg/100 Kcal) except SMA and NUT flours. Most cereals, legumes and fruits used in flours are generally rich in magnesium.

Sodium levels in commercial flours ranged from 6.16±1.86 mg/100 Kcal (NUTR flour) to 45.82±2.34 mg/100 Kcal (SMA flour), and from 3.86±1.12 (FT) to 70.61±2.52 (FTO 20) mg/100 Kcal in experimental flours. The sodium FTO 20 which was very close. The constituents of these flours may be responsible for this finding.

Potassium levels in commercial complementary flours ranged from 127.82±12.30 mg/100 Kcal (FIT flour) to 188.87±11.30 mg/100 Kcal (VIT flour), and from 106.78±3.21 (FTO 25) to 173.23±2.23 (FTO 20) mg/100 Kcal for experimental flours.

### 3.3. Microbiological Characteristics of Flours Treated with Egg Powder

Infant formulas must not contain pathogenic germs which could have harmful repercussions on infant health. Table 7 shows the microbiological characteristics of flours treated with egg powder.

The results of microbiological analyses of control flour and flours treated with egg powder showed germ counts (FAMT, CTH, STAPH, LM) below the microbiological criteria applicable to foodstuffs. Salmonella was also absent from all flours.

**Table 7. Microbiological characteristics of egg powder-treated flours**

| Parameters parameters | FAMT CFU/g        | CTH CFU/g | STAPH CFU/ g | L + M CFU/g       | SALM in 25g |
|-----------------------|-------------------|-----------|--------------|-------------------|-------------|
| Criteria (1)          | $1.0 \times 10^5$ | 10        | $10^2$       | $1.0 \times 10^3$ | Absence     |
| FT                    | < 100             | < 10      | < 100        | < 100             | Absence     |
| FTO 10                | < 100             | < 10      | < 100        | < 100             | Absence     |
| FTO 15                | < 100             | < 10      | < 100        | < 100             | Absence     |
| FTO 20                | < 100             | < 10      | < 100        | < 100             | Absence     |
| FTO 25                | < 100             | < 10      | < 100        | < 100             | Absence     |
| FTO 30                | < 100             | < 10      | < 100        | < 100             | No          |

(1) Microbiological criteria applied to foodstuffs, Guidelines for interpretation (Ministry of Health, Grand Duchy of Luxembourg, 2015)SALM: Salmonella spp; FAMT: Total Anaerobic Mesophilic Flora at 30°C; STAPH: Coagulase-positive Staphylococci at 37°C; CTH: Thermo-tolerant Coliforms at 44°C ; L+M : Yeasts and molds at 25°C

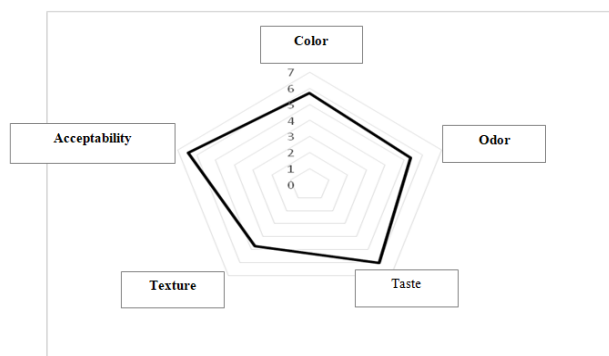
### 3.4. Sensory Analysis

The porridge prepared from roasted corn flour enriched with 20% egg powder and no added sugar. was presented to a panel of 25 mothers for evaluation according to the appropriate descriptors (color, odor, taste, texture and acceptability). Average scores ( $\pm$  standard deviation) are shown in Table 8.

**Table 8. Average scores /9 for the BFTO 20 slurry sensory test**

| Color           | Odor            | Taste        | Texture         | Acceptability   |
|-----------------|-----------------|--------------|-----------------|-----------------|
| 5.68 $\pm$ 1.57 | 5.37 $\pm$ 1.70 | 6 $\pm$ 1.78 | 4.68 $\pm$ 1.95 | 6.43 $\pm$ 1.63 |

From Table 8, the values attributed to the descriptors (color, Odor, taste, texture and acceptability) of the porridge were respectively 5.68 $\pm$ 1.57; 5.37 $\pm$ 1.70; 6 $\pm$ 1.78; 4.68 $\pm$ 1.95; 6.43 $\pm$ 1.63 out of 9 and were above average (4.5). Figure 6 illustrates the sensory descriptor values.



**Figure 6. Sensory profile of BFTO slurry**

The color of the porridge was judged to be slightly light

by 81% of mothers. This may be explained by the less thorough roasting of the white corn. The roasting time would have to be increased slightly to obtain a brown porridge. The smell of the porridge was judged scarcely pleasant by the panelists. Only 31% of mothers felt that the porridge had a characteristic eggy smell. Most mothers (81%) thought the porridge had a good taste. Others thought it would be very good if sugar were added. The texture of the porridge was lumpy according to 54% of mothers. This could be explain by the fact that the corn flour and egg powder do not have the same particle size. This texture can be corrected by mixing and homogenizing the corn meal and dehydrated egg powder at the mill. In sum, 94% of mothers found the porridge satisfactory.

## 4. Discussion

The research focuses on the aim of formulating an enriched infant flour based on corn flour and egg powder to improve infant nutrition quality during weaning.

It can be inferred that the cereals making up FOR flour are improved varieties and the low content of the other commercial complementary flours is due either to inappropriate formulation or to the protein-poor components used. In the case of experimental flours, this could be attributed to the protein-rich egg according to Rybicka [22]. The protein content of flours treated with egg powder was clearly higher than that of commercial complementary flours and the difference was significant ( $P < 0.05$ ). NUTR and MAP flours (17.61 $\pm$ 0.73 and 21.79 $\pm$ 0.08 g/100g DM respectively) have values in line with recommendations (20-21.54 g/100g DM), no doubt due to the use of an adequate proportion of soya, a legume rich in fat [23,24]. Other flours that do not comply with recommendations should be enriched with legumes such as soy and peanuts. Only FTO 20 and FTO 25 flours comply with the recommendations. It should be noted that these lipid contents were significantly ( $P < 0.05$ ) better than most commercial complementary flours [25]. The high carbohydrate content of commercial complementary flours could be explained by the fact that all these flours were composed of high proportions of cereals, in this case corn, which is rich in carbohydrates. The difference was significant ( $P > 0.05$ ) between these two types of flour. These results are similar to those of Mbame, et al. [26]. The low energy value of FT indicates that corn flour is low in lipid and protein but high in carbohydrate. The difference was significant ( $P < 0.05$ ) between commercial complementary flours and flours with egg powder.

The results indicated that the components making up commercial complementary flours were low in iron and that these flours could be enriched with vegetables or fortified with iron. This implies that egg powder incorporated into corn flour at varying rates had no major impact on the iron content of the resulting flour. Similarly, these results show that egg powder incorporated into corn flour at varying rates had no major impact on the iron content of the resulting flour [27]. Similar report showed that egg powder incorporated into corn flour at varying rates had no major impact on the iron content of the resulting flour [27]. However, egg flours are slightly

richer in calcium than commercial complementary flours, indicating a difference ( $P < 0.05$ ) between them [28]. The potassium content of all commercial complementary flours complied with recommendations (129 mg/100 Kcal), but only FTO 20 flour complied with recommendations among the experimental flours. The cereals and flours would therefore be rich in this element. These results showed that FTO 20 flour meets the necessary criteria for enriched infant flour [22].

Microbiological data showed that flours treated with egg powder were free from germs. These flours are therefore of satisfactory quality for the germs of interest. This result is close to that of the works of Daramola-Oluwatuyi, et al. [29] and Al-Bachir [30]. According to the people interviewed (over 90%), roasted corn flour treated with 20% egg powder (FTO 20) is a safe highly nutritious, energetic, popular and low-cost flour [31]. It can be recommended as a complementary food for infants (6 months and over) and used to correct nutritional deficiencies of children [32]. Here is a revised discussion with short sentences and very recent references, within 20 lines:

These research findings are consistent with WHO recommendations for complementary foods for children aged 6–23 months [33]. WHO emphasizes that complementary foods should be energy-dense and rich in high-quality protein [33,34]. The enriched flours, especially FTO 15–30%, meet these macronutrient requirements better than most commercial flours. The inclusion of egg powder aligns with WHO guidance promoting animal-source foods in infant diets [33,35]. However, iron, zinc, and calcium levels remain below WHO recommended intakes. WHO identifies these micronutrients as critical gaps in cereal-based complementary foods [33,34]. Eggs improve overall nutrient quality but are not sufficient to meet iron and zinc needs alone. Additional fortification or dietary diversification is therefore required. Microbiological results fully comply with WHO food safety criteria [37]. The absence of *Salmonella* and low microbial counts confirm product safety for infants. Overall, the formulation meets WHO standards for energy, protein, and hygiene. It partially meets mineral requirements, with FTO 20 showing the best balance. Further micronutrient fortification would be needed for full WHO compliance.

## 5. Conclusion

Eggs are a remarkable source of protein, lipids, minerals, and vitamins, which makes them an essential food for human nutrition. To improve the quality of infant foods during the weaning period, an infant flour enriched with egg powder was developed. The nutritional composition analysis showed that the formulated flour is rich in energy, high-quality proteins, and lipids, in line with World Health Organization (WHO) recommendations for complementary foods intended for children aged 6–23 months. These results indicate that the product meets WHO standards for energy density and protein adequacy, which are essential to prevent protein-energy malnutrition in developing countries. Although mineral contents were improved, some key micronutrients

identified by WHO as critical (iron, zinc, calcium) remain below recommended levels, suggesting the need for additional fortification or dietary diversification. Microbiological analyses demonstrated the absence of pathogenic microorganisms, confirming compliance with WHO food safety criteria for infant foods. Sensory evaluation showed good acceptability of the porridge, supporting its potential use in infant feeding. Future research should focus on the product's long-term stability, digestibility, and micronutrient fortification to ensure full compliance with WHO complementary feeding standards.

## Acknowledgment

We express our gratitude to the World Bank group for funding this research.

## Conflict of Interest

The authors declare that there are no conflicts of interest regarding this paper.

## References

- [1] W. Widiastuti and I. Ropii, "A Medico-Legal Study on the Use of Infant Formula as an Alternative to Breastfeeding for Children Aged 0–2 Years," *Golden Ratio of Law and Social Policy Review*, vol. 5, no. 1, pp. 44–61, 2025.
- [2] Y. Adegoke, J. Mbonigaba, and G. George, "Sustainable Development Goals (SDGs), Public Health Expenditures, and Maternal and Child Mortality in Selected African Countries: Forecasting Modelling," *International Journal of Environmental Research and Public Health*, vol. 22, no. 4, p. 482, 2025. [Online]. Available: <https://pmc.ncbi.nlm.nih.gov/articles/PMC12027358/>.
- [3] Y. Tossou, "Analysis of nutritional inequalities in children under five in Togo," 2020.
- [4] Y. F. Djoumessi, "The impact of malnutrition on infant mortality and life expectancy in Africa," *Nutrition*, vol. 103, p. 111760, 2022. [Online]. Available: <https://www.sciencedirect.com/science/article/abs/pii/S0899900722001733?via%3Dihub>.
- [5] A. Bouët, F. Traoré, P. Mamboundou, I. Diop, and A. Sy, *The political economy of food self sufficiency policies and food security in African countries*. Intl Food Policy Res Inst, 2025.
- [6] J. Briaux et al., "Dissimilarities across age groups in the associations between complementary feeding practices and child growth: Evidence from rural Togo," *Maternal & child nutrition*, vol. 15, no. 4, p. e12843, 2019.
- [7] K. Kota, R. Pongou, and M.-H. Chomienne, "Impact of household food insecurity on the use of maternal health services in the Savanes region, Togo: a qualitative study," *BMC Public Health*, vol. 25, no. 1, p. 2040, 2025. [Online]. Available: <https://pmc.ncbi.nlm.nih.gov/articles/PMC12128485/>.
- [8] K. A. Amy, A. L. Sipoaka, F. O. Efogo, and M. Melila, "Impact of international food price fluctuations on nutritional quality in Senegal and Togo," *VeriXiv*, vol. 2, no. 156, p. 156, 2025.
- [9] D. T. Togo, "Etude des facteurs associés à la connaissance des mères d'enfants de 0 à 5 ans sur les pratiques alimentaires du nourrisson et du jeune enfant pendant leur séjour à l'URENI au CRéf de la CV," 2024.
- [10] I. M. Mitchodigni, W. A. Hounkpatin, G. Ntandou-Bouzitou, C. Termote, F. S. U. Bodjrènou, M. Mutanen, and D. J. Hounhouigan, "Complementary feeding practices among children under two years old in west Africa: a review," *African journal of food, agriculture, nutrition and development*, vol. 18, no. 2, pp. 13541–13557, 2018.
- [11] Z. Noukpozounkou, M. Melilla, E. M. Badoussi, B. A. Fagla, E. C. Mitchikpè, and N. W. Chabi, "Formulation of Weaning Flours and Supplements Based on Flours From Three Tigernut Cultivars in



- the Fight Against Protein-energy Malnutrition (Pem)," 2024.
- [12] A. N. Ukom, E. C. Adiegwu, P. C. Ojmelukwe, and I. N. Okwunodulu, "Quality and sensory acceptability of yellow maize ogi porridge enriched with orange-fleshed sweet potato and African yam bean seed flours for infants," *Scientific African*, vol. 6, p. e00194, 2019.
  - [13] W. N. Damndja, E. S. Ngangoum, C. Saidou, and S. Mohamadou, "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*, vol. 3, p. 100313, 2023.
  - [14] R. Rafed, M. H. Abedi, and S. R. Mushfiq, "Nutritional value of eggs in human diet," *J. Res. Appl. Sci. Biotechnol.*, vol. 3, pp. 172-176, 2024.
  - [15] E. Derbyshire, "The role of egg consumption in the first 1001 days of life: a narrative review," *British Journal of Midwifery*, vol. 32, no. 5, pp. 248-257, 2024.
  - [16] A. F. Marshall, F. Balloux, N. Hemmings, and P. Brekke, "Systematic review of avian hatching failure and implications for conservation," *Biological Reviews*, vol. 98, no. 3, pp. 807-832, 2023.
  - [17] Y. G. Akyereko, V. O. Edusei, M. Adu, S. O. Anim, G. B. Yeboah, and F. D. Wireko-Manu, "Nutritional and physico-chemical properties of egg powder are affected by different drying methods," *Food Agricultural Sciences and Technology*, vol. 11, no. 1, pp. 17-34, 2025.
  - [18] M. G. Usturoi, R. N. Rațu, I. C. Crivei, I. D. Veleşcu, A. Usturoi, F. Stoica, and R. M. Radu Rusu, "Unlocking the Power of Eggs: Nutritional Insights, Bioactive Compounds, and the Advantages of Omega-3 and Omega-6 Enriched Varieties," *Agriculture*, vol. 15, no. 3, p. 242, 2025.
  - [19] S. K. Dewi, F. R. Fadhila, A. Margawati, N. Rustanti, and F. Ayustaningwarno, "Sensory Analysis of Instant Complementary Food with Fermented Egg Flour Substitution as a Source of Protein and Selenium in Stunting Children," *National Nutrition Journal/Media Gizi Indonesia*, vol. 20, no. 2, 2025.
  - [20] L. L. K. Mason, B. Masuda, R. R. Swaisgood, and A. M. Flanagan, "Nest quality predicts the probability of egg loss in the critically endangered 'Alalā (*Corvus hawaiiensis*)," *Zoo Biology*, vol. 43, no. 5, pp. 481-490, 2024.
  - [21] M. J. Sánchez-Peña, F. Márquez-Sandoval, A. C. Ramírez-Anguiano, S. F. Velasco-Ramírez, G. Macedo-Ojeda, and L. J. González-Ortiz, "Calculating the metabolizable energy of macronutrients: a critical review of Atwater's results," *Nutrition reviews*, vol. 75, no. 1, pp. 37-48, 2017.
  - [22] I. Rybicka, "Comparison of elimination diets: Minerals in gluten-free, dairy-free, egg-free and low-protein breads," *Journal of Food Composition and Analysis*, vol. 118, p. 105204, 2023.
  - [23] R. Anwar, M. Borbi, and A. Rakha, "Significance and the use of legumes in developing weaning foods with a balanced nutrition—a review," *Legume Science*, vol. 6, no. 3, p. e249, 2024.
  - [24] Y. Vandenplas, B. Hegar, Z. Munasir, M. Astawan, M. Juffrie, S. Bardosono, and E. Wasito, "The role of soy plant-based formula supplemented with dietary fiber to support children's growth and development: An expert opinion," *Nutrition*, vol. 90, p. 111278, 2021. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0899900721001404?via%3Dihub>.
  - [25] S. A. Korma, L. Li, K. A. Abdrabo, A. H. Ali, A. Rahaman, S. M. Abed, and X. Wang, "A comparative study of lipid composition and powder quality among powdered infant formula with novel functional structured lipids and commercial infant formulas," *European Food Research and Technology*, vol. 246, no. 12, pp. 2569-2586, 2020.
  - [26] M. C. Mbame, B. Tiencheu, R. Feumba, F. D. Tiepma, A. O. Ashu, A. A. Ufuan, and J. Oben, "Formulation of adequate complementary food for children 6–24 months using local staple foods in the South-west region of Cameroon," *European Journal of Nutrition and Food Safety*, vol. 13, no. 12, pp. 89-108, 2021.
  - [27] E. R. Werner, C. D. Arnold, B. L. Caswell, L. L. Iannotti, C. K. Lutter, K. M. Maleta, C. P. Stewart, "The effects of 1 egg per day on iron and anemia status among young Malawian children: A secondary analysis of a randomized controlled trial," *Current developments in nutrition*, vol. 6, no. 6, p. nza094, 2022. [Online]. Available: <https://pmc.ncbi.nlm.nih.gov/articles/PMC9213210/>.
  - [28] T. Z. T. Chilek, N. A. Kairuaman, F. Ahmad, R. A. Wahab, A. I. Zamri, and A. Mahmood, "Development of white bread fortified with calcium derived from eggshell powder," *Malaysian Applied Biology*, vol. 47, no. 6, pp. 29-39, 2018.
  - [29] E. I. Daramola-Oluwatuyi, T. S. Olugbemi, and E. Z. Jiya, "Quality evaluation of differently processed whole egg powder yield, nutritional value and microbial load," *Nigerian Journal of Animal Production*, vol. 48, no. 5, pp. 268-274, 2021.
  - [30] M. Al-Bachir, "Improvement of microbiological quality of hen egg powder using gamma irradiation," *International Journal of Food Studies*, vol. 9, 2020.
  - [31] J. D. Nyefene, F. Mills-Robertson, I. Amoah, C. Apprey, and C. Edeh, "Nutritional Composition and Acceptability of Egg Powder-Fortified Tom Brown Among School-Aged Children in the Wa Municipality," *Food Science & Nutrition*, vol. 13, no. 7, p. e70288, 2025.
  - [32] A. Omer, D. Mulualem, H. Classen, H. Vatanparast, and S. J. Whiting, "Promotion of egg and eggshell powder consumption on the nutritional status of young children in Ethiopia," *Int. J. Food Sci. Nutr. Res.*, vol. 1, no. 1, pp. 1-11, 2019.
  - [33] World Health Organization, \*WHO Guideline on Complementary Feeding of Infants and Young Children Aged 6–23 Months\*, Geneva, Switzerland, 2023.
  - [34] WHO and UNICEF, \*Indicators for Assessing Infant and Young Child Feeding Practices\*, Update, Geneva, Switzerland, 2024.
  - [35] World Health Organization, \*Guiding Principles for Complementary Feeding of the Breastfed Child\*, Geneva, Switzerland, reaffirmed 2023.
  - [36] World Health Organization, \*Food Safety: Microbiological Risk Assessment in Infant Foods\*, Geneva, Switzerland, 2022.

