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Studies on foam mat drying of whole egg liquid in cabinet dryer

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Abstract : Foam-mat drying studies were conducted with foamed whole egg liquids at different temperatures *viz.*, 60, 65 and 70°C and at different foam-mat thicknesses of 1, 3 and 5 mm. The drying characteristics and biochemical qualities were determined and statistically analyzed. Quality factors like the colour, rehydration ratio, water activity and solubility were determined for foam-mat dried whole egg powders. Based on these experimental values, best treatment for the whole egg powder was optimized. The percentage of foam expansion for whole egg liquid was found to be 243.5 ± 12.5 per cent. From the statistical analysis of foam mat dried egg powders, it was observed that one mm thickness samples dried at 60°C retained higher biochemical and nutritional content when compared to samples dried at 65 and 70°C for 3 and 5 mm foam thicknesses respectively. The rehydration ratio, foamability of rehydrated foam mat dried whole egg and solubility of foam were observed as 3.70 ± 0.2, 236 ± 13.5 and 93.5 ± 5.3 per cent, respectively.

Key words: Whole egg liquid, foam mat drying, rehydration ratio, solubility.

Introduction

Egg *(Gallus gallus)* is one of the food items, which fulfills the balanced daily dietary requirement of the human body. Egg is a rich source of protein that is of high biological value. The protein quality of the egg is often the standard for measuring the quality of all other food proteins. Egg is also an important source of essential unsaturated fatty acids (Linoleic, oleic acid), iron, phosphate, trace minerals and the fat-soluble vitamins. Egg contains 11 per cent of fat, 12 per cent of protein and other important components of minerals and vitamins (Panda, 1995). Egg provide a unique, well-balanced source of nutrients for persons of all ages. Egg contribute significantly to the body's nutrient needs during rapid growth and hence an excellent food for growing children and teenagers (Stadelman and Cotterill, 1995). The production of egg has been rising at the rate of 8 to 10 per cent per annum. Considerable loss of 2.5 per cent due to breakage occurs during transportation of fresh eggs to different regions (Jayaraman *et al.*, 1976). Therefore surplus eggs have to be utilized to greater extent possible to reduce wastages and also to protect price structure. Because of the increased production and the disadvantages in the storage of whole egg, there is a need to preserve the egg for domestic consumption and also to promote export (Rao *et al.*, 1995).

Foam-mat drying is a promising new development in the field of drying. The dried product obtained from foam-mat drying is of better quality, porous and can be easily reconstituted. In foam-mat drying, a liquid concentrate along with or without suitable foam stabilizer is subjected to dehydration in the form of mat of foam. Drying rate is comparatively high because of enormous increase in liquid-gas interface, inspite of the fact that a large volume of gas present in the foamed mass impedes the higher rate of heat transfer (Chandak and Chivate, 1972). The finished product is superior than the drum dried or spray dried product because of its honeycomb structure and better rehydration properties (Labelle, 1984; Srinivasan, 1996). The reason for adopting foam-mat drying for production of egg powder is that egg albumin is a good foaming agent, hence addition of separate foaming agent is not required. Foam-mat drying requires less time, less power requirement, less cost of production and no need for pre-concentration. This method gives powder with more rehydration property (Martin, 1987).

Egg powder can be used for various food preparations instead of using liquid egg. Foam-mat dried egg powder is having better structure compared to spray dried powder (Rao *et al.*, 1987). Hence, foam-mat dried powder can be used as an ingredient with ease for the preparations of cakes, custards, noodles and some of the confectionery products.

Materials and Methods

Foaming Experiments

The eggs of "white leghorn" birds were procured and washed with clean water to remove adhering material on the surface. The cleaned eggs were soaked in 2 per cent bleaching powder solution for 30 min. Finally they were washed and dried at room temperature to remove surface moisture. The eggs were broken and egg liquid was inspected visually for any spoilage. The egg liquid was filtered through muslin cloth to remove the shell pieces and any other foreign materials. The egg liquid was pasteurized at 64°C for 3 min in a water bath, and then immediately cooled to 4°C with ice and salt for conducting further experimental trials.

Foaming properties

Foaming properties such as foam expansion (Durian, 1995), foam stability (Akiokato *et al.*, 1983), foam density and bubble size were determined for whole liquid egg.

Foam mat drying

For optimizing the drying time and foam mat thickness, the egg liquid foam was dried by using a batch type cabinet dryer. In cabinet dryer, drying was carried out at 60, 65 and 70°C in 1, 3 and 5 mm thickness of foam mat. The dryer mainly consists of heating coils, blower, drying chamber, thermostat, and air inlet and outlet openings. Eighteen coils of each 500 watts capacity were placed in along the side of the drying chamber. Two numbers of axial fans operated by 0.5 hp electric motor were fitted at the air delivery side to suck the fresh air and to remove the humid air from the drying chamber. The drying chamber was made of a 3 mm thick mild steel sheet to a size of 100 x 100 x 100 cm. The drying chamber could accommodate 24 numbers of aluminum trays of size 90 x 40 x 2.5 cm in two rows. A thermostat was used to control the temperature inside the chamber. A schematic view of cabinet drier is shown in Figure 1.

For foam mat drying of egg liquid, the trays were cleaned by wiping with cotton dipped in alcohol for sterilization and then the homogeneous foamed egg liquid at a thickness of 1, 3 and 5 mm were evenly spread on the teflon lined aluminum trays. In order to prevent sticking and to facilitate easy removal of the egg powder after drying, the tray was lined with food grade teflon sheet. The foam thickness was arrived by multiplying foam of known bulk density and drying area to get the foam thickness in terms of g/mm. This was taken as the base for determining the thickness of foamed egg liquid to be dried. Before keeping the tray in the dryer, the dryer was operated for a known period after setting at required temperature, in order to stabilize the temperature inside the drying chamber. The trays were placed on the tray stand in position. The temperature was maintained at 60, 65 and 70°C. The trays were taken out of the drying chamber at 10 minutes interval for weight loss determination. The drying rate was computed at different moisture content. Drying was continued till the moisture content of the samples recorded constant values.

Drying rate (DR)

Drying rate was obtained by taking the weight of moisture removed per unit time per unit weight of dry material.

DR = g of water removed/min/g of dry material (4)

Dehydration ratio

The ratio of weight of the sample before drying to the dried weight of sample was determined and described as dehydration ratio (Kalra *et al.,* 1995).

$$\text{Dehydration ratio} = \frac{W}{W_D} \qquad (5)$$

where,
W = weight of the sample before drying, g
Wd = weight of the sample after drying, g

Quality analysis

The quality parameters like water activity, rehydration ratio, solubility, colour along with biochemical parameters were analyzed and reported as an average of three replicates.

Water activity

The concept of water activity is important in determining product quality and safety in a particular environment. Water activity meter (M/s Aqua Lab, USA) was used to measure the water activity of the foam-mat dried egg powder. Water activity was measured by keeping the sample in a container and placing the container in a sealed chamber and then the knob was closed to read the water activity of the sample. The water activity of the egg powder was recorded with respect to room temperature of 25 ± 1°C. The experiments were replicated thrice and the average values were reported.

Rehydration ratio

The dehydrated samples were rehydrated by dipping in distilled water and the rehydration ratio was computed as the ratio of the weight of the rehydrated sample to that of dehydrated sample (Kalra *et al.,* 1995).

$$\text{Rehydration ratio} = \frac{Wr}{W_D} \qquad (6)$$

Where,
Wr = rehydrated sample weight, g
Wd = dehydrated sample, weight, g

Solubility

Ten gram of dehydrated sample was added in 100 ml of water at room temperature. The mixture was thoroughly mixed and centrifuged at high speed for 90 sec. Again 10 g of dehydrated sample was added in

100 ml of water and centrifuged for 90 sec. This was continued up to 85 g. After that addition of powder was reduced as 2g. At a particular stage, sediment of powder would be there in the centrifuge tube. The amount of powder added was noted at that time.

$$\text{Solubility} = \frac{\text{Weight of dehydrated sample}}{\text{Weight of water}} \quad (7)$$

Colour

Hunter lab color flex meter (Hunter color meter, USA) was used for the measurement of colour of egg powder. It works on the principle of focusing the light and measures energy reflected from the sample across the entire visible spectrum. The colour meter uses filters rely on "standard observer curves" that define the amount of red, green and blue colours. The primary lights required matching a series of colours across the visible spectrum and mathematical model used to describe the colours are called as Hunter model. It provides reading in terms of L, a and b. where, luminance (L) forms the vertical axis, which indicates whiteness to darkness. Chromatic portion of the solids is defined by: a (+) redness, a (-) greenness, b (+) yellowness, and b (-) blueness. The colour of the dried egg powder was measured by using CIELAB scale at 10° observer at D65 illuminant. Before measuring the colour of the samples, the instrument was standardized by placing black and white standard plates. The sample colour was measured by filling the whole egg liquid in the transparent cup without any void space at the bottom. The deviation of the colour of the samples to standard were also observed and recorded in the computer interface. Though all the 'L', 'a' and 'b' values were observed, the +b values, which represent the measure of yellowness of whole egg powder was more useful and the same was used for the present study.

Biochemical analysis

The pH value was determined by using a digital pH meter and the pH meter was standardized with double distilled water of pH 7.0 and standards at pH 5.0 and 8.5. For powdered sample, 10 g of sample was weighed accurately and taken in to 250 ml beaker. 100 ml of water was added and mixed. The mixture was allowed to stand for ten minutes with occasional stirring till uniform suspension results. The pH reading was taken by observing all the precautions given for the instrument by its manufacturer (BIS:10382,1982). Protein content of the sample was determined by Kjeldahl method (Pellet and Young, 1980). The analysis was done with the use of Kel plus apparatus. Fat content of the sample was determined by Sohxlet method. The apparatus used for fat estimation is sox plus apparatus. The carotenoid pigments are of importance from the standpoint of human and animal nutrition because of the conversion of some of them into vitamin A. The carotenoids are a group of yellow, orange and orange red, fat-soluble pigments widely distributed in nature. One molecule of β-carotene is converted to two molecules of vitamin A by hydrolysis. β-carotene in the sample was estimated as per the method described by Rao (1995). The reducing sugar content of the sample was determined by Nelson - Somogyi method (Somogyi, 1952).

Results and Discusison

Foaming Properties

The foaming properties of whole egg liquid were determined using standard procedures and reported in Table 1.

Table 1. Foaming properties of whole egg liquid

Sl.No.	Foaming property	Value
1.	Foam expansion (%)	243.5+12.5
2.	Foam stability at 180 min (%)	83.0 + 3.2
3.	Foam density (g/cm3)	0.28 + 0.03
4.	Bubble size (μm)	238.0 + 10.8

Table 2. Quality parameters of foam mat dried egg powder at 60°C with one mm foam mat thickness.

Composition	Value
pH	7.52 ± 0.26
Water (%)	4.17 ± 0.51
Colour : 'b' value	-2.15 ± 0.12
Protein (%)	48.26 ± 1.17
Fat (%)	39.8 ± 1.28
Reducing sugars (g/100 g)	0.62 ± 0.07
β-carotene, (μg/100g)	16.7 ± 0.9
Standard plate count (cfu/g)	$28 \times 10^2 \pm 0.1 \times 10^2$

Due to the albumen content (58%) in the whole egg liquid, 243.5 ± 12.5 per cent of foam expansion was achieved without adding any foaming agent. The foam stability after 180 minutes was found to be 83.0 ±3.2 per cent, where as foam density and bubble size were 0.28 g/cm^3 ± 0.03 and 238 ± 10.8 μm, respectively.

Drying characteristics of whole egg liquid

Foam mat drying of whole egg liquids were carried out at three foam thicknesses *viz.,* 1, 3 and 5 mm and at three drying temperatures of 60, 65 and 70° C in a batch type cabinet dryer. Based on the statistical analysis of foam mat dried egg powders, it was concluded that the whole egg dried at 60°C with one millimeter foam thickness retained significantly higher amount of biochemical / nutritional qualities and hence the drying characteristics of foamed whole eggs at 60°C are discussed below.

Effect of foam thickness on moisture content of whole egg

The effect of foam thickness on the moisture content of foamed whole egg during drying at 60°C is shown in Figure 2. From the figure, it is observed that the time taken for drying 1 mm thick foamed fresh whole egg from 316.67 to 4.17 per cent (d.b.) moisture content was 60 min. For the same level of moisture reduction, the time taken for 3 mm thick foam was 70 min and for 5 mm thick foam, it was 80 min. It is also noted that the reduction in the moisture content of foamed fresh whole egg at any point of time during drying increased with decrease in foam thicknesses. The drying data indicated clearly that the foamed whole egg dried with 1 mm foam thickness dried at faster rate as compared to the foamed whole egg dried with 3 and 5 mm thicknesses. This might be due to the complete exposure of foamed whole egg at lower mat thickness and subsequent removal of moisture from the foam surface immediately. Similar types of drying results were reported by Eduardo *et al.* (2001) for egg albumin treated tamarind and Falade *et al.* (2003) for egg albumin treated cowpea.

Effect of foam thickness on drying rate of whole egg

From the Figure 3 it was observed that the foamed whole egg dried at one mm foam mat thickness exhibited a higher drying rate than 3 and 5 mm thick foams. This clearly indicates that the drying rate of foamed whole egg was higher during the initial stage as compared to the final stage of drying. It might be due to the higher moisture content and increased surface area due to foaming of fresh whole egg. It also indicated that the drying of foamed whole egg at all thicknesses occurred at falling rate period because of the quick removal of moisture from thin surfaces of foams. The rate of moisture removal was more in the one mm thick foam as compared to three mm thick foam. This was due to the availability of more drying surface. These drying results are in confirmation with the results recorded in high moisture foods like tomato (Jayaraman *et al.*, 1975) and papaya (Levi *et al.*, 1983).

Moisture ratio of whole egg

Figure 4 depicts the relationship between moisture ratio and drying time at different foam thicknesses for foamed whole egg. It showed a linear relationship between moisture ratio and foam thickness for foamed non-desugarized whole egg while drying at 60°C. The relationship for the foamed whole egg dried at 1 mm thickness was,

$$MR = 1.097 \exp(0.0645) \quad (R^2 = 0.97) \quad (1)$$

where,

MR = Moisture ratio

x = Drying time, min

These relationships could be used to predict the moisture ratio at 60°C for whole egg at different drying times. The results are in line with the experiment of Rajkumar (2005) for foam mat drying of egg albumen treated mango pulp.

Quality parameters of foam mat dried egg powders

The biochemical qualities of one mm thick foamed whole egg, dried at 60°C using a cabinet dryer are presented in the Table 2. From the table, it was noted that the foamed whole egg retained protein and fat in the level of 48.26 ± 1.17 and 39.8 ± 1.28 per cent, respectively. The yellowness colour value (‘b’ value) of -2.15 ± 0.12 and β-carotene content of 16.7 ± 0.9 μg/100g were observed for the foam mat dried whole egg powder.

Dehydration ratio, Rehydration ratio, Water activity, Solubility and Foam ability of the Foam mat dried egg powders

From the Table 3 it was found that the dehydration ratio and rehydration ratio of foam-mat dried whole egg powders were 4.0 ± 0.2 and 3.7 ± 0.2, respectively. The water activity of foam mat dried albumen powder was lower than that of whole egg and yolk powder. This difference in the water activity

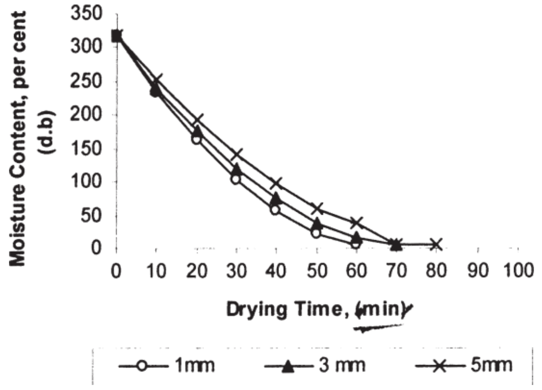


Fig. 2. Moisture content of whole egg at 60^{o}C

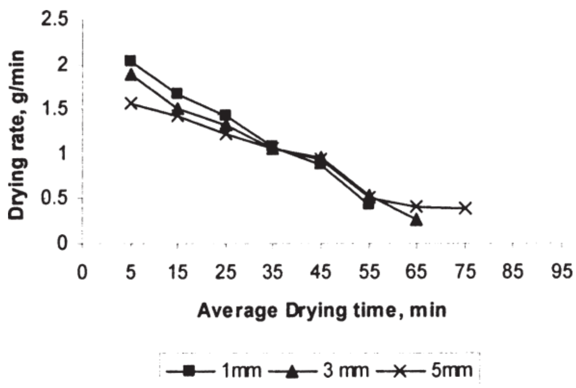


Fig. 3. Drying rate of whole egg at 60^{o}C

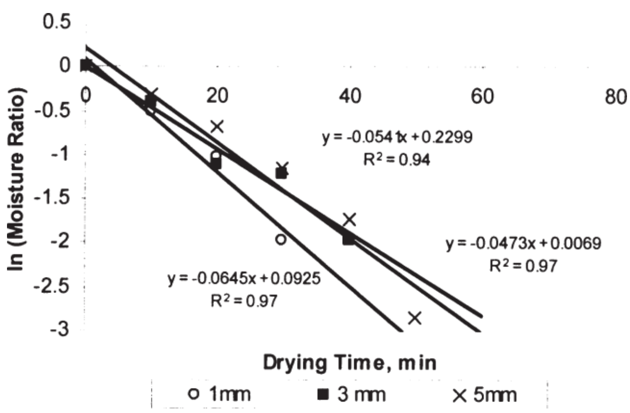
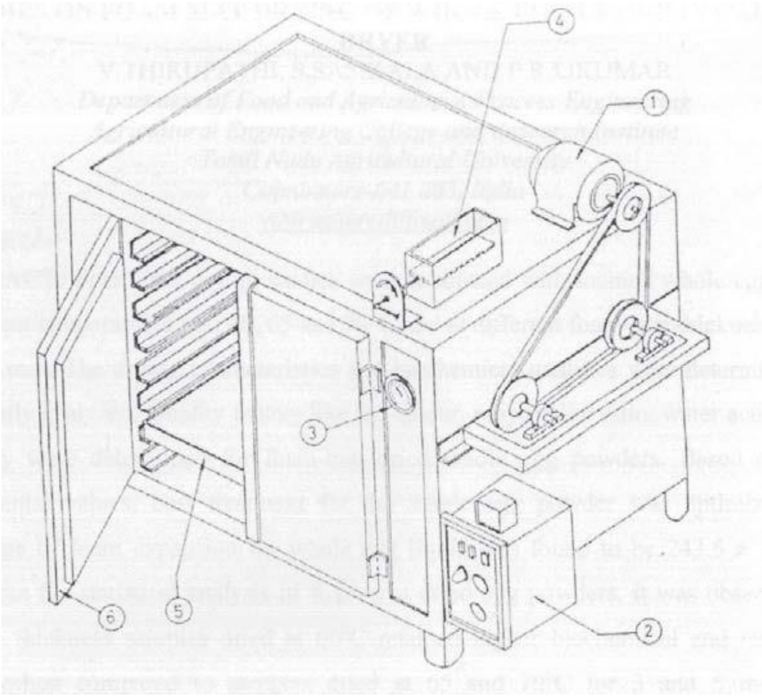


Fig. 4. Relationship between ln (moisture ratio) and drying time of whole egg at 60^{o}C



1. Motor
2. Panel Board
3. Temperature Indicator
4. Hot air outlet
5. Tray
6. Door

Fig.1. Cabinet Dryer

Table 3. **Dehydration ratio, rehydration ratio, water activity, foamability and solubility of the foam mat dried whole egg powders**

Properties	Whole egg powder
Dehydration ratio	4.0 ± 0.2
Rehydration ratio	3.70 ± 0.2
Water activity (a_w)	0.40 ± 0.03
Foamability %	236 ± 13.5
Solubility (%)	93.5 ± 5.3

might be due to the final moisture content of the dried products. All the foam mat dried egg powders which were packed in poly ethylene bags were safe from microbial cross contaminations. Foam mat dried egg powder was packed in polyethylene package, hermetically sealed and stored in dry place for further studies.

Foamability of rehydrated foam mat dried whole egg powder was 236 ±13.2 per cent and the foamabilty of the fresh whole egg liquid was found to be 243.5 percen. The percentage of reduction of foamability of rehydrated foam mat dried whole egg powder was 4.57 per cent and the foaming value is comparable. The analysis showed that the foam dried whole egg powder could be used as ingredient for the preparation of egg based food items due to its better rehydration and foaming properties.

The foam mat drying technique can be effectively used for producing whole egg powder. The drying time of the foamed whole egg powder was found to be lower in 1 mm foam thickness as 60 minutes when compared to 3 and 5 mm thicknesses as 70 and 80 minutes respectively. The quality of the foam mat dried whole egg powder at 60°C with 1 mm thickness retained more biochemical contents when compared to other drying temperatures and foam thicknesses.

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