Effect of Moderate Spray Drying Conditions on Functionality of Dried Egg White and Whole Egg

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ABSTRACT: Dried egg and egg-derived proteins have a range of applications in baking, dressings, and confectionery products. Egg powder was produced under high time–temperature scales (approximately 160 °C), which led to many changes in egg components, resulting in different functional properties of eggs after reconstitution. In this study, moderate operating conditions were selected to dry egg white and whole egg using a pilot-scale spray dryer. Functional properties changes were evaluated with an appropriate statistical technique. Major finding supports that spray drying of egg white at moderate conditions (air inlet temperature ranged from 110 to 125 °C) resulted in a product that enhanced considerably the water holding capacity of produced gels. Moreover, gel prepared with the dried samples was firmer than that of the fresh samples. Drying at a moderate scale allowed not only the increasing of the foaming capacity and the stability of foam but also an increase in their emulsifying capacity and stability of the emulsions.

Keywords: egg, foaming, gelling and emulsifying properties, spray drying

Introduction

Whole egg and egg-derived proteins are well known for their functionalities, for example, foaming, emulsifying, and gelling agents. Therefore they have a range of applications in baking, dressings, and confectionery products. Recently, there has been an increase in demand of dried egg derived products in the food industry for ready-for-use packages and handling consideration. However, drying process itself leads to many changes in egg components, resulting in different functional properties of eggs after reconstitution. On the other hand, innovative products with improved functionalities are in demand for production of foods with well-defined properties in terms of their structure and sensory attributes. Therefore, industrial egg processors need more information about the effects of operating conditions of spray-drying process on functional properties of egg after drying and reconstitution.

In contrast to milk drying, few studies have been published about the influence of drying conditions on the properties of whole egg. It should be noted that the compositions of egg and milk are completely different and eggs have equally or even more temperature-sensitive proteins; therefore, the knowledge developed from milk drying studies cannot simply be transferred to the egg drying process. Basic investigations of the influence of different drying procedures on the functionality of egg were carried out by Zabik and Brown (1969). Rao and Murali (1987) found that the whole egg powder dried by different procedures had no significant influence on its solubility or sensory attributes for use in scrambled egg. The influence of drying temperature (air inlet) was studied by Petrova and others (1986), who found that higher air temperatures during drying decreased protein solubility and foaming power. Franke and Kießling (2002) studied the influence of dry temperature and nozzle pressure on the functionality of spray-dried whole eggs. Recently, Guilmineau and Kulozik (2006) reported that the high temperature and a higher surface (air/product) exposer could lead the oxidation of fat fraction of spray-dried egg. In addition, the natural tocopherols and the other antioxidants present in egg are destroyed during heat treatment (Wahle and others 1993; Galobart and others 2001).

Despite these published studies, egg processors need more scientific data to deliver dried egg products that are able to meet special requirements of the end users of the products. Examples of such requirements may be the formation of good foam, stable emulsions, and firm gel structures. Such functionality can be favorable for bakery, sweet, and cream products.

Air inlet temperatures tested in all published studies were more than 140 °C. However, most egg functionality is determined by the protein fraction that is very sensitive to the air inlet temperature and the residence time in the dryer. Because of this sensitivity, the study of moderate drying conditions (air inlet temperature and residence time in the dryer) on the powder characteristic and the protein properties is of interest.

In this article, attention is drawn toward the influence of moderate drying conditions (inlet air temperature and residence time in the dry cylinder) on the functionality (foaming, gelling, and emulsifying properties) of spray-dried white and whole eggs.

Materials and Methods

Materials

Fresh eggs were collected from a local farm (hen house, Route Menzel cheker km 11, Sfax, Tunisia). These eggs were of category AA (intact shell, clean and white clearly, limpid, and gelatinous) and their conservation did not exceed 1 d.

First, egg white and yolk were separated. Thereafter, homogenization of egg white was carried out using a homogenizer (Heidolph RZR 2021, Germany) at 758 rotations per minute. A sifting (NF 11-501, diameter of the pores: 0.8 mm) was conducted to eliminate the chalazas and the suspended matter. In addition to the white preparations, the whole egg was diluted in a Milli-Q water at a ratio of 1:2 before drying to prevent circulation problems due to whole egg high viscosity.

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Spray drier and experimental design

Egg white and whole egg drying was conducted by a laboratory-scale mini spray dryer (Bücchi, Switzerland). Samples were pulverized with a cocurrent airflow produced by a blower. Airflow rate was 0.18 kg/min and humidity level of air was 5 g water/kg of dry air.

An experimental design was used for the drying parameters, where the inlet air temperature was varied at 3 levels (110, 120, and 125 °C) and the liquid flow rate was varied at 2 levels (0.2 and 0.3 L/h).

Composition analysis

Water content was determined using halogen desiccators (Mettler Toledo, HB 43, Switzerland). The ash content was determined by incineration at 550 °C during 4 h (AOAC 1997). Proteins were analyzed according to Kjeldahl method. A factor of 6.38 was used for conversion from total nitrogen to crude protein (AOAC 1997). Fat content was determined according to NF V 03-713 (AFNOR 1984).

Analysis of functional properties

Based on initial water content, egg white and whole egg solutions were prepared for gelling, foaming, and emulsifying analysis by adding the adequate quantity of Milli-Q water to obtain final reconstituted products at a level of approximately 12% (w/w) for egg white and approximately 26.5% (w/w) for whole egg. The pH was adjusted to 7 by adding an adequate quantity of 1 M acetic acid. The heat-induced gels were prepared in quadruplicates by heating 40 mL of reconstituted solution (in a cylindrical tube) in a water bath at 90 °C for 20 min followed by cooling in the tubes at 4 °C for 24 h.

Water holding capacity of gel. Gel water holding capacity (WHC) was analyzed by centrifugation (Handa and others 1998) at 10000 × g for 30 min. WHC is given by the relative weight as shown in Eq. 1.

$$\mathrm{WHC}(\%) = \frac{W_{\text{after centrifugation}}}{W_{\text{before centrifugation}}} \times 100 \quad (1)$$

where W is the weight.

Gel texture analysis. Cylindrical gel samples (20 and 15 mm diameter and length, respectively) were cut in quadruplicate. Gel texture was analyzed by uniaxial compression test until fracture of the gel (Texture analyser: Lloyd Instruments, U.K.) with a 1000 N load cell, 0.005 kgf detection range, 37-mm-dia flat stainless steel plate, and compression speed of 10 mm/min. Recording of force (N) and displacement (m) were converted to true axial stress σ (Eq. 2) and Hencky strain ε (Eq. 3), where F = force (N), A = initial surface (m^2), H_i = initial gel height (m), and H = height (m).

$$\sigma = \frac{F}{A} \times \frac{H}{H_i} \quad (2)$$

$$\varepsilon = \ln \frac{H}{H_i} \quad (3)$$

σ_f and ε_f were obtained as gel stress and gel strain, respectively, at the fracture point and used for statistical analysis.

Foaming capacity and foam stability. Foaming capacity and foam stability were analyzed in quadruplicate according to the method reported by Hammershoj and others (2006). Foaming properties (10 mL) of reconstituted dried egg white (1%, w/w) in closed 50-mL cylindrical cones were analyzed at room temperature by shaking for 30 s. Foaming capacity (FC) is given by Eq. 4, and foam stability against liquid drainage (LD) is a relative ratio of the liquid volume retained in the foam at time t (Eq. 5) and the volume retained at $t = 0$ s.

$$FC = \frac{V_{\text{foam}}}{V_{\text{liquid}}} \quad (4)$$

where V_{foam} = volume of foam (L) and V_{liquid} = volume of liquid (L).

$$FS(t) = \frac{V_{bf} - V_d(t)}{V_{bf} - V_d(t = 0)} \quad (5)$$

where V_{bf} is the volume of liquid taken for foaming and it was always 10 mL, $V_d(t)$ is the volume of drained liquid from foam after time t, and V_d ($t = 0$) is volume of liquid not incorporated in the foam just after foaming.

Emulsifying properties. Dried whole egg was reconstituted in Milli Q water to reach the same dry matter of the fresh samples. Twenty milliliters of this suspension were mixed with 50 mL of sunflower oil. Subsequently, the mixture was homogenized at 22000 rpm in an Ultra-Turrax (Heidolph RZR 2021, Germany) with a fine disperser bar. The sunflower oil was added drop by drop using a peristaltic pump.

Size distribution of the oil droplets was observed using an optical microscope (Olympus U-CMAD-2, Japan). The observation was achieved employing a 100× objective lens. The stability of emulsion (ES) is determined by a centrifugation of the samples at 10000 × g for 30 min. ES was calculated by the following equation:

$$ES(\%) = \frac{W_{ac}}{W_{bc}} \times 100 \quad (6)$$

where W_{ac} is the weight of mayonnaise after centrifugation and W_{bc} is the weight of mayonnaise before centrifugation.

Statistical analysis

Three replicates for each dried egg property (foaming, gelling, and emulsifying) were made. The results were subject to a one-way analysis of variance (ANOVA) using statistical software (SPSS 11.0 for Windows, SPSS Inc., Cary, N.C., U.S.A.). The confidence level for the multiple range tests was 95%, and the means were compared by the Fisher's least significant difference (LSD) procedure.

Data were subjected to statistical analysis by the general linear model procedure of SPSS 11.0. The data were distributed by the normality function; hence, no further data transformation was used. The model (Eq. 7) of analysis was:

$$Y_{ijk} = a_i + b_j + d_{ij} + e_{ijk} \quad (7)$$

Hence, a_i temperature i (110, 120, and 125 °C), b_j treatment time, or flow rate (0.2 and 0.3 L/h), d_{ij} interactions, and e_{ijk} replicate (1 to 3). When interactions were nonsignificant, the parameter d_{ij} was excluded from the model and data were analyzed by the reduced model. The least squared mean values were calculated and differences regarded significant at a minimum of 95% level ($P < 0.05$).

Results and Discussion

Physicochemical properties and composition

Physicochemical properties and composition of fresh white egg and dried samples are summarized in Table 2. These results show that the principal components were conserved except for a slight decrease in the protein amount after the spray-drying process. This result could be explained by heat denaturation of proteins present in egg white and chemical change (such as deamination) in amino acid residues induced by spray-drying process. A remarkable increase in the pH was observed. This result is in agreement with those reported by Mine (1997, 1998) and Hammershoj and others (2006). This increase is explained by the evaporation of carbon dioxide dissolved in liquid egg and by the exposure of some basic amino acids such as lysine and the arginine.

Functional properties

Gel aspect and textural analysis. The egg gel appearance is important in food applications, depending on whether transparency or turbidity is required. Figure 1 shows the photos of egg gels obtained from dried egg white and whole egg samples at different operating conditions. It appears that the gel obtained from fresh egg white sample has the most whitish color. However, high temperature with high residence time affected the gel color significantly. Indeed, the more the drying conditions (air temperature and residence time in the cylinder) were severe the more the color of gels tends toward a yellow color and a transparent aspect. Only a few data on gel color as function of drying condition exist. Mine (1997) found that white egg gel transparency increased by dry treatment.

Table 1 – Approximate composition and pH value of fresh and dried egg-white and whole egg.

g/100 g of dry matter	Fresh sample		Dried samples	
	Whole egg	Egg white	Whole egg	Egg white
Fat	36.7 ± 0.18	Traces	33.64 ± 0.27	Traces
Proteins	42.73 ± 0.32	88.63 ± 0.39	41.18 ± 0.33	79.34 ± 0.42
Ash	4.02 ± 0.03	4.29 ± 0.09	6.13 ± 0.11	5.69 ± 0.09
pH	7.61 ± 0.06	9.11 ± 0.02	8.20 ± 0.15	10.10 ± 0.06

Table 2 – Significance levels of class variables and their interactions for various analytical parameters and standard error of mean (SEM).

Functionality of dried egg	Hot air temperature	Liquid flow rate	Interaction	SEM
Egg white				
WHC	***	***	***	0.337
Gel stress (σ)	***	***	NS	1.444
Gel Hencky strain (ε)	**	NS	NS	0.016
FC	***	**	***	0.059
FS after 2 h	NS	NS	NS	1.235
FS after 18 h	NS	NS	*	1.222
Whole egg				
WHC	*	*	**	0.506
Gel stress (σ)	***	***	***	0.022
Gel Hencky strain (ε)	**	*	NS	1.324
ES	NS	***	*	1.043

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$; NS = no significant effect.

Figure 1B shows that gels obtained from dried whole egg samples were greener than that obtained from the fresh one. These color changes could be attributed to the fact that secondary components appeared during egg drying because of the Maillard reactions. Indeed, the presence of proteins and reducing sugars supports the appearance of these reactions (Eskin 1990; Friedman 1996).

The ability of a gel to hold water is important for both sensory properties, and product processing and stability. The gel structure is essential for water holding capacity (WHC) as finer pore sizes are able to bind water more firmly than larger pores (Hermansson 1994).

Figure 2 shows the WHC evolution compared with hot air temperature and liquid flow rate. Figure 2A shows that the gel obtained with the dried egg white presents a WHC higher than that of the gel obtained with fresh egg white. Indeed, WHC reaches a value of 97.3% for the dried egg white at a temperature of 125 °C and a liquid flow rate of 0.2 L/h. However, the gel obtained with the dried egg white with 110 °C and a liquid flow rate of 0.3 L/h presents the lower WHC.

Figure 2B shows that gel obtained with dried whole egg at 110 °C and 0.3 L/h presents the lower WHC. However, WHC of gel obtained with spray-dried samples was similar to that obtained with the fresh sample.

Texture of the gels, evaluated by the true axial stress σ_f and Hencky strain ε_f , obtained using fresh and dried white and whole egg samples is shown in Figure 3. Figure 3A shows the axial stress of gel obtained with fresh and spray-dried white eggs. First, Figure 3A shows that σ_f of gels obtained with spry-dried samples were higher than σ_f of gel obtained with the fresh sample. Second, σ_f of gels obtained with spray-dried white egg at 0.2 L/h were higher than σ_f of gels obtained with samples dried at 0.3 L/h. Finally, σ_f increases significantly for the gels dried at 125 °C for the 2 flow rates tested. For example, the breaking stress of the gel obtained with egg white dried at 125 °C and 0.2 L/h is 4 times higher than that of the gels obtained with fresh egg white.

Figure 3C shows the axial stress of gel obtained with fresh and spray-dried whole eggs. It also appears that the σ_f of gel obtained from dried sample increased significantly compared to σ_f of the gel obtained from fresh sample.

Hencky strain (ε_f) is the characteristic of elasticity of a gel. Figure 3B shows the Hencky strain (ε_f) of gel obtained with fresh and spray-dried egg white. ε_f of dried egg white at 0.2 L/h (for

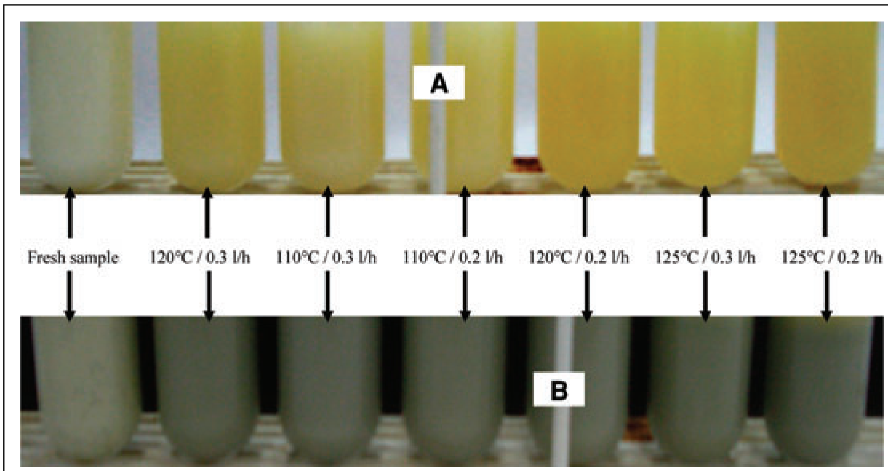

Figure 1 – Photographs of egg gels obtained from fresh and dried samples: (A) white egg; (B) whole egg.

3 tested inlet air temperatures) are lower than ε_f of gel obtained with fresh sample. In addition, a maximum value was observed for the gel obtained with dried white egg at the temperature of 120 °C (for the 2 tested flow rates).

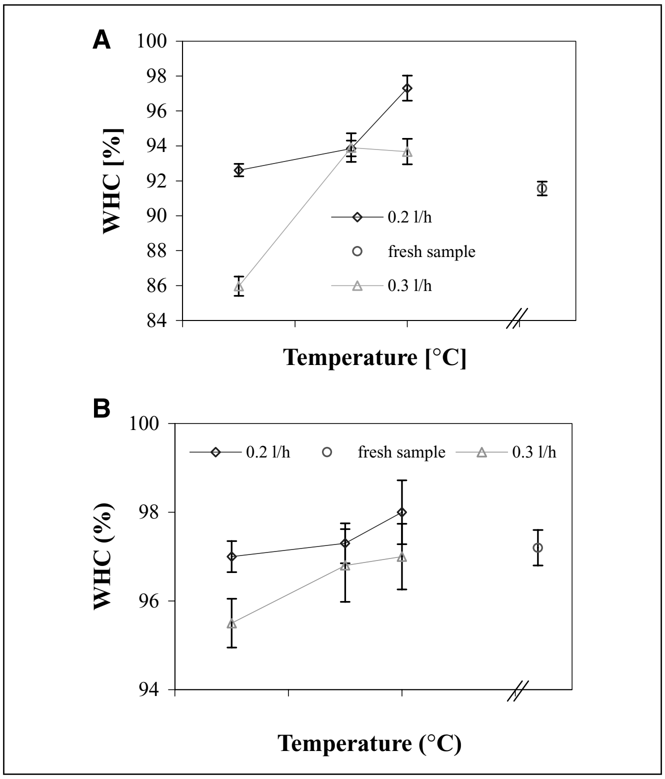

Figure 2— Water holding capacity of gels made of dried egg powder issued from different drying temperature: (A) egg white; (B) whole egg.

Figure 3D shows the Hencky strain of gel obtained from fresh and spray-dried whole eggs. Figure 3D shows that ε_f of gels obtained from dried samples was lower than that of gel obtained from the fresh sample.

The gel texture and WHC are affected by a number of factors such as, protein concentration, heating rate and temperature during gelation, pH, and ionic strength (Campbell and others 2003). Hammershoj (2001) and Matsudomi and others (2003) reported that intermolecular disulphide bond formation during gelation contributes to the egg albumen gel network formation and texture. Disulfide bonding or sulfhydryl–disulphide interchange is suggested to take place during dry heating and to partly explain the improvement of gel texture (Kato and others 1990; Mine 1997). However, others found the disulphide bond formation during dry heating of ovalbumin to be limited (Matsudomi and others 2003). Simultaneously, the destabilization of hydrogen bonding and hydrophobic interactions induce a much higher and significant decrease in gel strength (Kato and others 1990). In general, surface hydrophobicity increases during dry heating of egg protein and has a beneficial effect on the gel texture (Kato and others 1990; Handa and others 2001; Baron and others 2003). Residence time in the heating cell and the contact with hot air increase both hydrophobicity and the Schiff's base formation (Hammershoj and others 2006 b).

Based on our results and above-mentioned discussion, we could suggest that the surface hydrophobicity together with covalent interactions through Schiff's base formation during dry heating is at least as essential for the improved gel texture by spry drying as the contribution from intermolecular disulfide bonds.

Spray drying at the highest temperature and high residence time correlates with the highest gel strain (σ_f) and the highest WHC values (Figure 2 and 3). It is interesting to note that in addition to the protein heat denaturation, spray drying causes an increase in the pH after reconstitution. For example, the pH of white egg reaches a value of 10.1. It is well established that egg protein gel strength

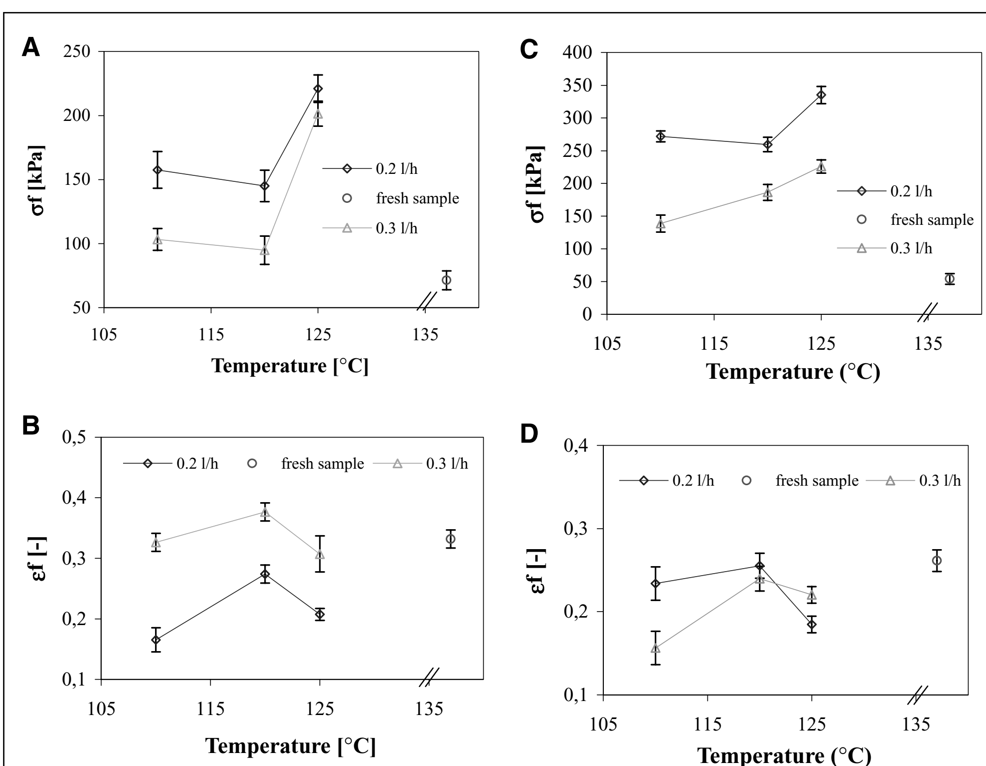

Figure 3—Gel texture analysis at the rupture point: (A) true axial stress σ_f of white samples; (B) Hencky strain ε_f of white samples; (C) true axial stress σ_f of whole egg samples; (D) Hencky strain ε_f of whole egg samples.

is low near isoelectric point (pI), that is, for the majority of white egg at pHs 5 to 7, and it increases with increased alkalinity (Handa and others 1998; Chang and others 1999; Hammershoj 2001). Near pI, a network of colloidal particles is formed in contrast to pH conditions of large repulsion that result in fine stranded gels (Langton and Hermansson 1996). The significant increase in WHC as a result of high temperature and time in the heating cell thus indicates that the gel structure is altered. Such changes in the gel network are assumed to reflect molecular differences in secondary structure, tertiary structure, and/or flexibility. Previous studies confirm the observed effects on gel's WHC. Hence, high gel strength in compression (Figure 3A and 3C) is related to high resistance to mechanical deformation during centrifugation and less loss of liquid and protein.

Foaming properties. Evolution of foaming capacity and foam stability compared with drying condition is presented in Figure 4. Foaming capacity of white egg increases significantly after drying (Figure 4A). Indeed, the foaming capacity of the dried egg white at 120 °C and 0.2 L/h is 4 times higher than that of the fresh sample. However, at high temperature (125 °C) and low flow rate (0.2 L/h), a reduction in this capacity was observed. Figure 4B shows that foam, once formed, remains stable even after 18 h. This figure also shows the importance of the thermal scale, that is, coupling of time and temperature. Indeed, stability of foam is maximum in the following 2 cases: (1) treatment at low temperature (110 °C) and high residence time (low flow: 0.2 L/h), (2) treatment at high temperature (125 °C) and low residence time (high flow: 0.3 L/h).

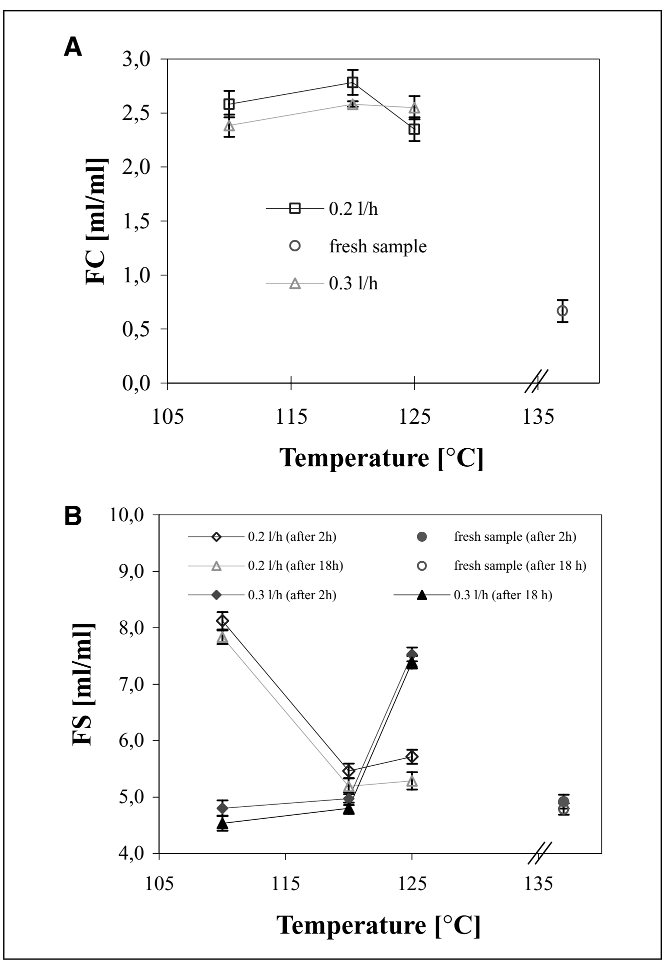

Figure 4— Foaming properties compared with drying conditions: (A) foam capacity; (B) foam stability.

The ability to foam is an important functional property of egg white, which finds application in aerated foods and confectionery. Both foam formation and its stability against liquid drainage and bubble breakdown depend on the surface activity of the protein molecules. Because of the intermolecular interactions of proteins at the air–water interface, a cohesive viscoelastic protein film is formed, which stabilizes the bubbles and retains water via formation of a surface tension gradient (Hammershoj and others 1999).

In contrast to previous studies on dry heating, where increased time and temperature improve both foaming capacity and foam stability against liquid drainage (Kato and others 1989; Baron and others 2003), we could not confirm this in our study. Indeed, foaming capacity and foam stability of dried sample increased significantly compared to the fresh sample, except that at 125 °C and 0.2 L/h foam capacity of dried sample decreased slightly.

The foam stability was measured as the relative amount of liquid retained in the foam after foam formation. We studied the time period of 120 to 1080 min after foam formation, but found no differences in the drainage patterns between samples as function of drainage time.

The composite mixture of proteins in egg white foams well because of the different functions of each protein, in contrast to, for example, pure ovalbumin solutions, which foam poorly (Poole 1989). Only few processes in the production of egg white powder have succeeded in improving the foaming properties compared with the native one. One of these processes is dry heating as discussed previously, and others may be the controlled preheating of egg albumen protein solutions (Hagolle and others 1998). This improvement could be attributed to the partial protein unfolding to the "molten globule" state, which enhances the protein chain flexibility as long as aggregates are not formed. In subsequent studies, this behavior was positively correlated with foam stability against liquid drainage of both ovalbumin and lysozyme (Hagolle and others 2000). It might be speculated that the findings of Hagolle and others (1998) correspond to our observations, where, extended heat treatment leads to increasing FC and FS, which may be due to the aggregate formation that impairs the protein unfolding and interaction at the air–water interface.

Emulsifying properties. Whole egg (or egg yolk) is used as an emulsifier for many food formulation and preparation. This functionality depends essentially on the presence and the state of the egg yolk protein. When whole egg is spray dried, the proteins are subject to structural changes. Depending on the temperature–time conditions of the dry process, these changes may involve denaturation of the proteins.

Microscopic observations of emulsions obtained from fresh egg and dried eggs at various operating conditions are presented in Figure 5. These images show that the size of the oil droplets dispersed in fresh egg is more significant than those obtained with dried eggs. Moreover, the average size of the oil droplets formed in the mayonnaise obtained from dried eggs decreases according to the drying conditions. Indeed, the more the heat treatment is violent (high air inlet temperature and low residence time), the more the egg is able to disperse the oil droplets.

Figure 6 shows the evolution of emulsion stability compared with air inlet temperature. This figure also shows that the stability of the emulsions obtained from dried eggs is more significant than those obtained from the fresh eggs. A slight decrease of the emulsion stability was observed from the mayonnaise obtained with dried eggs at 125 °C and 0.2 L/h.

It is evident that different proteins have different emulsifying capacities. This may be attributed to particular properties of proteins that affect their adsorption capacities at the oil-in-water interface.

It has been stated that yolk proteins and particularly lipoproteins have a higher adsorption capacity compared to globular proteins due to their flexible molecular structure and a greater surface hydrophobicity (Mine 1998). Nevertheless, the efficiency of protein as an emulsifier depends not only on the type and the state (native or unfolded) of protein but also on the pH of solution, presence of other emulsifiers, ionic strength, and type of oil added (Hermansson 1994). It means that making an emulsion with proteins that vary in emulsifying capacities does not ensure that the most surface-active proteins end up dominating the interface (Dalgleish 1999). Consequently, the composition of the interfacial film depends on the conditions under which an emulsion is formed as well as on the type of proteins used (Anton and Gandemer 1999). The lipoproteins of low-density apoproteins (LDL apoproteins), like some livetines (insoluble granules of lipoproteins of high density and phosphoproteines called phosvitine bound by bridges phosphocalcic), play a significant role in the stabilization of the oil-in-water interface (Mel'nikov 2002). The increase in the emulsifying activity of egg after drying can be attributed to the thermal unfolding of LDL apoproteins. The change of the structure of these proteins causes the increase in the hydrophobicity and molecular flexibility, thus allowing a fast and effective adsorption of these molecules in the oil-in-water interface. The livetines can also play a similar role provided that they can enter in competition with other components of the egg (Guilmineau and Kulozik 2006). Moreover, the dissociation of the native structure of LDL

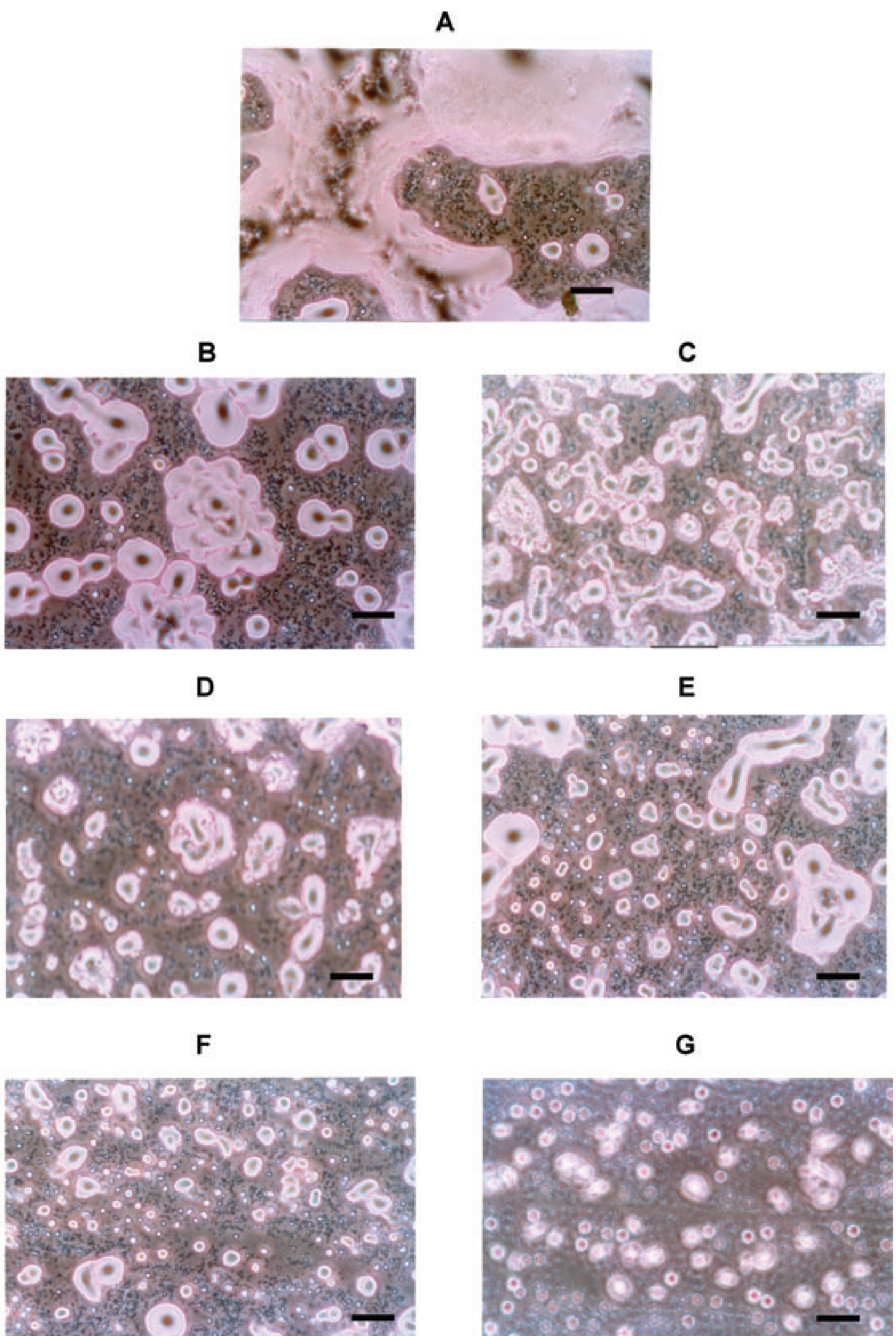

Figure 5—Comparison of microscopic images of emulsions made with (A) fresh whole egg, and whole egg dried at operating condition of (B) 110 °C and 0.2 L/h, (C) 110 °C and 0.3 L/h, (D) 120 °C and 0.2 L/h, (E) 120 °C and 0.3 L/h, (F) 125 °C and 0.2 L/h, and (G) 125 °C and 0.3 L/h. Magnification is 100; scale bar = 50 μm.

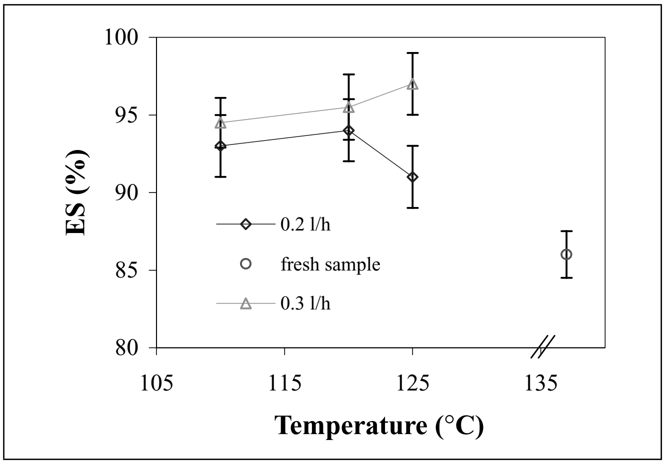

Figure 6—Characteristics of emulsions obtained from dried whole egg in terms of their stability.

during thermal unfolding allows a great availability of LDL components in oil-in-water interface, including the high surface activity of phospholipids.

Statistical analysis of functional properties

Table 2 summarizes the significance levels of class variables and their interactions with various analytical parameters, and standard deviation. Significant level of the heat treatment effect was found on a number of functional property parameters (Table 2). In the case of egg white, the air inlet temperature has great impact on WHC of its gel and foam capacity ($P < 0.01$), but no effect on foam stability ($P > 0.05$). Another parameter, the liquid flow rate, had less effect on gel properties. In the case of whole egg, liquid flow rate has a great impact on the emulsion stability ($P < 0.01$). In both experiments, treatment time was significant for most parameters and subsequently interactions with temperature and moisture level were significant.

Conclusions

In this study, a moderate spray drying time–temperature scale (temperature < 140 °C) was applied to produce white and whole egg powders. Functional properties of reconstituted eggs were studied and compared to those of fresh ones. The results obtained showed that spry drying under moderate scale led to egg products with specific foaming, gelling, and emulsifying properties, depending on liquid flow rate and inlet air temperature. No significant impact of air inlet temperature was observed on the WHC of both white and whole egg. Gel firmness is not so much affected compared to liquid flow rate. However, high temperature (125 °C) and low liquid flow rate (0.2 L/h) improve gel firmness, reduce gel elasticity, increase foam capacity, and improve emulsion capacity and stability. This study shows that spry drying of eggs products under moderate conditions could be a good alternative to develop dried egg products having special functionality.

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