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Physical, Functional and Sensory Properties of Foam Mat Dehydrated Whole Egg Powder

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Authors' contributions

This work was carried out in collaboration between all authors. Author COO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors IBI and MES managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Two types of edible eggs were subjected to foam-mat dehydration to determine properties of the egg powder. Both fresh local and poultry eggs (LE and PE, respectively) were obtained from Anyigba, Nigeria, separately prepared into whole liquid egg of stable foam by whipping and dried (60℃) in tray dryer. Then, milled into powder (180 µ size), packaged and kept under refrigeration for physical, functional property, sensory evaluation and statistical data analysis using standard methods. Foaming capacity of liquid egg (LE and PE) ranged from 20.1%–20.5%, and corresponding egg powder, 17%–18.2%. Egg powder bulk density (0.45–0.62 g/mL), local egg sample with greater value. Water absorption capacity (7.8–8.0 mL/g powder), poultry egg showing higher value, which did not seem to affect its reconstitution. The wettability values (2.5–8.2s range) showed significant variation ($P<0.05$). Colour of reconstituted boiled local egg powder was rated higher (6.10), so also the texture (6.71), flavour (6.64), taste (6.57) and mouthfeel (6.45) of boiled

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poultry egg. Reconstituted fried poultry egg powder has higher texture, colour, flavor, mouthfeel scores and lower taste than local egg powder. Apparently, more desirable properties of foam–mat dried poultry egg powder, suggest its suitability for different food applications.

Keywords: Edible eggs; foam drying; egg powder; functional and sensory properties.

1. INTRODUCTION

Egg is an animal based product, laid by different species (birds, fish, reptiles, amphibians). Bird's eggs, especially those produced by local hens (Galosgalos domesticus, local specie) and poultry layers, are consumed by humans and a typical egg has balanced nutrients. Local egg (proteins, 13.49%; fat, 10.52%; carbohydrate, 3.85%; vitamins, 7.25%), and poultry (proteins, 13.7%; fat, 12.68%, carbohydrates, 5.05%, vitamins, 6.19%). An egg is a source of complete amino acids. Unfortunately, raw egg has short shelf-life (2–3 weeks) at the tropical ambient conditions, and a little extended under refrigeration storage [1]. The use of different processing techniques for eggs, such as pasteurization, canning, dehydration and, fermentation, has been severally reported to produce egg products which are quite shelf stable and convenient to use [2]. Again, dehydration of egg by spray and drum drying has been shown to be associated with high energy input costs and is not technologically feasible for commercialization. Foam–mat drying which involves controlled whipping of liquid concentrate (25–35% solids) to form stiff foam with the aid of foam agent, then spread on tray and dried under low temperature in a stream of warm air has been shown to be a suitable alternative drying option for food. It enhances flavour, colour and nutrients retention, as well as excellent reconstitution properties of product (examples include foam – mat dried fruit powder, milk powder, kunun zaki and yoghurt powder extra). It also requires low energy and labour inputs and is easy to run and operat [3]. Sources of suitable foam agents for drying food include; glyceryl monostearate, monoglyceryl palmitate, methylcellulose, soy protein isolate and egg white as reported by many researchers [4,5,6]. Fortunately, the availability of albumin in liquid whole egg serves as a natural foam agent for drying whole egg and hence, would require no synthetic source of foam agent [7,8]. High quality egg powder has several applications in food and food related systems, such as confectioneries, baked goods, baby food and food beverages [9]. Therefore, the objective of this study was to produce and characterize the physical and functional properties of foam – mat dried whole egg powder (local hens and poultry layer's eggs) for standardization purpose and also evaluate the sensory attributes to ascertain suitability for different food applications.

2. MATERIALS AND METHODS

2.1 Materials

Fresh local eggs, LE (fertilized type from local hens) and poultry eggs, PE (unfertilized type from poultry layers), were obtained in Anyigba, Nigeria. Also, sodium metabisulphite (sms) as a preservative to prevent egg discoloration and calcium triphosphate as anticaking agent were obtained from a reputable food chemical store Lagos, Nigeria.

2.2 Liquid Whole Egg Preparation

Local eggs (LE) with an average of 63% egg white (albumin) content and poultry egg (PE) containing 58% albumin on the average, were separately prepared into liquid whole egg, with added sodium metabisulphite (0.02 g/100 g liquid egg) thoroughly mixed manually in a plastic bowl for use.

2.3 Foaming of Liquid Egg by Whipping and Drying Operation

Each prepared sample of liquid whole egg (LE and PE) in a mixer (Kenwood, model BL3) was whipped (600 rpm, 32 – 35℃) for 10 mins (in a previous preliminary work by the researchers 5, 7.5, 10 and 12.5 mins whipping durations were investigated and 10 mins produced the largest volume increase, and, therefore, whipping for 10 mins, was used in this study), [10]. The foamed liquid egg was spread thinly (0.5 – 1.0 mm thickness) on a tray and dried in a laboratory tray dryer (Bench Series Model) with fan at 60℃ for 5 hrs to a constant mass and scrapped. It was then incorporated with calcium triphosphate as an anticaking agent (0.05% of scrapped mass), dry milled (150 – 180 micron particle size), packaged in heat sealed HDPE (0.22 mm gauge) bag and, kept under refrigeration not longer than 2 weeks before use (for physical, functional and sensory property assessment).

2.4 Physical/Functional Property and Moisture Content Analysis

2.4.1 Foaming capacity determination

Foaming capacity of raw liquid egg and egg powder samples were each determined according to the method described [9]. Two grams powder (2.67 g raw egg equivalent of 2.22 mL volume). Sample was blended as applicable with 100 mL distilled water in a warring blender, (England, Model WB-1), and the suspension whipped at 1,600 rpm for 5 minutes. The mixture was then poured into a 150 mL, measuring cylinder and volume recorded after 30 mins.

Foaming capacity (%) = Vol. after whipping (mL) – vol. before whipping (mL) x 100/ vol. before whipping (mL).

It is expressed as percent (%). Average triplicate determinations were taken.

2.5 Bulk Density Determination

The bulk density of each sample of egg powder was determined according to method described by [5]. It is the ratio of unit mass (g) of egg powder to the volume (mL) it occupies, expressed as g/mL. For each sample, average value of triplicate determinations was recorded.

2.6 Water Absorption Capacity Determination

Water absorption or hydration capacity was determined as described by [7]. One gram egg powder was weighed into a conical graduated centrifuge tube, 10 mL distilled water added, mixed and, centrifuged (in centrifuge tube Model Tx425 made in England) at 5,000 rpm for 30 mins. Then, it was allowed to stand for 30 mins, free water volume was recorded and weights of tube before mixing with water and after decanting were recorded. Water absorption capacity (mL/g) = Volume of water absorbed (weight of water absorbed. g) = Wt of tube after decanting (g)-Wt of tube before mixing with water (g) (Note: density distilled water=1g/mL)

Water absorption capacity is expressed as mL water/g powder. Triplicate measurements made for each powder and average recorded.

2.7 Reconstitution Ratio Determination

The method described by [5] was used. One gram egg powder was collected in a crucible and water added in ratios (1:1, 1:2, 1:3, 1:4, 1:5, 1:6, 1:7, 1:8) gradually to make the mixture have the same consistency with that of fresh liquid whole egg by observation. The appropriate ratio of powder: water to make, it resemble original fresh liquid whole egg is the reconstitution ratio and, therefore, recorded for each sample. Three measurements were made and the average value taken.

2.8 Wettability Determination

The method described by Stadelman was used to determine wettability of egg powder samples [9]. One gram egg powder was weighed into 20 mL graduated cylinder with diameter 1.0 cm. Hand palm was placed over the open end and then inverted, and clamped at a 10.0 cm height from the surface of a 600 mL beaker containing 500 mL distilled water. The finger was removed and sample allowed to drop. The time taken for the sample to become wet was recorded as wettability. Three determinations for each sample were made and an average value recorded.

2.9 Emulsification Capacity Determination

Each egg powder sample was subjected to emulsification capacity determination as described [7]. Two grams powder was blended with 25 mL distilled water at 28±2℃, for 30s, at 1,600 rpm. Then 25 mL groundnut vegetable oil was gradually added, blended for another 30s, then transferred into a centrifuge tube (Model Tx 425) and centrifuged at 1,600 rpm for 5 mins. Height of whole solution in tube (Amm) and height of emulsified layer, with no separation (Bmm) were taken.

$$\text{Emulsification capacity (\%)} = \frac{\text{B mm x 100}}{\text{A mm}}$$

Triplicate determinations for each sample were made and the mean value recorded.

2.10 Gelation Capacity Determination

The gelation capacity of each egg powder sample was determined as described by [7]. Sample suspensions (2% - 20% W/V) were prepared each into 5 mL distilled water in a test tube, heated for 1hr in a boiling water bath, cooled rapidly under running cold tap water, then cooled further at 4℃ for 2 hrs in the freezer. The least gelation concentration (%) was then determined (as that concentration when the sample from inverted test tube did not fall or slip). An average of 3 determinations was taken in each case.

2.11 Moisture Content Determination

Moisture content of samples were determined using oven drying method as described by [7]. Oven dried evaporating dish was weighed, 5 g powder was added, transferred to hot air electric oven (Model J. 02707 Michel, England) set at 105℃ for 3 hrs, cooled in desiccators for 1 hr and weighed.

% Moisture content (dry weight basis) = Loss in sample weight as moisture (g) X 100/Original sample weight (g) – Loss in weight (g)

Triplicate values were obtained for each sample.

2.12 Sensory Evaluation of Egg Powder (Reconstituted, Boiled and Fried) and Data Analysis

Each sample of egg powder was reconstituted in water (powder: water being 1:3) at 28±2℃, and then divided into two portions. One part was packaged in low density polyethylene (0.11 mm, gauge) and boiled for 10 mins in a boiling water bath, and the control sample (liquid egg) similarly boiled. The second part was fried using grand vegetable oil into omelet egg as well as control sample. Each of pouched and omelet egg sample was then presented for sensory attributes assessment (colour, flavour, texture, taste, mouth feel), involving ten untrained panelists who are familiar with eating boiled and fried egg using a 7–point hedonic scale rating [11]. Sensory scores were subjected to statistical analysis, using ANOVA and Tukey’s least significant difference method of mean separation.

3. RESULTS

3.1 Some Physical Attributes, Functional Properties and Moisture Content of Foam-Mat Dried Egg Powder

The foaming capacity values (liquid and powdered egg), bulk density, water absorption or hydration capacity, reconstitution ratio, wettability, gelation and emulsification capacities and moisture content of egg powder samples are shown in Table 1.

The foaming capacities of raw liquid whole egg (both local and poultry) had similar values (20.1%–20.5% range). While the corresponding foaming capacity of foam-mat dried egg powder were also similar (17%–18.2% range), but found to reduce by about 10% when compared with the value for raw liquid egg irrespective of the type.

Bulk density values ranged from 0.45-0.62 g/mL, with sample LE showing the greater value (0.62 g/mL). Water absorption capacities for LE and PE samples were 7.8 and 8.0 mL/g, respectively and a higher value for PE did not seem to affect reconstitution ratio of the egg powder samples [9].

Table 1. Some physical, functional properties and moisture content of foam–mat dried egg powder samples

Physical/Functional property	Sample LE	Sample PE
Foaming capacity (%)		
Before drying	20.1±0.02	20.5±0.02
After drying	17±0.01	18.2±0.01
Bulk density (g/mL)	0.62±0.01	0.45±0.02
Water absorption cap. (mL/g)	7.8±0.02	8.0±0.02
Reconstitution ratio (powder: water)	1:3	1:3
Wettability (s)	8.2±0.02	7.5±0.03
Gelation capacity (%)	6.0±0.11	5.0±0.08
Emulsification capacity (%)	44.8±0.15	32.0±0.11
Moisture (%) d.b	5.1±0.01	4.8±0.02

Values represent average of 3 determinations ± SEM. Sample codes: LE (eggs from local hens), PE (eggs from poultry hens) and SEM (standard error of the mean)

Reconstitution ratio (powder: water) value of 1:3 was the same for both LE and PE samples. Wettability values also ranged from 7.5 – 8.2 s, which is quite low and showed no significant variation among both egg powder samples. Emulsion capacity of 44.8% and 32.00% for LE and PE respectively, were obtained. Also, LE and PE powders had gelation capacities of 6.0% and 5.00%, respectively. Moisture contents, db of 5.1% and 4.8% for LE and PE powder, respectively were obtained.

3.2 Sensory Quality Properties of Whole Egg Powder (Reconstituted Boiled and Fried Products)

3.2.1 Reconstituted boiled egg powder (Pouched egg)

Table 2 shows the mean sensory scores of reconstituted boiled egg powder samples: local egg powder (LEP) and poultry egg powder (PEP) and the control.

The average colour ratings of boiled LEP and PEP are 6.10 and 5.86, respectively and the control, 6.05 – 6.55 without any detectable significant difference ($p<0.05$). The mean texture scores of foamed LE and PE (6.40 and 6.71, respectively) were found to be slightly lower than the control samples (6.70), which did not constitute any significant difference ($P<0.05$). The flavour of foamed egg powder (LEP and PEP) had high mean scores of 6.55 and 6.15, respectively, while 6.64 and 6.54 mean values were obtained for their respective taste. The raw liquid egg samples, that is local egg liquid (LEL) and poultry egg liquid (PEL) had similar flavour and taste mean scores as the corresponding powder product. Foamed poultry egg powder (PEP) sample had mouthfeel average rating of 6.45, local egg powder (LEP), 6.20 and control sample with 6.38 mean score.

3.3 Reconstituted, Fried Egg Powder (Omelet Egg)

The mean sensory scores for reconstituted fried egg powder samples are shown in Table 3. The colour rating of reconstituted fried PEP (6.25) was slightly greater than LEP sample (5.95) and both had similar ratings as the respective control samples (LEL and PEL) with attractive brownish – yellow colour and no significant difference ($p<0.05$) detected among the experimental and control egg powder samples. Samples LEP and PEP had texture rating of 6.30 and 6.38, respectively while the control had texture rating of 6.72 – 6.90. The flavour rating of sample LEP (5.95) was lower than that of PEP (6.05) as well as the, mouthfeel rating (5.83) while LEP has higher taste rating (6.90) even greater than the control of both egg powder samples (6.85 and 6.05) mean scores.

4. DISCUSSION

There was slight reduction of about 10% in the foaming capacity of foam – mat dried egg powder (LE and PE samples), due to heat effect during drying which must have slightly affected the albumin protein (egg white) that is responsible for the egg foam formation. For dried egg powder, it has been reported that drum drying greatly affected foaming capacity due to high temperature exposure (Wet heat), though for a short time and, therefore, foam-mat drying at low temperature is preferable. Greater bulk density of local egg powder (Sample LE) is an indication of bulkier particle which might be

Table 2. Mean sensory scores of reconstituted boiled whole egg powder and control sample (boiled whole liquid egg)

Sensory	Samples			
Attribute	**LEP**	**LEL**	**PEP**	**PEL**
Colour	$6.10^{a}\pm0.13$	$6.00^{a}\pm0.11$	$5.86^{a}\pm0.11$	$6.35^{a}\pm0.21$
Texture	$6.40^{b}\pm0.09$	$6.55^{b}\pm0.22$	$6.71^{b}\pm0.82$	$6.85^{b}\pm0.15$
Flavour	$6.55^{c}\pm0.16$	$6.85^{c}\pm0.09$	$6.64^{c}\pm0.63$	$6.77^{c}\pm0.32$
Taste	$6.15^{d}\pm0.11$	$6.45^{d}\pm0.18$	$6.57^{d}\pm0.64$	$6.42^{d}\pm0.18$
Mouthfeel	$6.20^{e}\pm0.30$	$6.67^{e}\pm0.20$	$6.45^{e}\pm0.22$	$6.38^{e}\pm0.20$

Values represent means of 10 determinations, ± SEM. Means in a row with the same superscripts are not significantly different (P<0.05).
Sample Codes: LEP: Local egg powder, PEP: Poultry egg powder; LEL: Local egg liquid; PEL: Poultry egg liquid (control)

Table 3. Mean sensory scores of reconstituted fried whole egg powder and control samples (liquid egg)

Sensory	Samples			
Attribute	**LEP**	**LEL**	**PEP**	**PEL**
Colour	$5.95^{b}\pm0.21$	$6.50^{b}\pm0.10$	$6.25^{b}\pm0.08$	$6.85^{b}\pm0.10$
Texture	$6.30^{a}\pm0.15$	$6.72^{a}\pm0.11$	$6.38^{a}\pm0.20$	$6.90^{a}\pm0.18$
Flavour	$5.95^{c}\pm0.09$	$6.38^{c}\pm0.12$	$6.05^{c}\pm0.32$	$6.45^{c}\pm0.26$
Taste	$6.90^{d}\pm0.01$	$6.85^{d}\pm0.08$	$5.88^{d}\pm0.11$	$6.05^{d}\pm0.20$
Mouth feel	$5.85^{e}\pm0.10$	$6.35^{e}\pm0.08$	$6.40^{e}\pm0.06$	$6.50^{e}\pm0.02$

Values represent average of 10 determinations, $\pm$SEM. Means in a row with the same superscripts are not significantly different ($p<0.05$).

Sample codes: LEP: Local egg powder; LEL: Local egg liquid (control); PEP: Poultry egg powder; PEL: Poultry egg liquid (control)

attributable to the egg yolk content of whole egg. Higher water absorption capacity of PE powder than LE sample is due to its slightly lower moisture content (4.8%, db), which did not affect egg powder reconstitution. However, the hydration capacity values for both LE and PE powders fall within the range already reported for drum dried egg powder [9].

The application of reconstitution ratio of 1:3 (powder: water) that was obtained for both LE and PE samples to make reconstituted egg powder that resembled the original raw liquid whole egg, which was not affected by the type of egg, shows that foam – mat drying technique is quite suitable for liquid egg.

The low wettability values (7.5 – 8.2 s) of egg powder samples (LE and PE) which showed no significant variation ($P<0.05$) among the samples is an indication of good reconstitution property which is desirable for food applications, as also shown by other investigators [9]. Low gelation capacity of egg powder (LE and PE) shows high protein quality in which low concentration of egg white experienced gelation (emulsion formation). This good gelation property would make foam-mat dried egg powder a desirable emulsifying agent. This is also revealed by greater emulsification capacity (44.8%) of local egg; sample LE, which has higher gelation capacity (6%) than poultry egg (PE sample) of lower emulsification capacity, (32%). Low moisture contents of egg powder samples (4.8 – 5.1% range) indicates low water activity which would ensure good keeping quality when packed in moisture and gas proof package with hermetic sealing. Apparently, powders of moisture contents not greater than 8% have been reported to have appreciable shelf-life under proper packaging and storage [12,13].

The colour of boiled LEP and PEP samples is similar and quite comparable to the control (boiled liquid whole egg). This shows that foam-mat drying seemed not to affect the colour of reconstituted boiled egg powder. Similarity in the flavour/taste of raw liquid egg samples (LEL and PEL) and reconstituted, boiled egg powder (LEP and PEP) due to low temperature drying which enhanced the retention of volatile egg flavour constituents and original taste.

It was also found that foamed poultry egg powder (PEP) sample received higher mouthfeel rating than both the control (PEL/LEL) and foamed local egg powder (LEP) probably attributable to the characteristic finer structure of PEP due to the absence of any fibrous material. Similar attractive brownish – yellow colour of reconstituted, fried egg powder (PEP and LEP) and the control samples (LEL and PEL) is due to the normal maillard reaction (non-enzymatic) and not caramelization of sugars in egg, showing that foam-mat drying did not constitute any negative effect on the colour of egg powder. Fried sample LEP had lower texture rating than PEP, while control samples showed highest texture rating, which, however, did not constitute any significant difference ($p<0.05$). Frying might contribute to high – uniform texture of fried egg and not the drying process. The superior taste of fried local egg powder could be attributable to higher proportion of soluble solids content of egg yolk than that of poultry egg. Also, increased detectable flavour in PEP could be explained due to more fats contributed by feeding the poultry layers with compounded and refined poultry feeds, since chicken flavor profile has been shown to be associated with the fatty acid composition of its fats content which is slightly higher in poultry than local egg [14]. Generally, the colour, texture, flavour and mouthfeel sensory attributes of reconstituted fried poultry egg powder (PEP) are found to be more superior and would, therefore, command desirable industrial applications to different food and related systems.

5. CONCLUSION

Whole egg powder (local and poultry) was produced by foam-mat drying. The functional and sensory properties were determined for purpose of specification formulation, standardization and food application. Poultry egg powder has been shown to be more suitable than local egg as a potential industrial ingredient for various food applications based on desirable physical, functional and sensory attributes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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