

A Process Development, Nutritional Facts, Sensory Properties and Storage Stability of Shelf Stable Egg Cube

Deepthi P. Pawar, K. Rathina Raj and V.K. Modi
Meat Fish and Poultry Technology,
Central Food Technological Research Institute (CSIR), 570020 Mysore, India

Abstract: A shelf stable, convenience product whole Egg Cube (EC) was developed by incorporation of optimized quantities of wheat flour, corn starch, maltodextrin, soya protein in liquid egg. Dehydrated EC was packed in metalised polyester pouches, stored at ambient condition ($27\pm 2^\circ\text{C}$) for 6 months and sampled periodically for quality evaluation. The protein and fat content of dehydrated EC was $33.43\pm 2.10\%$ and 25.90 ± 1.95 , respectively. A good amount (mg/100 g) of calcium 125.21 ± 10.54 , iron 6.59 ± 0.88 and zinc 2.71 ± 0.17 was available in the product whereas vitamin A and cholesterol was $17.2\pm 0.23 \mu\text{g}/100 \text{g}$ and $289\pm 17 \text{mg}/100 \text{g}$, respectively. The shelf stability of the product was achieved by keeping a moisture content ($3.88\pm 0.43\%$) and water activity (0.36 ± 0.01) low. An excellent rehydration capacity ($78.16\pm 5.74\%$) was observed in the EC. Changes in free fatty acids, thiobarbituric acid, textural profile analysis and Hunter colour units (L, a and b) during storage did not affect the quality characteristics of the product. About 67% loss in carotenoid content was recorded during storage of the product. Standard plate count was $<1 \text{cfu g}^{-1}$. *Staphylococci aureus*, *E. coli*, Salmonella, Shigella, yeast and molds, however were not detected in any sample throughout the storage period. Sensory evaluation revealed that rehydrated whole egg cube had excellent egg flavour and texture. The EC had very high *in vitro* digestibility (88.32%) with highest PDCAAS score 1.00 for all the group of population.

Key words: Liquid egg, egg cube, rehydration, minerals, carotenoids, India

INTRODUCTION

Eggs are a rich and well-balanced source of essential nutrients for human diet composed by fatty acids, minerals, vitamins and proteins of high biological value. With these properties, eggs are one of the few products that are used throughout the world and therefore, the egg industry is an important segment of the world food industry. Therefore, egg considered particularly important in human nutrition and health. Research work by the South African Egg Board on new egg products, viz., egg and bacon patty, bite-sized egg snacks, frozen egg pizza and egg fingers (crumb-coated scrambled eggs and bacon bound by white sauce) has been reviewed by Willense (1991). Information is available on different egg products such as egg coated potato (Muller, 1994), premixed flavoured egg product (Wu *et al.*, 1995), egg flakes containing monosodium glutamate and onion/garlic extracts (Lee *et al.*, 1998), egg white chips containing stabilizers and flavouring (Yang *et al.*, 2000), formulated fried egg (Merkle *et al.*, 2003), egg loaf containing spices and refined wheat flour (Yashoda *et al.*, 2004), deep

fatfried egg albumen cube and egg yolk cube (Modi *et al.*, 2008) and egg chips containing millet fours (Yashoda *et al.*, 2008). Today's consumer needs products that are simple to prepare, convenient, healthy and rich in natural ingredients.

Hen's egg is one such ingredient that can provide all these benefits. It would also provide sufficient nutritional benefits to the health consciousness consumers who require whole proteins. However, although nutritional qualities are well documented, information on products using egg that would appeal to the consumer both nutritionally and sensorially are scanty.

Against this background, whole egg was used for the development of shelf stable Egg Cubes (EC). EC can be used in soups or in curry preparation similar to paneer in curry, a delicacy in Indian cuisine (Paneer is an acid and heat coagulated milk product used extensively in India for various culinary preparations).

The main objective of this research was to produce a dried product that is shelf-stable, shorter reconstitution time and microbiologically safe with minimal degradation of nutrients and sensory properties. The other objective

was to study its physico-chemical properties, textural quality, colour, microbiological, sensory acceptability and oxidation changes during storage at ambient temperature ($27\pm 2^{\circ}\text{C}$).

MATERIALS AND METHODS

Fresh hen eggs and binders viz; wheat flour and corn starch and foam stabilizer, defatted soya flour were procured from local market. Eggs were stored under chilled conditions whereas binders were stored in air tight glass containers for further use. The maltodextrin was supplied by HiMedia Laboratories Pvt. Ltd, Mumbai and a combination of acidulates (malic acid and citric acid) was used in formulation was supplied by Loba Chemie Ltd, Mumbai. The garlic powder was supplied by Venkatesh Food Industries, Chindwara. The appropriate optimized quantities of ingredients of EC are shown in Table 1.

Product preparation: Hen eggs were procured from local market. A batch of 100 eggs (50-55 g each), kept under room temperature ($27\pm 2^{\circ}\text{C}$) were broken over a sieve to separate albumen and yolk. The liquid egg albumen was mixed with a wire balloon whisk in Hobart mixer (Model M-50, USA) for 4-5 min at speed 2 to get the maximum fully blown foam. Later egg yolk was added and mixed for 1-2 min. Malic acid and citric acid were added at the beginning of beating, when egg yolk starts becoming frothy. The binder mix containing garlic powder wheat flour, corn starch, maltodextrin and soya protein was added slowly to homogenize liquid egg while mixing continuously to obtain a batter with homogenous consistency. The mixing was carried out for 3-4 min till a uniform smooth batter was obtained. The resultant batter was transferred to rectangular stainless steel moulds of $22\times 9\times 9$ cm ($1\times b\times h$) dimension lined with polypropylene sheet and the product steamed at atmospheric pressure for 35 min (internal temperature $86\pm 2^{\circ}\text{C}$) to obtain solidified product followed by cooling at ambient temperature ($27\pm 2^{\circ}\text{C}$) for 30-45 min. The loaf was cut into cubes by using a cutting mould of $1\times 1\times 1$ cm. size. The resultant product was then dried in cross flow dryer (C.M.

Equipments and Instruments India Pvt. Ltd, Bangalore, India) by spreading in stainless steel trays at the rate of 0.75 kg m^{-2} . The drying was carried out at $82\pm 3^{\circ}\text{C}$ for 3 h to obtain dried cubes called EC. The dried EC were allowed to cool. After cooling, the product was then packed in metalized polyester (polyester 10-11 micron/aluminum foil 9-12 micron/polythene 100 gauges) bags of 50 g capacity each and stored at ambient temperature ($27\pm 2^{\circ}\text{C}$). The stored products were drawn periodically for 6 months for quality evaluation.

Quality evaluation

Physical properties: The percentage yield on drying of the product was determined by weighing the EC before and after drying. Rehydration in terms of percent water in rehydrated cube was carried out by following the procedure described of Ranganna (1995) with some modifications. About 15 g sample was placed in 500 mL beaker, 300 mL of distilled water was added and covered with watch glass, brought to a boil within 2 min on an electric heater and boiled for 3 min. Temperature of the heater was controlled to avoid excess boiling and evaporation of water. The samples were removed from the heater and transferred into a 100 mm glass funnel, drained for 2 min undisturbed, until the drip from the funnel has stopped, removed from the funnel and weighed. The rehydration (%) was calculated using the Eq. 1. The drained rehydrated EC samples were set aside in covered petri-plates for textural profile and shear force analysis:

$$\text{Rehydration (\%)} = \frac{\text{Wt.(g) of rehydrated EC} - \text{Moisture (\%)} \text{ in dried EC}}{\text{Wt.(g) of rehydrated EC}} \times 100 \quad (1)$$

The percent increase in the volume after rehydration was determined by measuring the area ($1\times b\times h$) of EC pieces before and after rehydration by using the Eq. 2. An average of six measurements was recorded:

$$\text{Increase in volume (\%)} = \frac{\text{Area (cm}^2\text{) after rehydration} - \text{Area (cm}^2\text{) before rehydration}}{\text{Area (cm}^2\text{) before rehydration}} \times 100 \quad (2)$$

Bulk density of the product was determined by filling the product to the rim of 500 mL graduated cylinder and weighing the sample filled in cylinder. The results were expressed as g/cc (mass/volume). An average of five measurements for all physical parameters is reported.

Chemical properties: About 50 g of dried cube samples was powdered using mortar and pestle. The resultant

Table 1: Formulation for the preparation of egg cube

Ingredients	Percentage
Egg albumin	50.90
Egg yolk	29.90
Wheat flour	13.25
Corn starch	2.82
Salt	1.12
Garlic powder	1.00
Maltodextrin	0.56
Soya protein	0.28
Malic acid	0.07
Citric acid	0.07

powder was used for chemical analysis. Moisture, protein, fat, salt and ash contents were determined according to AOAC (2007) procedures. Carbohydrate was calculated by difference. About 10 g of EC powder in a beaker was stirred with 90 mL distilled water and pH measured by immersing combined glass-calomel electrode directly in a mixture using pH meter (Control Dynamic, APX 175 E/C, Bangalore India). Water activity (a_w) was measured using water activity meter (AquaLab 3TE, Decagon Devices Inc., Washington, USA). An average of four measurements is reported. For determination of Free Fatty Acid (FFA), a sample (10 g) was mixed with anhydrous Na_2SO_4 (100 g) and fat was extracted in 100 mL solvent mixture of chloroform: methanol (2:1) and filtered. A known volume of chloroform: methanol extract was then washed 3 times with 4-5 volumes of distilled water in a separating funnel to remove non fatty acids that may have come from formulation ingredients. The FFA as percentage of oleic acid was estimated in washed chloroform: methanol extract using AOAC (2007) procedure. Lipid oxidation, Thiobarbituric Acid (TBA) was determined by the method of Tarladgis *et al.* (1960).

Instrumental colour measurements: Colour reflectance values of dehydrated EC were measured on Hunter colour difference meter (Labscan XE, Hunter Associates Laboratory Inc., Virginia, USA) at 2° view angle. The Hunter colour meter was standardized with a white tile ($L = 90.71$, $a = -1.11$ and $b = 0.63$). Colour was described as coordinates e.g., L, a and b (where L measures relative lightness, a relative redness and b relative yellowness). The visual impression of colour is formed from hue [$h = \tan^{-1}(b/a)$], Chroma [$C = (a^2 + b^2)^{1/2}$] and lightness (Eagerman *et al.*, 1977). The measurements were used to calculate the Hue angle (H) which represents the relative position of colour between redness and yellowness and Chroma (C) which assesses the colour intensity. Colour stability was expressed as the rate of change (the slope of the fitted linear model) in L, h and C.

Texture profile analysis: Rehydrated EC samples were subjected to texture profile analysis and shear force using a Texture Analyzer (LR5K, LLOYD Instruments Ltd, Hampshire, UK). The rehydrated samples were placed on the platform of texture analyzer. A cylinder plunger of 32 mm diameter attached to a 1 KN load cell and sample (13 mm) was compressed to 50% of its original height at a cross head speed of 100 mm min^{-1} twice in two cycles. The texture parameters viz. hardness (N), cohesiveness, adhesiveness, springiness (mm), chewiness and gumminess (N) were measured. Shear force was measured by applying a load of 50 Newton with a speed of

100 mm min^{-1} using triangle probe. The values were recorded based on the software, Nexigen version 6.0 (Lloyd Instruments Ltd, Hampshire, England) available with the instrument. The mean value of six readings for each texture profile is reported.

Nutritional facts and Protein Digestibility Corrected Amino Acid Score (PDCAAS): The mineral contents viz; calcium, iron and zinc were estimated by AOAC (2007) procedures using atomic absorption spectrophotometer (Model AA-6701, Shimadzu, Japan) Cholesterol was estimated following the colorimetric method (Spectrophotometer UV-160, Shimadzu, Japan) as described by Zlatkis *et al.* (1953). Vitamin A was estimated by HPLC method (Sangeetha *et al.*, 2008). The HPLC system (LC-10AVP, Shimadzu, Kyoto, Japan) was equipped with shimadzu photodiode array detector (SPD-M20A). The vitamin was separated on phenomenon C_{18} -OSU column (150×4.6 mm; 5 μm).

The peak identifying of vitamin A was confirmed by its characteristic spectrum. Quantification of vitamin was evaluated by comparing its peak area with standard. *In vitro* digestibility of the prepared EC was determined by the method of Akeson and Stahman (1964). Pepsin followed by pancreatin digestion was carried out using sample equivalent to 100 mg protein. Initially the sample was digested with 1.5 mg pepsin in 15 mL 0.1N HCl (pH 2.5) at 37°C for 3 h. After neutralization with 7.5 mL of 0.2N NaOH, the digestion was continued using 4 mg pancreatin in 7.5 mL of phosphate buffer (pH 8.0) at 37°C for an additional 24 h. These enzymes were inactivated using 10% tri-chloroacetic acid. The digest were filtered and quantitatively made up to 100 mL. Digestibility was calculated based on the soluble and total nitrogen content. Amino acid contents were calculated based on the published values (Gopalan *et al.*, 1996) of the ingredients. Protein Digestibility Corrected Amino Acid Score (PDCAAS) was calculated as per Sarwar and McDonough (1990) by determining the un-corrected amino acid score using the reference protein requirement levels (mg g^{-1} of crude protein) for pre-school (2-5 years), school (10-12 years) children along with adults-prescribed by FAO/WHO (1985). The un-corrected amino acid score is calculated by dividing the mg of EAA in 1 g of test protein by mg of amino acids in 1 g of the reference protein which is the requirement for a particular group. Finally, multiplying the lowest of the un-corrected amino acid scores by the digestibility value yields the PDCAAS score.

Microbiological analysis: A 10 g sample of dried EC was placed in a sterile Stomacher bag containing 90 mL of

sterile saline (0.85% NaCl) solution and blended in Stomacher (Model SEWARD Stomacher 400, London, England). The blended samples were tested for Standard Plate Counts (SPC), *Staphylococcus aureus*, *E. coli*, Salmonella, Shigella, yeast and molds, by spread plate and pour plate method as per APHA (2001) procedures.

Sensory quality evaluation: Dehydrated EC samples were used for the preparation of curry. A traditional curry was prepared by using an optimum amount of spices and condiments. The curry contained chopped onion, ginger paste, garlic paste, green chillies, tomato puree, fresh coriander leaves, red chilly powder, coriander powder, turmeric powder and garam masala powder (a combination of spices like cardamom, clove, cinnamon, cumin and black pepper). The dried EC were added in hot cooked curry. The curry with EC was further cooked for 2-3 min. The rehydrated EC samples in curry were evaluated for sensory quality for appearance (shape retention), colour, flavour, texture, after taste and overall acceptability by 18 in house trained panelists using 9 point Hedonic scale (Szmanko *et al.*, 2006). The product was presented to panelists at 60±5°C in coded white ceramic plates. Samples for evaluation were served in a well lit room on white enamel. The mean scores for each attributes are reported. Freshly prepared, dehydrated and rehydrated EC in curry was treated as control for sensory analysis.

Statistical analysis: The experiment was carried out in 4 batches (n = 4). The mean of all parameters were examined for significance (p<0.05) by Analysis of Variance (ANOVA) and mean separation and the significant effect was tested by Duncan's Multiple Range Test using software STATISTICA (StatSoft, 1999).

RESULTS AND DISCUSSION

Product optimization: Several trial formulations for development of EC were attempted using different binders and fillers and time-temperature schedules of processing in order to obtain the product which was acceptable to taste panelists and did not disintegrate during cooking along with curry, retain the shape and dehydrate easily. The trial experiments for optimization indicated that a combination of wheat flour and corn starch for the preparation of EC resulted in the best quality product with respect to rehydration properties and texture of the rehydrated product. During optimization of ingredient levels, care was taken to ensure that the product is not disintegrated during rehydration or cooking in gravy. Based on the textural properties of rehydrated product and judged by sensory evaluation, 13.0% wheat flour and

Table 2: Physical properties of dehydrated egg cube (mean±SD, n = 4)

Physical properties	Values
Yield after drying (%)	44.00±2.580
Bulk density (g/cc)	0.13±0.000
Increase in volume after rehydration (%)	134.49±10.66
Water activity	0.36±0.010

3.0% corn starch were found optimum (Table 1). Further for improving the foam stability and rehydration properties in product, a mixture of soya flour and maltodextrin in the ratio of 1:2 was added to the formulation. The use of citric acid and malic acid in combination improved sensory acceptability of the product. Further it was found that the foam formed during beating the egg white was better stabilized at low pH and also helped in uniform distribution of binders and other ingredients during cooking period. Further, the stabilized egg white froth did not allow the settling of ingredients during resting or molding time. Therefore, the pH of egg white was brought down to 5.9 by adding malic acid and citric acid in combination. These acids kept the foam elastic but stable and can expand to its fullest when cooked (Anonymous, 2010).

Mleko *et al.* (2007) demonstrated that egg albumen at low pH leads to a substantial increase in foam firmness and gave the foam different properties than foams from untreated egg albumen. Further soya flour also improves the foaming and structural stability as reported by Heywood *et al.* (2002). Maltodextrin improves the dehydration by forming a gel network in the system when used as a carrier and provides improved rehydration properties upon hydration (Chronakis, 1998). Raikos *et al.* (2007) reported that the adhesiveness was highest at pH 5 for egg white.

The egg white proteins showed the best foaming properties at pH 5 (Malgorzata *et al.*, 2009). Optimum levels of garlic powder (1.0%) as a natural antioxidant was added to the formulation maltodextrin. The addition of garlic powder also improved the sensory properties of the product. The yield of the dried product was 44±2.58 (Table 2).

Rehydration properties: The various stages of EC (fresh before drying, dried and rehydrated) as a product are shown in Fig. 1a. Samples had a high degree of rehydration.

The rehydration capacity of the EC was 78.16±5.74% which in turn showed an increase in volume by 134.49±10.66% (Table 2). High rehydration capacity was due to porous structure of product which allowed more water absorption on rehydration. The porous structure of the product was also due to very low value of bulk density (0.13±0.01 g/cc). A significant increase in volume and porosity of the product has also been showed

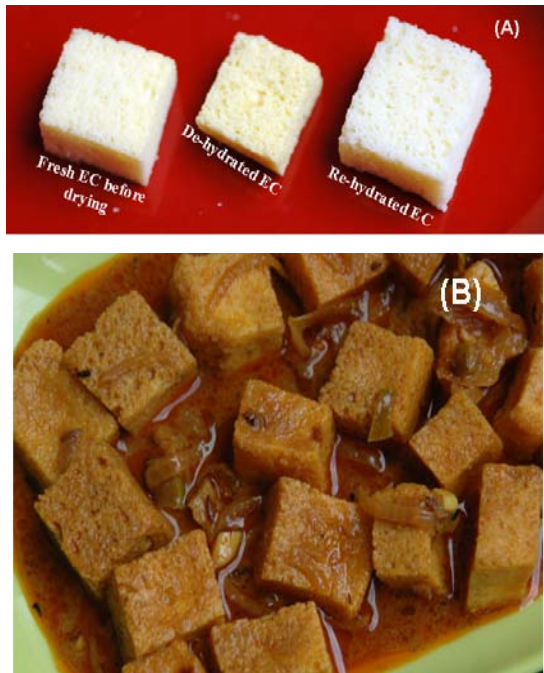


Fig. 1: (a) Different stages of egg cube as a product and (b) Curry prepared from egg cube. EC = Egg Cube

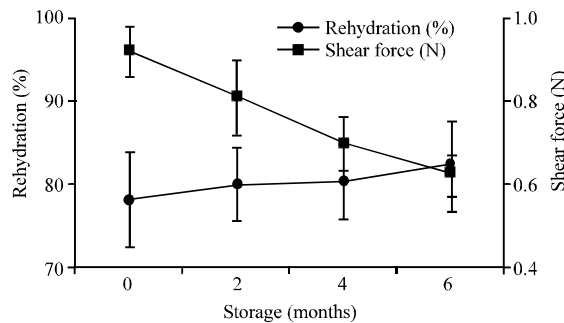


Fig. 2: Changes in rehydration characteristics and shear force in egg cube during storage at 27±2°C (mean±SD, n = 4)

through photographs (Fig. 1a). An average 5.0% increase in rehydration was observed after 6 months of storage under ambient temperature (27±2°C) (Fig. 2).

Proximate composition: The shelf stability of the product was achieved by keeping low moisture content (3.88±0.43%) (Table 3) and low a_w (0.36±0.01). The protein content was 33.43±2.10% and fat content was 25.90±1.4% (Table 4). Shelf stable dried flake shaped egg products prepared from liquid egg using common salt, monosodium glutamate, garlic and onion extract had a_w in the range of 0.20-0.50 with moisture content of 4.1-8.3% (Lee *et al.*, 1998). The salt contents in the dehydrated product were 4.02±0.40%.

Chemical characteristics: The fall in pH from 6.67±0.15-6.50±0.11 in dehydrated EP (Table 3) during 6 months storage period was marginal ($p>0.5$). Freshly prepared products had low FFA values (as % oleic acid) of 3.12±0.24% which gradually increased ($p>0.5$) to 3.75±0.23% during 6 months of storage. Increase in FFA due to lipase action in food products during storage is well documented and this increase did not increase the rancidity of food products such as pork sausages (Zalacain *et al.*, 1995) and egg loaf (Yashoda *et al.*, 2004). The oxidative rancidity measured by TBA values (mg malonaldehyde/kg sample) also showed an ascending trend ($p\leq 0.05$) from the initial values of 2.12±0.10-4.07±0.28 during 6 months storage (Table 3). The increase in TBA values could be due to increased lipid oxidation and production of volatile metabolites in the presence of oxygen due to aerobic packaging and storage. On the contrary in spite of high contents of fat in the product, the increase in oxidation was found marginal ($p\leq 0.05$). This could be due to presence of carotenoids (Suraj and Speake, 1998) and the inclusion of garlic powder (Salam *et al.*, 2004) in product formulation, providing antioxidant protection to the product. At the end of 6 months of storage a significant loss (66%) in

Table 3: Changes in chemical properties of dehydrated egg cube during storage under ambient conditions (27±2°C) (mean±SD, n = 4)

Storage (months)	Moistur (%)	pH	TBA (mg malonaldehyde kg ⁻¹)	FFA (% oleic acid)	Carotenoid (µg g ⁻¹)
0	3.88±0.43 ^a	6.67±0.15 ^a	2.12±0.10 ^a	3.12±0.24 ^a	9.57±0.46 ^a
2	5.55±0.25 ^b	6.59±0.12 ^a	2.31±0.14 ^a	3.37±0.29 ^a	6.75±0.28 ^b
4	6.41±0.33 ^b	6.58±0.13 ^a	2.65±0.22 ^b	3.49±0.22 ^a	4.73±0.38 ^b
6	6.59±0.40 ^b	6.50±0.11 ^a	4.07±0.28 ^c	3.75±0.23 ^b	3.15±0.20 ^d

Values in column with different superscripts differ significantly ($p\leq 0.05$)

Table 4: Changes in colour characteristics of egg cube during storage at 27±2°C (mean±SD, n = 4)

Storage (months)	Lightness (L)	Redness (a)	Yellowness (b)	Hue angle (H)	Chroma (c)
0	77.25±6.34 ^a	-3.92±0.68 ^a	28.35±1.42 ^a	-82.12±1.40 ^a	29.61±1.40 ^a
2	78.43±6.95 ^{ab}	-3.14±0.09 ^b	29.00±1.18 ^a	-83.82±0.83 ^b	29.17±1.00 ^a
4	79.34±6.16 ^b	-2.94±0.35 ^b	29.15±1.33 ^a	-84.24±0.85 ^b	29.30±0.91 ^a
6	79.67±6.95 ^b	-2.57±1.08 ^c	32.81±2.09 ^b	-85.52±1.63 ^c	32.91±2.15 ^b

Values in column with different superscripts differ significantly ($p\leq 0.05$)

carotenoid content was recorded. Wenzel *et al.* (2010) reported, after the 6 months of storage, the contents of carotenoid in the egg yolk powder were significantly lower.

Hunter colour values: Colour reflectance values measured on Hunter colour measuring system revealed an increase ($p \leq 0.05$) in L values of EC from 77.25 ± 6.34 - 79.67 ± 6.95 and a values increased ($p \leq 0.05$) from -3.92 ± 0.68 - 2.57 ± 1.08 during 6 months storage (Table 4) whereas changes in b values were marginal ($p \geq 0.5$). Changes in Chroma and Hue-angle values were in narrow range ($p \geq 0.5$) from 28.35-32.81 and -82.12 -85.52, respectively after 6 months of storage. Changes in colour values are influenced by method of processing (Pesek and Wilson, 1986) and interaction of ingredients (Osuna-Garcia *et al.*, 1997). There was no definite trend changes in Hunter L, a and b values during storage of fried egg yolk cubes (Modi *et al.*, 2008). Change in colour due to browning reaction does not occur very rapidly in egg products containing carbohydrates (Bergquist, 1995). In the present investigation, despite changes in instrumental chromatic attributes (L, a and b values), the visual colour appearance of EC products was acceptable even after 6 months storage at ambient conditions.

Textural profile: Changes in shear values during storage were significant (Fig. 2). It was further noticed that the shear values were decreasing with increase in rehydration of the product. This variation could be attributed to high rehydration percentage which could impart a soft texture to the product. There seemed to be appropriate binding attributes imparted to the product when maltodextrin was added in the formulation.

Maltodextrin have been found highly suitable for obtaining desirable organoleptic (texture, fat-like mouth feel, etc.) as well as physical properties (water holding, gelling, crystallization prevention, etc.) of various food products Chronakis (1998) whereas soya protein has been reported to improve cohesiveness in sausages because of its gelling and binding nature (Huffman *et al.*, 1992).

Hardness and gumminess of the rehydrated EC decreased ($p \leq 0.05$) with the storage period (Fig. 3). A decrease ($p \leq 0.05$) in chewiness was observed after 2 months of storage however, further storage did not change the characteristics of chewiness of the product. TPA also indicated that there was no definite trend in cohesiveness, springiness and adhesiveness values during storage period. Further, time temperature combination of processing and formulation might be the factors for the very low values of aforesaid characteristics

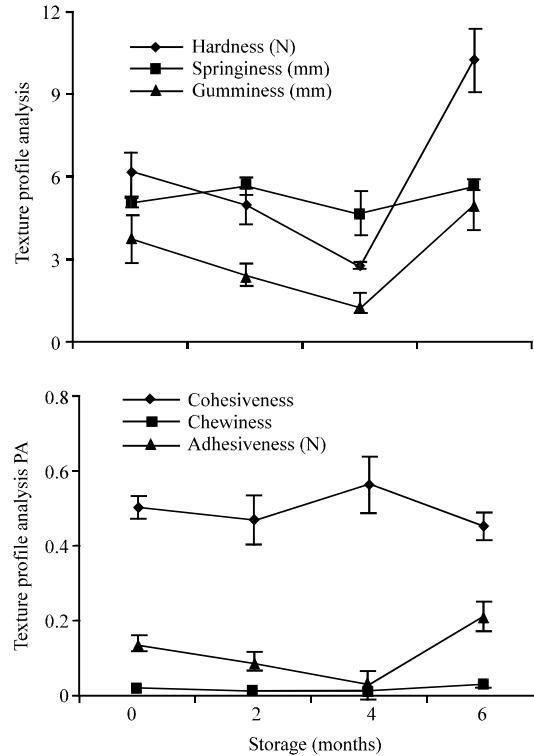


Fig. 3: Changes in textural profile of the egg cube during storage at $27 \pm 2^\circ\text{C}$ (mean \pm SD, n = 4)

observed in EC as it affects the binding properties of the ingredients used. An average low values of TPA in samples could also be due to rich foam formation during egg beating for product preparation. However, low TPA values did not affect the product quality negatively.

Nutritional facts and Protein Digestibility Corrected

Amino Acid Score (PDCAAS): A good amount (mg/100 g) of calcium 125.21 ± 10.54 , iron 6.59 ± 0.88 and zinc 2.71 ± 0.17 was present in the product while vitamin A and cholesterol were $17.2 \pm 0.23 \mu\text{g}/100 \text{g}$ and $289 \pm 17 \text{mg}/100 \text{g}$, respectively (Table 5). The calculated values of amino acid composition (Table 6) of the EC clearly indicated the presence of several essential amino acids like leucine (8.46%), lysine (6.66%), valine (6.17%) and isoleucine (5.30%) thus making it nutritionally beneficial. Difference in protein digestibility of various foods arise from inherent difference in the nature of the food protein, presence of non-protein constituents or from processing conditions that alter the release of amino acids from proteins by processes (Kies, 1981; Sarwar, 1987). The higher digestibility (88.32%) (Table 6) further proves quality proteins in product. The PDCAAS values calculated from analyzing amino acid data is also shown in Table 6. PDCAAS accurately depicts protein quality because it

Table 5: Nutritional facts of dehydrated egg cube (mean±SD, n = 4)

Nutrients	Values
Protein/100 g	33.43±2.100
Total fat (%) Fat (g/100 g)	25.90±1.950
Carbohydrate (g/100 g)	25.54±2.630
Calcium (mg/100 g)	125.21±10.54
Iron (mg/100 g)	6.59±0.880
Zinc (mg/100 g)	2.71±0.170
Vitamin A (µg/100 g)	17.20±0.230
Cholesterol (mg/100 g)	289.00±17.00
Trans fat	Nil

Table 6: Essential amino acid composition and Protein Digestibility Corrected Amino Acid Score (PDCAAS) values of dehydrated egg cube

Essential amino acids	Content (mg g ⁻¹ crude protein)	Uncorrected amino acid score		
		2-5 years	10-12 years	Adults
Histidine	24.52	1.29	1.29	1.53
Threonine	38.71	1.14	1.38	4.30
Valine	61.76	1.76	2.47	4.75
Cysteine+methionine	48.54	1.94	2.21	2.86
Isoleucine	53.03	1.89	1.89	4.08
Leucine	84.60	1.28	1.92	6.51
Tyrosine+phenylalanine	88.85	1.41	4.04	4.68
Lysine	66.62	1.15	1.51	4.16
Invitro digestibility (% [Ⓔ])	88.32±2.33	-	-	-
PDCAAS	-	1.00	1.00	1.00

Standard PDCAAS values (mg g⁻¹ crude protein) as per FAO/WHO (1985) for histidine, threonine, valine, cystine+methionine, isoleucine, leucine, tyrosine+phenylalanine and lysine are 19, 34, 35, 25, 28, 66, 63 and 58 (for 2-5 year olds); 19, 28, 25, 22, 28, 44, 22 and 44 (10-12 year olds) and 16, 09, 13, 17, 13, 19, 19 and 16 (adults), respectively [Ⓔ](Mean±SD; n = 4)

rates protein foods relative to a given reference protein (Sarwar and McDonough, 1990) and is based on the needs of humans rather than on the Protein Efficiency Ratio (PER) criterion of a protein's ability to support growth in young rats. The PDCAAS values for the EC were highest (1.00) for all the group of population (pre-school, 2-5 years, school, 10-12 years children and adults). The PDCAAS scores for a variety of food proteins include 1.0 (casein, soy protein isolate), 0.92 (beef protein), 0.68 (kidney beans) and 0.40 (whole wheat). This indicated the potential of EC as a food in nutritional programmes.

Microbiological quality: The Standard plate counts were <1 cfu g⁻¹. Total Staphylococci counts were decreased gradually during storage and were <1 cfu g⁻¹. The Yeast and mold counts, *E. coli*, Salmonella and Shigella however could not be detected in samples throughout 6 months storage. Lower counts of mesophiles (SPC), yeasts and moulds and absence of *Staphylococcus aureus*, *E. coli*, Salmonella and Shigella could be due to thermal processing, low a_w values of the product, hygienic practices followed during processing and storage. Further antibacterial effects of garlic (Grohs *et al.*, 2000) used in formulation could have protected the product from microbial growth. The results in the present investigation

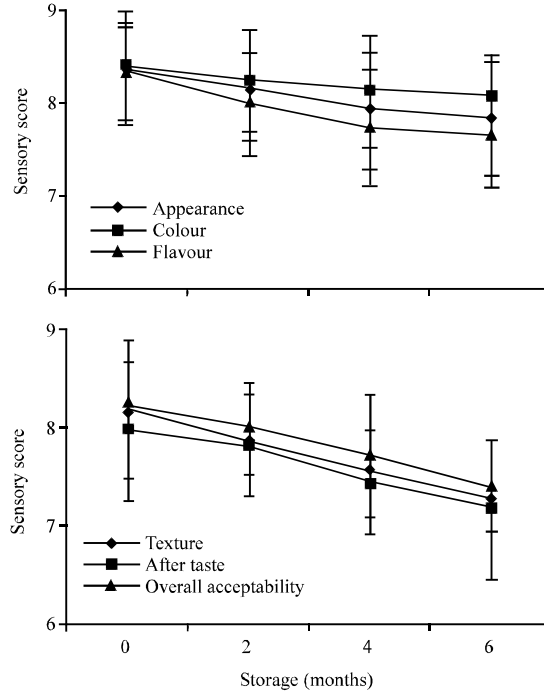


Fig. 4: Changes in sensory score of the egg cube during storage at 27±2°C (mean±SD, n = 4)

indicated that the dehydrated EC is microbiologically safe when packed in metalized polyester bags and stored at 27±2°C for 6 months.

Sensory quality: The sensory evaluation of EC was carried out in curry preparation as showed in photograph (Fig. 1b) and the sensory quality of egg cube is shown in Fig. 4. After thermal processing, dehydration and rehydration in curry the analyzed products differed in sensory properties. During storage samples received lower scores for flavour attributes as egg and typical of cooked egg than control. The change in flavour was detected after 2 months of storage, at very low intensity but it was significant after 4 months of storage. The intensity of such flavour attributes as typical of cooked egg further decreased after 4 months of stored. After taste scores also decreased over the storage period. A little undesirable flavour attributes which was reflected in after taste scores were of dehydrated storage odour, recorded over storage and its intensity increased significantly with time. A warmed over flavour was also noted only in stored samples after 6 months of storage and was hardly perceptible. This probably resulted from the masking effect of the egg's own flavour.

The panelists indicated a relatively low incidence in changes in appearance (disintegration on rehydration) after storage and rehydration of EC and this is likely to

have been due to the well set structural strength, obtained by processing technique and product formulation. The panelists also characterized by a soft texture in product stored for 6 months than control. The soft texture overall did not effect the acceptable level of product. A marginal change in visual colour intensity was observed after 4 or 6 months of storage of EC compared to control. This change could be due to a significant loss of carotenoid (Table 3), a principal pigment of egg yolk, during storage. It was also pointed out by the panelist that the product has been becoming whiter during storage compared to control EC. A gradual increase in FFA and TBA values (Table 3) and constant decrease in shear values (Fig. 1) explains the descending trends in ratings for overall sensory quality attributes. However, the product was rated acceptable by panelist with sensory scores of 7.4-8.2 during studied period of storage.

CONCLUSION

A convenience and ready to use product from liquid egg was prepared using all natural food ingredients. The dehydrated product packed in metalized polyester pouch had a shelf life of 6 months under ambient conditions (27±2°C). It has a good rehydration capacity and does not lose its integrity during rehydration or curry preparation. The texture of the rehydrated product resembles the traditional dairy product paneer. The product was found microbiologically safe and was rated acceptable by panelist with high sensory scores during storage period. Higher values of mineral, protein digestibility and PDCAAS values made a nutritionally rich product.

ACKNOWLEDGEMENTS

This research was supported by the Supra-Institutional Project (SIP) under the 11th five year plan funded by CSIR. Researchers thank the Director, CFTRI for encouragement and permission to publish the research. Thanks also to Dr. A.G. Appu Rao, Head, Protein Chemistry and Technology, for his valuable technical suggestions during research and preparation of this manuscript.

REFERENCES

AOAC, 2007. Official Methods of Analysis. 18th Edn., Association of Official Analytical Chemists, Washington, DC USA.
APHA, 2001. Compendium of Methods for the Microbiological Examination of Foods. 4th Edn., American Public Health Association, Washington, DC USA.

Akeson, W.R. and M.A. Stahman, 1964. A pepsin pancreatin digestion index of protein quality evaluation. *J. Nutr.*, 83: 257-261.
Anonymous, 2010. Beat egg whites. http://www.baking911.com/howto/egg_whites_beat.htm.
Bergquist, D.H., 1995. Egg Dehydration. In: *Egg Science and Technology*, Stadelman, W.J. and O.J. Cotterill (Eds.). 4th Edn., Food Products Press, New York, pp: 335-376.
Chronakis, I.S., 1998. On the molecular characteristics, compositional properties and structural-functional mechanisms of maltodextrins: A review. *Crit. Rev. Food Sci. Nutr.*, 38: 599-673.
Eagerman, B.A., F.M. Clydesdale and F.J. Francis, 1977. Determination of fresh meat colour by objective methods. *J. Food Sci.*, 42: 707-710.
FAO/WHO, 1985. FAO/WHO/UNU joint expert consultation: Energy and protein requirements. WHO Technical Report Series No. 724, Geneva.
Gopalan, C., B.V.R. Sastri and S.C. Balasubramanian, 1996. Nutritive Value of Indian Foods. National Institute of Nutrition, Hyderabad, India.
Grohs, B.M., N. Kliegel and B. Kunz, 2000. Bacteria grow slower effects of spice mixtures on extension of shelf life of pork. *Fleischwirtschaft*, 80: 61-63.
Heywood, A.A., D.J. Myers, T.B. Bailey and L.A. Johnson, 2002. Functional properties of low-fat soy flour produced by an extrusion-expelling system. *J. Am. Oil Chem. Soc.*, 79: 1249-1253.
Huffman, D.L., W.B. Mikel, W.R. Egbert, C. Chen and K.L. Smith, 1992. Development of lean pork sausage products. *Cereal Foods World*, 37: 439-442.
Kies, C., 1981. Bioavailability: A factor in protein quality. *J. Agric. Food Chem.*, 29: 435-440.
Lee, C.H., S.H. Yang and S.P. Chi, 1998. The development and quality evaluation of two-stages drum-hot air dried egg flakes. Effect of various egg yolk and egg white ratio and drying conditions. *J. Chinese Soc. Anim. Sci.*, 27: 579-587.
Malgorzata, K., T. Alexander and K. Ulrich, 2009. Impact of pH on the interactions between whey and egg white proteins as assessed by the foam ability of their mixtures. *Food Hydrocolloids*, 23: 2174-2181.
Merkle, J., H. Ball and J. Mathews, 2003. Formulation and process to prepare a premium formulated fried egg. US Patent US 0118714 A1. <http://ip.com/patapp/US20030118714>.
Mleko, S., H.G. Kristinsson, Y. Liang and W. Gustaw, 2007. Rheological properties of angel food cake made with pH unfolded and refolded egg albumen. *LWT Food Sci. Technol.*, 40: 908-914.

- Modi, V.K., P.N. Sheela and N.S. Mahendrakar, 2008. Egg albumen cubes and egg yolk cubes and their quality changes during storage. *J. Food Sci. Technol.*, 45: 161-165.
- Muller, C.L., 1994. Method of preparing egg coated potato slices. United States Patent 5372830. <http://www.freepatentsonline.com/5372830.html>.
- Osuna-Garcia, J.A., M.M. Wall and C.A. Waddell, 1997. Natural antioxidants for preventing colour loss in stored paprika. *J. Food Sci.*, 62: 1017-1021.
- Pesek, C.A. and S.A. Wilson, 1986. Spice quality: Effect of cryogenic and ambient grinding on colour. *J. Food Sci.*, 51: 1386-1386.
- Raikos, V., L. Campbell and S.R. Euston, 2007. Rheology and texture of hens egg protein heat-set gels as affected by pH and the addition of sugar and/or salt. *Food Hydrocolloids*, 21: 237-244.
- Ranganna, S., 1995. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. 2nd Edn., Tata McGraw-Hill Publishing Company Limited, New Delhi, pp: 977-979.
- Salam, K.I., M. Ishloroshi and K. Samejima, 2004. Antioxidant and antimicrobial effects of garlic in chicken sausage. *Lebenson Wiss Technol.*, 37: 849-855.
- Sangeetha, R.K., N. Baskar and V. Baskar, 2008. Fucaxanthin restrains oxidative stress induced by retinol deficiency through modulation of Na⁺ K⁺ ATPase and antioxidant enzyme activities in rats. *Eur. J. Nutr.*, 47: 432-441.
- Sarwar, G. and F.E. McDonough, 1990. Evaluation of protein digestibility-corrected amino acid score method for assessing protein quality of foods. *J. Assoc. Off. Anal. Chem.*, 73: 347-356.
- Sarwar, G., 1987. Digestibility of protein and bioavailability of amino acids in foods: Effects of protein quality assessment. *World Rev. Nutr. Dietetics*, 54: 26-70.
- StatSoft, 1999. *Statistica for Windows Computer Program Manual*. StatSoft Inc., Tulsa, OK.
- Suraj, P.F. and B.K. Speake, 1998. Distribution of carotenoids from the yolk to the tissues of the chick embryo. *J. Nutr. Biochem.*, 9: 645-651.
- Szmanko, T., M. Oziembowski, E. Dworecka and D. Dobrowolska, 2006. Sensory quality and selected physicochemical properties of processed meat products produced in different plants. *Acta Sci. Polish Technol. Aliment*, 5: 93-105.
- Tarladgis, B.G., B.M. Watts, M.T. Younathan and L. Dudan, 1960. A distillation method for the quantitative determination of malonaldehyde in rancid foods. *J. Am. Oil Chemists Soc.*, 37: 44-48.
- Wenzel, M., I. Seuss-Baum and E. Schlich, 2010. Influence of pasteurization, spray- and freeze-drying and storage on the carotenoid content in egg yolk. *J. Agric. Food Chem.*, 58: 1726-1731.
- Willense, M., 1991. Egg product ideas from South Africa. *Poult. Int.*, 30: 44-46-55-61.
- Wu, M.Y., J.I. Fann, M. Hsieh and S.C. Yang, 1995. Studies on the development and shelf-life of premixed flavoured egg products. *J. Chinese Soc. Anim. Sci.*, 24: 215-227.
- Yang, S.C., T.Y. Lien and M.C. Liao, 2000. Investigation on processing conditions of vacuum-dried egg white chips and its quality evaluations. *J. Chinese Soc. Anim. Sci.*, 29: 101-113.
- Yashoda, K.P., R.J. Rao, N.S. Mahendrakar and D.N. Rao, 2004. Egg loaf and changes in its quality during storage. *Food Control*, 15: 523-526.
- Yashoda, K.P., V.K. Modi, R.J. Rao and N.S. Mahendrakar, 2008. Eggs chips prepared by using different millet flours as binders and changes in product quality during storage. *Food Control*, 19: 170-177.
- Zalacain, I., M.J. Zapelena, I. Astiasaran and J. Bello, 1995. Dry fermented sausages elaborated with lipase from *Candida cylindracea*. Comparison with traditional formulations. *Meat Sci.*, 40: 55-61.
- Zlatkis, A., B.B. Zak and G.J.B. Boyle, 1953. A colorimetric method for determination of cholesterol. *J. Laboratory Clin. Med.*, 41: 486-496.