Physico-chemical and functionality of air and spray dried egg powder: implications to improving diets

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\textbf{ABSTRACT}

Weak market linkages, unavailability of cold-storage, and the significant loss of eggs due to breakage and low shelf-life contribute to the unaffordability and the low consumption of eggs in low-income countries like Ethiopia. The effect of spray- and oven-drying of eggs from local (Ethiopian) and exotic (imported) chicken breeds on physical, techno-functional, and nutritional composition of egg-powders were evaluated. Exotic (n = 150) and local (n = 140) eggs were spray/oven dried. The yield, bulk-density, flowability, and the foaming-, emulsification-, and water/oil absorption-capacity of the egg powders were assessed. The concentrations in energy, protein, fat, ash, and minerals were determined. The egg-powders’ contribution to nutrient requirements for a child and their potential use as an alternative protein source in ready to use therapeutic foods (RUTF) were estimated. The low moisture (<5%) and water activity (aw=0.4–0.5) of the egg-powders implied unfavorable conditions for microbial growth. Local eggs had higher energy and fat content, whereas protein was higher in the exotic eggs (P < 0.05). About 12.5 g of egg powder (one egg) can fulfill >75%, 30%, and 40% of fat, energy, and calcium requirements for children 6–23 months of age, respectively. Only 6 g and 4 g of egg-powder are needed to fulfill protein and choline requirements, respectively. Considering the quality/quantity of proteins, egg powders can be alternative protein sources in RUTFs. The drying of local and exotic eggs with oven- and spray-drying yielded egg powders with acceptable techno-functional properties, but future studies should elucidate differences observed by egg type and drying; and investigate the shelf-life. Drying eggs can be a viable food systems’ intervention that can improve the safety and quality of diets in low-income countries like Ethiopia.

\textbf{Introduction}

Child malnutrition is highly prevalent in low- and middle-income countries (LMICs) as reflected by growth faltering, nutritional deficiencies, and the related poor cognitive outcomes.\textsuperscript{[1]} The timing of child growth faltering illustrates that poor complementary feeding is a key determinant.\textsuperscript{[2]} Indeed, a large majority of children in LMICs have suboptimal diets, characterized by low consumption of fruits, vegetables, and nutrient-dense animal source foods.\textsuperscript{[3]} Low dietary diversity, particularly the low consumption of animal source foods has consistently been linked to child stunting.\textsuperscript{[4,5]}

Egg is one of the most versatile and nutrient-dense food that, relative to other animal source foods, is more available and accessible.\textsuperscript{[6]} For example, poultry are the most widely owned livestock in LMICs like Ethiopia, but paradoxically they are still unaffordable for a large share of population in these countries.\textsuperscript{[7,6]} The poor infrastructure (e.g., absence of cold-chain) and the weak market linkages in
countries like Ethiopia, complemented with the low shelf-life of eggs and the significant loss due to breakage during transportation and storage increases the price of eggs; hence, constraining consumption and related benefits to child growth and cognition.\textsuperscript{[9,10]} Therefore, along with increasing production and creating demand for eggs, innovations that reduce transaction costs related to transportation and breakage of eggs, as well as improving shelf-life is critical.

Drying eggs into powder offers numerous advantages, including reduction of transport and storage costs, protection against microbial growth (low water activity) and easier dosage for the use of eggs as ingredients in mixed dishes and food formulations.\textsuperscript{[11]} Egg powder is nutrient-dense and can be used for food-to-food fortification of complementary foods or possibly as a complement or an alternative to milk powder in ready-to-use therapeutic foods (RUTF). However, evidence evaluating this potential is scarce and the use of egg powders is not common in LMICs, partly because of their low availability.

In Ethiopia, two types of eggs are recognized by lay consumers: i) the larger eggs with lighter yellow yolk known as Ferengi eggs and obtained from imported breeds (exotic), and; ii) the smaller eggs with deep-yellow colored yolk known as Habesha (local) egg. Despite this differentiation and consumer preference for the local egg, little information exists about the difference in nutritional and technofunctional composition of these two egg types, and how they are impacted by oven and spray drying. Such information is timely and can inform food systems’ interventions that aim to improve the adoption of healthy diets.

Therefore, the aim of this study was to evaluate the effect of two drying methods (spray- and oven-drying) and egg types (Ethiopian local and exotic) on physical, technofunctional, and nutritional quality of whole egg powder. The contribution of egg powders to meeting children’s nutritional requirements has also been calculated.

\textbf{Materials and methods}

\textit{Experimental design}

The influence of egg type and drying methods on the nutritional composition and functional property of the whole egg powder was studied. The nutritional contribution of the egg powder was also evaluated.

\textbf{Raw materials: egg sample collection and preparation}

White eggs from exotic breeds (\(n = 150\)) and local breeds (\(n = 140\)) were obtained from the poultry research program at Debrezzeit Agricultural Research Center and from a private poultry farm, respectively. The eggs were all three days old and their freshness was further checked using candeling techniques.\textsuperscript{[12]} This simple test relies on the principle that as eggs age, the shell becomes more porous allowing air to flow through making the air cell larger. After screening for freshness, the eggs were washed, broken, and de-shelled manually following aseptic procedures. The liquid whole egg (yolk and egg white) was homogenized, pasteurized in water-bath at 70°C for 3 min., and was oven- or spray-dried.

\textbf{Drying}

\textit{Oven drying}: Oven drying of the liquid whole egg was carried in a ventilated-oven at 44°C for 6 h. (DHG-9123A Zenith Lab, China). The dried egg was allowed to cool; the flakes were scooped, milled, and sieved to pass through a 60 mm mesh. The resulting whole egg powder was bagged in self-seal polyethylene bags and was stored at \(-20°C\) until further analyses.

\textit{Spray drying}: Spray drying was carried out using the method described by Koç.\textsuperscript{[13]} Briefly, 500 g of liquid whole egg was injected into the spray drier (FT 80 Armfield, USA) under the following specifications: inlet air temperature (Ti) of 180 °C, outlet air temperature (To) of 80 °C, atomization pressure (AP) of 1 bar, feed temperature of \(\pm 10 \)^\circ\text{C}, hot air flow rate of 1.54 m\textsuperscript{3}/min. The resulting egg-
powder was sieved and bagged in self-seal polyethylene bags and stored at −20°C until further analyses.

**Whole egg powder yield**
The yield in percentage was calculated using the following formulae:

\[
\text{Flour yield (\%) = \left(\frac{\text{weight of extracted flour (g)}}{\text{weight of whole egg used (g)}}\right) \times 100}
\]  

(1)

**Physicochemical characteristics**
Moisture, protein, fat, and ash were analyzed according to the methods of the Association of Official Analytical Chemists.\(^{[14]}\) Moisture content was determined by oven drying at 105°C to constant weight (protocol no: AOAC. 925.10). Protein content (N × 6.25) was determined by the Kjeldahl method based on determination of nitrogen content (AOAC. 981:10). Fat content was determined using the semi-automatic Soxtec system (AOAC 991:36; Barnstead Electro-thermal, Staffordshire, UK). Ash was determined gravimetrically in a heated muffle furnace at 550°C. Total carbohydrate content was calculated by difference as follows:

\[
\text{Total carbohydrate (\%) = (100 - (Moisture + Ash + Crudeprotein + Crudefat))%}
\]  

(2)

The gross energy was calculated from protein, fat, and carbohydrate values, as follows:

\[
\text{Gross energy (kcal/100g) = (4 \times \text{protein (\%)}) + (4 \times \text{Carbohydrate (\%)}) + (9 \times \text{fat(\%)})}
\]  

(3)

The pH value of the reconstituted egg powder was measured with a digital pH meter (Type H1 98106, HANNA, UK). Water activity (aw) of the egg powders was measured according to the method described by Koç.\(^{[13]}\) using a water activity measurement device (Wert-Messer, Germany) (±0.001 sensitivity).

**Mineral composition**
The concentration of the macro-minerals (calcium, potassium, sodium, magnesium, and phosphorus) and micro-minerals (iron, zinc, copper, and manganese) was determined using the official method of AOAC,\(^{[15]}\) code 923.03. Briefly, 1 g of egg powder was ashed using muffle furnace (Carbolite, Aston Lane, Hope, Sheffield s30 2RR, England) at 550°C for 4 h. The ash was dissolved in 5 mL of 6M HCl. Subsequently, 15 mL of 3M HCl was added and heated until the solution boiled. The digested sample was cooled, filtered, and adjusted to the required volume using demineralized water. The mineral concentration was determined using atomic absorption spectrophotometer (AAS 4200, Agilent, USA). Phosphorus was determined using UV-Vis spectrophotometer (JENWAY 6300, UK) at 690 nm, according to the AOAC method (AOAC 965.17).\(^{[14]}\)

**Aerated and tapped bulk densities**
The aerated and the tapped bulk density of the egg powder were determined by placing 20 g of egg powder in a 100 mL graduated cylinder as described in Jinapong et al.\(^{[16]}\) The densities were calculated by dividing the mass of the powder by the volume occupied in the cylinder with and without tapping, as follows:

\[
\text{Bulk density (g/mL) = \frac{\text{weight of sample}}{\text{volume of sample occupied the space}}}
\]  

(4)

\[
\text{Tapped density (g/mL) = \frac{\text{weight of sample}}{\text{volume of sample after tapping}}}
\]  

(5)
Flowability
Flowability of the egg powders was evaluated according to Carr\textsuperscript{[17]} in terms of Carr index (CI), calculated from the bulk densities of the powder, as follows:

\[ CI = \frac{(\text{aerated density} - \text{Tapped density})}{\text{Tapped density}} \times 100 \]  

(6)

Foaming capacity (FC)
Whole egg powder (1 g) was mixed with 50 mL distilled water in a waring blender (Model WB-1, England), and the suspension was whipped at 494 x g for 5 min. The mixture was then poured into a 100 ml measuring cylinder and volume was recorded.\textsuperscript{[18]} The foaming capacity of the egg powder was calculated as follows (Equation 7):

\[ FC(\%) = \frac{\text{Volume after whipping (ml)} - \text{Volume before whipping (ml)}}{\text{Volume before whipping (ml)}} \times 100 \]  

(7)

Emulsification capacity
Emulsification capacity of the egg powder samples was determined using the method described by Ownwuka and Onwuka.\textsuperscript{[19]} Briefly, 2 g powder was blended with 25 mL distilled water at 28°C and was centrifuged (Model Tx425, England) at 494 x g for 30s. Then, 25 ml groundnut oil was gradually added, blended for another 30s, and centrifuged at 494 x g for 5 min. The emulsification capacity of the egg powder was calculated as follows:

\[ \text{Emulsification capacity(\%)} = \frac{B}{A} \times 100 \]  

(8)

where A referred to the height (mm) of the whole solution in a tube and B the height of the emulsified layer without separation.

Water absorption capacity (WAC)
Water absorption or hydration capacity of the egg powder was determined as described by Onwuka.\textsuperscript{[19]} One-gram egg powder was weighed into a conical graduated centrifuge tube, and 10 mL distilled water was added and centrifuged (Model Tx425, England) at 4821 x g for 30 min. Then, allowed to stand for 30 min. The free water volume (W) and weight of tube before mixing with water (Wb) and after decanting (Wd) were recorded. The WAC was calculated as follows:

\[ \text{WAC(ml/g)} = \frac{W}{Wd - Wb} \]  

(9)

Oil absorption capacity (OAC)
The oil absorption capacity of the egg powders was determined by centrifugation method as described by\textsuperscript{[19]} Briefly, 1 g of the powder was mixed with 10 mL of sunflower oil in 50 mL centrifuge tubes. The dispersions were occasionally vortexed while held at 22 ± 1.0°C for 30 min., followed by centrifugation for 30 min. at 1736 x g (Model Tx425, England). The following equation was used to calculate the OAC after weighing the decanted supernatant and the volume of the oil absorbed:

\[ \text{OAC(\%)} = \frac{\text{Volume of oil absorbed (mL.)}}{\text{weight of decanted supernatant (g)}} \times 100 \]  

(10)
**Soluble protein content (SPC)**

The SPC was determined according to the method described by Franke & Kiebling.\(^{[20]}\) Briefly, 2 g of egg powder was reconstituted with 0.3M NaCl solution to obtain a protein concentration of 0.7 mg/mL and a pH value of 7.0. The mixture was stirred for 2 h. at temperature 22 ± 1.0°C, centrifuged for 20 min at 27,771 x g to sediment insoluble proteins, and the protein content in the soluble fraction was determined using the Kjeldahl method as described earlier. The SPC was calculated as follows:

\[
SPC (\%) = \frac{\text{Total amount of protein in the supernatant}}{\text{Total amount of protein in egg powder}} \times 100
\]

**Contribution to nutrient intake**

The potential contribution of the egg powder as an ingredient for complementary food was evaluated by comparing the nutrient contributions to the estimated nutrient requirements from complementary foods.\(^{[21]}\) The potential of egg powder as an alternative protein source in ready to use therapeutic food (RUTF) with the potential to fully or partly replace milk powder was also evaluated. The compositions in the egg powder were evaluated against protein recommendations in RUTF.\(^{[22]}\)

**Statistical analysis**

Results were expressed as means ± standard error. Comparisons between the two drying procedures and egg types were made using independent t-test. P-values < 0.05 were considered statistically significant. All analyses were conducted in triplicate and were analyzed using SPSS software version 22.0 (SPSS Inc. Illinois, USA).

**Results**

The weight of the egg powder obtained relative to the original weight (liquid egg) was 22–25% (Figure 1). Considering an average moisture content of liquid egg being ~75% (as measured), this suggests that the yield was >97%. Comparing oven to spray drying, the yield was slightly lower for spray drying (P < .05) but drying was more rapid than oven drying. The drying of eggs from the local breeds led to a slightly better yield than the eggs from the exotic breeds, irrespective of the drying procedure applied.

A moisture content of <5% was obtained for all the whole egg powders (Table 1). Spray drying led to a powder with lower moisture content than oven drying. Egg powder obtained from exotic breeds had slightly higher moisture content than the local ones, irrespective of the drying procedure (P < .05). All the egg powders had a low water activity of 0.4 and an alkaline pH (7.5–8.5). Irrespective of the egg varieties, the bulk density was lower in the spray – than in the oven-dried egg powders (p <.05).

For the spray dried product, the aerated bulk density was significantly higher in the local breed eggs, but the reverse was true for tapped bulk density (P < .05). The highest flowability was observed for spray drying of exotic breed eggs. There was no significant difference in foaming capacity by drying and egg type (P > .05). The average emulsion capacity was 55 mL/g with slight, but significant difference between local and exotic for oven drying. The oil absorption capacity was between 0.9 (oven dried local) to 1.2 (oven/spray dried exotic). The soluble protein content ranged between 47 (spray dried exotic) and 52% (oven dried exotic). Differences in soluble protein by egg types were only significant for oven drying (P < .05).

The proximate composition of the egg powders is presented in Table 2. The energy content (/100 g) of the egg powders ranged between 565 kcal (exotic-spray dried) and 579 kcal (local-spray dried). Drying only affected the energy content of the egg powder from the local breed. The energy content of the egg powder from the local breed was significantly higher than the exotic breed, irrespective of drying types. The protein content (/100 g) ranged between 44 and 48 g and was higher in the egg powder obtained from the exotic than the local breed. In contrast, fat content was significantly higher
in the egg powder obtained from local breeds. The fat content ranged between 36 g/100 g in the exotic and 39 g/100 g in the local spray-dried products. The utilizable carbohydrate was significantly higher in spray- than in oven-dried powders (P < .05).

The macro- and trace-mineral composition of the whole egg powders are presented in Table 3. The minerals are not disaggregated by drying type as this has no effect on mineral content. No significant differences between egg powders from local and exotic breeds were observed for calcium, magnesium, potassium, sodium, iron, zinc and copper. Phosphorus and Manganese were however significantly higher in the egg powder obtained from the exotic than from the local breeds (P < .05).

The nutritional contribution of whole egg powder (1 egg equivalent) relative to the proposed nutrient requirements from complementary foods is reported in Table 4. Among the studied nutrients, except for manganese and zinc, a one egg equivalent egg powder contributed to >50% of the proposed daily requirement from complementary foods. This same amount of egg powder can contribute ~200% of the required protein, suggesting that even 6 g of dried product (half an egg) can allow children meet their protein requirements. The equivalent of one egg provided in the form of egg powder (12.5 g) can contribute more than 75% and 30% of the fat and energy requirements, respectively.

**Discussion**

The present study evaluated the effect of spray and oven-drying of local and exotic eggs on physical, techno-functional, and nutritional composition of egg powders. The energy and fat content of the local eggs were significantly higher than the exotic eggs, whereas the exotic eggs had higher protein content. The spray drying of both egg types resulted in whole egg powders with optimal physical and techno-functional properties as reflected by the low water activity, >97% yield, and high nutrient composition. Egg powders can significantly contribute to meeting energy and nutrient requirements.

Although some differences were observed by drying method and egg type, the low moisture and water activity of the whole egg powders confirm the anticipated advantage of extending the shelf-life. At such low moisture and water activity, the powders are less susceptible to microbial growth. The drying of eggs can extend the shelf-life of eggs from two weeks (unprocessed eggs) to 6–12 months at ambient...
temperature [24]. The high yields obtained (>97% of the liquid egg recovered), complemented with economies made in the transportation costs related to the removal of water that accounts 75% of the egg’s weight, and the requirement of lesser space for storage of the dried egg could contribute to making eggs more affordable. This in the long run can increase demand and provide incentives for increasing egg production, since barriers like low demand and high transaction costs are part of the reasons why supply is low in low income countries. [25] However, this warrants detailed cost-benefit analyses.

Although spray drying is the preferred method for processing whole egg powders with better flowability as confirmed by our findings, the results from oven-drying was also promising and suggests that in the absence of advanced technologies, oven-drying can be a good alternative. [26] However, long-term evaluation of the shelf-stability of the egg powders and the cost of production (e.g. time/energy consumption) is needed. The emulsion as well as water and oil absorption capacity were similar for both egg types, but with slightly higher values for the spray-dried product. These functions are useful, particularly when egg powders are used as ingredients in other food matrices. The high

**Table 1.** Techno-functional properties of egg powder obtained from spray- and oven-drying of whole eggs from local (Ethiopian) and exotic (imported) chicken breeds.

| Whole egg powder | Local | Exotic |
|------------------|-------|--------|
| **Moisture (g/100 g)** | 3.6 ± 0.0<sup>ab</sup> | 4.3 ± 0.1<sup>aA</sup> |
| Oven | Spray |
| Water activity (a<sub>w</sub>) | 0.5 ± 0.0<sup>aA</sup> | 0.5 ± 0.0<sup>aA</sup> |
| Oven | Spray |
| pH | 7.5 ± 0.0<sup>ab</sup> | 8.6 ± 0.0<sup>aA</sup> |
| Oven | Spray |
| Aerated bulk density (kg/m<sup>3</sup>) | 501.9 ± 5.3<sup>aA</sup> | 500.1 ± 0.1<sup>aA</sup> |
| Oven | Spray |
| Tapped bulk density (kg/m<sup>3</sup>) | 632.0 ± 11.6<sup>ab</sup> | 666.8 ± 0.2<sup>aA</sup> |
| Oven | Spray |
| Flowability (%) | 20.6 ± 0.7<sup>bB</sup> | 25.0 ± 0.0<sup>ba</sup> |
| Oven | Spray |
| Foaming capacity (%) | 31.2 ± 0.9<sup>aA</sup> | 33.9 ± 0.9<sup>aA</sup> |
| Oven | Spray |
| Emulsion capacity (%) | 55.1 ± 1.2<sup>ab</sup> | 56.8 ± 2.4<sup>aA</sup> |
| Oven | Spray |
| Water absorption capacity (mL/g) | 1.5 ± 0.1<sup>ab</sup> | 1.6 ± 0.1<sup>ba</sup> |
| Oven | Spray |
| Oil absorption capacity (mL/g) | 0.9 ± 0.0<sup>ab</sup> | 1.2 ± 0.1<sup>ba</sup> |
| Oven | Spray |
| Soluble protein content (%) | 49.6 ± 0.2<sup>ab</sup> | 51.7 ± 0.1<sup>aA</sup> |
| Oven | Spray |

Values are expressed as mean ± SE (n= 3). The different lowercase letters in the same column and different capital letters in the same row within same parameter denote significant differences (P < 0.05) in mean comparisons using student’s independent t-test.
emulsion and oil absorption capacity as observed in our case, suggests that a homogenous mix with other ingredients is possible.[27] The high foaming capacity also suggests that the drying process did not induce significant denaturation of proteins.[28,29]

The findings from the proximate and mineral composition illustrated the potential of egg powders to contribute to meeting the high nutritional requirements of children. A key constraint in the formulation of nutrient-dense complementary foods is related to the very low gastric capacity of children.[30] This requires packing as much nutrients as possible in a small quantity/volume of food. An equivalent of one egg, in the form of egg powder (~12.5 g) can fulfill >75% of fat, >30% of energy, and close to half of the calcium requirements from complementary foods (6–23 months). With just 6 g of whole egg powder (half of a fresh egg), the protein requirements can be fulfilled, and with only ~4 g (about 1/3 of an egg = 49 mg choline),

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**Table 2.** Proximate composition (g/100 g) of egg powder obtained from spray- and oven-drying of whole eggs from local (Ethiopian) and exotic (imported) chicken breeds.

|                     | Local       | Exotic      |
|---------------------|-------------|-------------|
| **Moisture (g/100 g)** |             |             |
| Oven                | 3.6 ± 0.0^b| 4.3 ± 0.1^a|
| Spray               | 2.6 ± 0.1^b| 3.4 ± 0.0^a|
| **Energy (kcal/100 g)** |           |             |
| Oven                | 572.8 ± 0.9^bA| 567.7 ± 1.6^bB |
| Spray               | 579.3 ± 1.5^bA| 564.9 ± 1.4^bB |
| **Protein (g/100 g)** |             |             |
| Oven                | 45.2 ± 0.1^aB| 47.5 ± 0.4^aA |
| Spray               | 44.3 ± 0.3^bB| 45.9 ± 0.2^aB |
| **Fat (g/100 g)**   |             |             |
| Oven                | 38.3 ± 0.2^bA| 37.4 ± 0.3^aB |
| Spray               | 39.1 ± 0.4^aA| 36.3 ± 0.3^bB |
| **Utilizable carbohydrate (g/100 g)** |       |             |
| Oven                | 11.8 ± 0.1^bA| 10.2 ± 0.7^bB |
| Spray               | 12.6 ± 0.3^bA| 13.6 ± 0.2^bA |

Values are expressed as mean and their standard errors (mean ± SE; n = 3). The different lowercase letters in the same column and different capital letters in the same row within same parameter denote significant differences (P < 0.05) in mean comparisons using student’s independent t-test.

**Table 3.** Macro- and trace-mineral composition of whole egg powder from Ethiopian local and exotic egg varieties.

|                     | Local       | Exotic      |
|---------------------|-------------|-------------|
| **Macro-minerals**  |             |             |
| Calcium             | 326.0 ± 0.5^a| 341.0 ± 0.4^a |
| Magnesium           | 92.0 ± 0.1^a| 82.0 ± 0.0^a |
| Potassium           | 834.0 ± 0.0^a| 818.0 ± 0.1^a |
| Sodium              | 457.0 ± 0.0^a| 488.0 ± 0.5^a |
| Phosphorus          | 143.0 ± 0.1^b| 181.0 ± 0.1^b |
| **Trace-minerals**  |             |             |
| Iron                | 11.0 ± 0.0^a| 14.0 ± 0.0^b |
| Zinc                | 1.18 ± 2.5^a| 1.19 ± 1.5^a |
| Copper              | 0.27 ± 0.2^a| 0.26 ± 0.3^a |
| Manganese           | 0.12 ± 0.1^a| 0.16 ± 0.1^b |

Values are expressed as mean ± SE (n = 3). The different lowercase letters in the same row denote significant differences (P < 0.05) in means between local and exotic, using student’s independent t-test.
Table 4. Contribution of whole egg powder to selected nutrients requirements from complementary foods

|                | Requirements\(^b\) | Local | Exotic |
|----------------|-------------------|-------|--------|
| Energy (kcal)  | 220               | 34    | 33     |
| Protein, g     | 3–5.5             | 190   | 196    |
| Fat, g         | 6.3               | 80    | 74     |
| Calcium, mg    | 100–200           | 42    | 44     |
| Copper, µg     | 200–400           | 26    | 17     |
| Iron, mg       | 7.0–11.0          | 20    | 26     |
| Manganese, mg  | 0.6               | 5     | 3      |
| Phosphorus, mg | 75–100            | 24    | 31     |
| Zinc, mg       | 4.0–5.0           | 4     | 4      |

1 egg equivalent ~12.5 g

CF, complementary foods; \(^b\) requirements are based on proposed composition of complementary foods described in Dewey & Lutter (2003)

100% of choline requirements (45.9 mg) can be fulfilled. In addition, the easiness to mix the egg powder into children’s meal could encourage mothers to feed children eggs during the Ethiopian Orthodox fasting periods, as they would not have to worry about contaminating utensils.\(^{31}\)

The high protein content with comparable, if not superior, protein digestibility corrected amino acid score (PDCAAS) and the high choline content that is a precursor for the synthesis of insulin-like growth hormone 1 (IGF1),\(^{31}\) suggests that egg powder meet protein requirements for RUTFs and hence could be an ideal candidate to replace milk powder in future formulations.\(^{32}\) The oil absorption capacity and emulsion capacity also suggest the techno-functional feasibility of such replacement. However, more studies including non-inferiority clinical trials that evaluate recovery from malnutrition from egg-based RUTFs are needed.

The present study has several strengths and limitations. To our knowledge, this is the first study analyzing the nutritional composition and functional property of local (Habesha) eggs and comparing it to exotic eggs for which data is ample. The drying of whole egg powder using two alternative drying procedures, one suitable for industrial and the other for smaller scale (including household-level processing) and the evaluation of the contribution of egg powder as an ingredient in complementary foods and RUTFs is of direct application and can inform a much needed food systems’ interventions in countries like Ethiopia. The study could not, however, analyze all relevant nutrients because of technical and financial constraints. Changes in the amino acid composition, vitamins, the integrity of the proteins, and the stability of the techno-functional and nutritional properties during storage will need to be studied further.

Notwithstanding the above limitations, the present study illustrates that both spray- and oven-drying of local and exotic eggs yield good quality egg powders. The drying can also extend the shelf-life, reduce transportation cost and storage space, and contribute meaningfully to nutrient intake. Besides, with proper packaging and storage, it can improve food safety. Future studies should elucidate the differences observed by egg type and drying and investigate the shelf-life of the egg powders. The promotion of drying of eggs into powder can constitute a food systems’ intervention that can improve the quality of diets, reduce loss, and make eggs more affordable in LMICs like Ethiopia.

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