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ORIGINAL ARTICLE

Functional and physicochemical properties of whole egg powder: effect of spray drying conditions

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Abstract Pasteurized liquid whole egg was subjected to spray drying to determine the effect of spray drying conditions on moisture content, water activity, peroxide value, emulsion stability, gel texture, foaming stability and colour change of the powder product. Drying process was carried out in a pilot scale spray dryer (Mobile Minor Niro-Atomizer, Denmark). The inlet (165–195 °C) and outlet air temperatures (60–80 °C) and the atomization pressure (196–392 kPa) were investigated as spray drying process variables. Perturbation and 3-D graphs revealed that outlet air temperature and atomization pressure had more effect than inlet air temperature, on the properties of whole egg powder. Optimum spray drying conditions of whole egg powder were determined according to the specific end-product requirements (bakery foods, omelette and mayonnaise and salad dressing) targeting to obtain the desired value of functional properties, i.e.; emulsion stability, gel texture, foaming stability and colour change.

Keywords Whole egg powder · Spray drying · Optimization · Functional properties · Physical properties

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Introduction

The main roles of functional properties of whole egg are stabilization of emulsion, foamability and build up firm gels. Whole egg is also used as colorants (Stadelman and Cotterill 1995). These natural properties of whole egg are useful in bakery foods, bakery mixes, mayonnaise and salad dressings, confections, ice cream, pastas and many convenience foods (Stadelman and Cotterill 1995; Forsythe 1963). Recently, the use of shell egg in food production, as the raw material has reduced with the technological developments around the world food industry, and egg products such as frozen egg, pasteurized liquid egg and dried egg products have gained popularity. Prasad et al. (2004) suggested that biscuits enriched with spray-dried egg powder can form a good substitute instead of shell eggs for armed personnel stationed in remote areas. Further, the product may find use as protein-rich biscuits for infants and children. Furthermore, spray dried egg powder has great importance for food industry with respect to handling and hygienic aspects. Spray drying allows preparation of stable and functional powder products (Koç et al. 2010; Liu and Liu 2009; Re 2006; Sagar and Suresh Kumar 2010) and can be implemented for large scale throughputs (Chávez and Ledeboer 2007; Youssefi et al. 2009). The properties of eggs are very delicate, and the final quality of the dried product can be significantly affected by drying conditions (Bergquist 1980). For egg powder production, most of the researches in the literature were related with the method of spray drying and process conditions (Caboni et al. 2005; Franke and Kießling 2002; Guardiola et al. 1995; Guardiola et al. 1997; Hammershøj et al. 2004; Lechevalier et al. 2007; Morgan and Armstrong 1992). Franke and Kießling (2002) studied the effect of inlet air temperature and nozzle pressure of spray dryer on functional properties of egg powder and found that protein solubility and foaming power decreased as the inlet air temperature increased. Ayadi et al. (2008) studied the effect of moderate spray drying conditions on the functionality of dried white and whole egg powders. The researchers obtained that spray drying under moderate scale led to egg products with specific foaming, gelling and emulsifying properties, depending on the liquid flow rate and inlet air temperature. Since the drying process causes change in functional properties of whole egg powder after reconstitution, the influence of spray drying conditions, especially on functional properties of whole egg must be defined. A detailed search of the literature showed that no research has been conducted on the optimization of the spray drying conditions to obtain the maximum quality powder of whole egg. Optimization of drying conditions still needs improvement and in particular, their impact on storage stability of dried powder needs further investigation.

The present study was undertaken to optimize the spray drying process in terms of inlet and outlet air temperatures and the atomization pressure to have an optimum quality whole egg powder with a maximum gel texture and emulsion stability, and acceptable foaming capacity and change in colour.

Material and methods

Materials

Pasteurized liquid whole egg containing 24 (±1) % (wb, *w/w*) total solid, which was used as the test material was supplied from the Mix Food Company, Izmir, Turkey. Pasteurized liquid whole egg samples were kept at +4 °C until used.

Spray drying

Experiments were conducted in a pilot scale spray dryer (Mobile Minor Niro-Atomizer, Denmark). Pasteurized liquid whole egg was atomized from a rotary atomizer into vertical, co-current drying chamber, 0.87 m diameter and 1.2 m height, under various operating conditions. Feed temperature was below 10 °C and hot air flow rate of 1.54 m^3/min was fixed for all experiments. Inlet air temperature, outlet air temperature and atomization pressure, which were in the range of 165–195 °C, 60–80 °C and 196–392 kPa, respectively, were adjusted according to the Box-Behnken experimental design and outlet air temperature was controlled by regulating the feeding velocity (Table 1). The inlet and outlet temperature measurement errors were ±1 °C. The dried powder was collected in a single cyclone separator and then packaged in ALPE packaging material until used for analysis.

Analysis

Moisture content

The moisture content of egg powders were measured with a halogen moisture analyser (Ohaus MB45, Switzerland) which was correlated well with the vacuum oven method, drying at 70 °C for 2 h (AOAC 2000).

Water activity

The water activity (a_w) values of egg powders were measured with a water activity measurement device (Testo AG 400, Germany), with a ±0.001 sensitivity.

Oil extraction and peroxide value analysis

The method of Folch et al. (1957) method was used to extract lipids from egg powder for peroxide value determination. The method used for peroxide value determined all substances, in terms of milliequivalents peroxide per 1000 g of sample, which oxidize KI under conditions of test (AOAC 2000).

Functional properties

The functional properties except colour of the dried whole egg powder were analyzed after reconstitution according to the methods described below.

Emulsion Stability (ES)

The dried whole egg was reconstituted in 0.5 M NaCl solution to dry matter content of 1% (*w/w*) and a pH value of 7.0. A 50 ml aliquot of this suspension was mixed with 30 ml of corn oil. Subsequently, the mixture was homogenized for 60 s at 22000 rpm in a homogenizator (IKA T25 Ultra turrex, Germany). To estimate the emulsion stability at 20 °C, the electrical conductivity of the emulsion near the bottom of the glass jar was monitored at the end of 1 h. The higher the amount of creamed oil phase at the surface, the higher the conductivity of the emulsion at the bottom owing to the increased water concentration (Franke and Kießling 2002; Anton and Gandemer 1997). The proportion of creamed oil phase, f, can be calculated from the Eq. 1 (Anton and Gandemer 1997):

$$f = 1 - (m_w/m_0)(1 - c_e/c_o)$$
$$ES = 1 - f \tag{1}$$

where m_w (g) is the mass of the water phase, m_o (g) is the mass of the oil phase, c_e (μS/cm) is the conductivity after 1 h and c_0 (μS/cm) is the conductivity of pure water.

Table 1 Physicochemical and functional properties of whole egg powder at 17 different experimental spray drying conditions

Inlet air temperature (°C), X_1	Outlet air temperature (°C), X_2	Atomization Pressure (kPa), X_3	Flow rate* 10^{-6} (m^3/s)	ES (%)	GT (N)	FS (%)	ΔE	MC (%,wb)	a_w	Peroxide Value
165	60	294	1,1	88.3	7.1	57.9	25.1	2.6	0.093	0.480
195	60	294	1,4	88.0	7.2	69.1	22.3	3.0	0.141	0.400
165	80	294	0,67	91.4	8.2	63.0	25.3	2.0	0.066	0.519
195	80	294	0,99	90.1	8.3	60.0	26.8	1.7	0.074	0.799
165	70	196	0,90	89.1	7.7	50.8	23.4	2.5	0.096	0.360
195	70	196	1,3	90.6	7.7	47.4	22.3	2.3	0.081	0.400
165	70	392	0,83	92.8	8.3	40.3	27.5	2.4	0.133	0.520
195	70	392	1,2	90.7	8.8	38.7	26.1	1.8	0.064	0.400
180	60	196	1,3	87.6	6.7	73.0	20.7	2.6	0.104	0.600
180	80	196	0,96	89.8	8.4	49.7	25.9	2.2	0.107	0.480
180	60	392	1,2	89.1	8.6	46.7	26.5	2.3	0.096	0.320
180	80	392	0,86	91.6	8.2	67.5	26.2	1.8	0.052	0.639
180	70	294	1,0	90.2	8.5	50.1	26.9	2.3	0.065	0.680
180	70	294	1,0	90.9	8.6	43.0	26.4	1.8	0.053	0.420
180	70	294	1,0	90.0	8.6	45.0	26.0	1.7	0.055	0.440
180	70	294	1,0	90.2	8.6	42.8	26.3	2.5	0.125	0.599
180	70	294	1,0	90.5	8.5	44.4	26.9	2.5	0.124	0.480

ES Emulsion stability, *GT* Gel texture, *FS* Foaming stability, ΔE Colour change, *MC* Moisture content, *aw* Water activity

Gelling Textural analysis (GT)

The gelling properties were measured according to the method of Franke and Kießling (2002) with some modifications. The powder of whole egg was reconstituted in 0.5 M NaCl solution to achieve dry matter content of 20% (*w/w*) and pH value of 7.0. A metal container consist of 12 cells (71 mm in diameter, 33 mm in depth) was used and each cell was filled with 50 ml of egg suspension, then container was covered with an aluminium foil and tempered in water bath for 15 min at 90 °C. Subsequently, sample container were cooled down at room temperature and stored at 4 °C overnight. To achieve the desired temperature (8 °C), samples were kept at ambient temperature just before the measurement. A small cylinder sampler (15 mm in both height and diameter) was used for sampling from the whole egg gel. Sample was deformed (compressed) by using a 7.5 cm diameter plate probe integrated with texture analyzer TA-XT Plus (Stable Micro Systems, England) with a plate velocity of 1 mms^{-1}. The maximum force obtained during compression was used as the parameter for gelling property.

Foaming Stability (FS)

The powder of whole egg was reconstituted in distilled water up to a dry matter content of 20% and was foamed using a mixer (Sinbo, SMX-2128, Turkey) at speed 1 during 5 min. Calculation of the foam stability (FS) was calculated as given in Eq. 2 (Hammershøj et al. 2006):

$$FS = \frac{V_{Liquid\ before\ foa\min g} - V_{Drained\ liquid\ t=90\,\min}}{V_{Liquid\ before\ foa\min g} - V_{liquid\ at\ time\ t=1\ \min}} [L/L] \qquad (2)$$

where $V_{\text{liquid before foaming}}$=0.1 L, $V_{\text{drained liquid at time t=90min}}$= volume of liquid drained from foam at time t=90 min after foaming (L) and $V_{\text{liquid at time t=1min}}$=volume of liquid not incorporated in the foam at time t=1 min after foaming (L).

Colour Change (ΔE)

The colour of pasteurized liquid egg and dried whole egg samples (L, a and b-value) was measured with a colorimeter (Colorflex, CFLX 45-2 Model Colorimeter, HunterLab, Reston, VA) and results were expressed in accordance with the CIE Lab. system. The total colour change (ΔE) of whole egg powder with respect to pasteurized liquid egg was calculated by Eq. 3.

$$\begin{aligned} \Delta E &= \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \\ \Delta L &= L_{\text{Pasteurized liquid whole egg}} - L_{\text{whole egg powder}} \\ \Delta a &= a_{\text{Pasteurized liquid whole egg}} - a_{\text{whole egg powder}} \\ \Delta b &= b_{\text{Pasteurized liquid whole egg}} - b_{\text{whole egg powder}} \end{aligned} \qquad (3)$$

Particle morphology

The morphological properties of egg powders (the appearance and the particle shape) were investigated by taking images via a scanning electron microscope (SEM, JSM–6060 JEOL).

Experimental design and statistical analysis

The effects of spray drying conditions on the functional properties; emulsion stability (ES), gel texture (GT), foaming stability (FS) and colour change (ΔE) during the production of whole egg powder production by spray drying were defined. A Box-Behnken design was used to arrange the experimental data. Box-Behnken design has been extensively applied for different process in foods (Raghavan et al. 1996; Kumar and Rao 2004) The inlet air temperature (165–195 °C) (X1), outlet air temperature (60–80 °C) (X2) and atomization pressure (196–392 °C) (X3) were selected as independent variables depending on the literature survey and preliminary experiments, which also enabled the explored experimental domain is to be fixed by taking into account industrial practice. Optimum spray drying conditions, targeting the maximum or minimum or acceptable values of the functional properties (the emulsion stability (ES), the gel texture (GT), the foaming stability (FS) and the colour change (ΔE)), were selected, setting the value of each functional property according to the area of use of egg powder (bakery foods, omelette and mayonnaise and salad dressing) by using Design Expert–version 7.0 software (Statease Inc., MI, USA). The influence of spray drying conditions on the moisture content, water activity and peroxide value was analyzed using SPSS version 13.0 Windows program (SPSS Inc., Chicago, IL). The analysis of variance (ANOVA) at a confidence level of 95% was performed.

Optimization

The desirability function method was used for simultaneous optimization of the multiple responses. The desirability function method finds the desired goals for each variable and response. All the independent variables were kept within range while the responses were either maximized or minimized. The numerical optimization finds a point that maximizes the desirability function. In the present study, the desirability functions were developed for each area of use of egg powder, according to the desired value of functional properties; emulsion stability, gel texture, foaming stability and colour change.

Results and discussion

The spray drying process caused substantial functional, physical and chemical changes in the powder of whole egg.

Table 2 ANOVA results of physicochemical and functional properties of whole egg powder

Source	DF	GT		FS		*ΔE*		ES		*MC*		a_w		Peroxide value	
		Sum of Squares	*p*-Value	Sum of Squares	*p*-Value	Sum of Squares	*p*-Value	Sum of Squares	*p*-Value	Sum of Squares	*p*-Value	Sum of Squares	*p*-Value	Sum of Squares	*p*-Value
Model	6	4.2	0.032	0.180	0.000	56.5	0.0001	2.85E-003	<0.0001	4.4	0.000	0.023	0.000	0.606	0.000
x_1	1	0.052	0.606	1.31E-004	0.729	1.2	0.0600	6.58E-005	0.042	0.130	0.165	0.000	0.517	0.005	0.352
x_2	1	1.4	0.019	5.15E-004	0.499	10.0	0.0003	1.26E-003	<0.0001	2.2	0.000	0.006	0.001	0.152	0.000
x_3	1	1.5	0.017	9.73E-003	0.017	24.8	<0.0001	6.30E-004	0.0001	0.500	0.008	0.000	0.232	0.000	0.755
x_1x_2	1	7.98E-005	0.983	5.02E-003	0.061	3.4	0.0070	2.42E-005	0.1764	0.480	0.009	0.001	0.155	0.097	0.000
x_1x_3	1	0.044	0.637	7.83E-005	0.789	0.013	0.8190	3.23E-004	0.0009	0.120	0.178	0.001	0.072	0.019	0.084
x_2x_3	1	1.1	0.033	0.049	0.000	7.8	0.0007	*2.28E-006*	0.6581	0.014	0.648	0.001	0.055	0.144	0.000
Error	10	1.9		7.10E-003		1.7		7.50E-005		2.4		0.018		0.235	
Total	16	6.0		0.180		58.1		2.93E-003		261.0		0.485		13.4	

ES Emulsion stability, *GT* Gel texture, *FS* Foaming stability, ΔE Colour change, *MC* Moisture content, *aw* Water activity

The moisture content (%, wb), water activity and peroxide values of whole egg powder with respect to the inlet and outlet air temperatures of spray drying and the atomization pressure were given in Table 1. Maximum moisture content (3.0%, wb) and water activity values were recorded at the same spray drying conditions; outlet air temperature of 60 °C, inlet air temperature of 195 °C and atomization pressure 294 kPa, while maximum value of peroxide (0.799) was recorded at the outlet air temperature of 80 °C. Moisture content and water activity of the egg powder increased with a decrease in the outlet air temperature since the feed flow rate to atomizer and also spray dryer is high to achieve lower outlet air temperatures, in which case the moisture removal rate gets lower. It is generally accepted that water activity of whole egg powder should be below 0.40 (Beuchat 1981) and thus moisture content below 5% (Stadelman and Cotterill 1995) in order to ensure stability. ANOVA results showed that the outlet air temperature had a significant effect on moisture content, water activity and peroxide value of whole egg powder (Table 2). In addition the moisture content was affected by the atomization pressure (Table 2).

Egg powders can be added to the various food products to fortify them and provide functionality such as foaming, emulsifying, gelling and colouring (Stadelman and Cotterill 1995). The proteins and colour pigments of whole egg during drying are subjected to the structural changes. Anandharamakrishnan et al. (2007) also reported that the protein denaturation was highly related with spray drying conditions. The functional properties of whole egg powder, emulsion stability, gel texture, foaming stability and colour change during spray drying at different combinations of inlet and outlet air temperatures and atomization pressure were presented in Table 1. The minimum emulsion stability value of whole egg powder was observed to be 0.876 at outlet air temperature of 60 °C, inlet air temperature of 180 °C and atomization pressure 196 kPa, whereas the

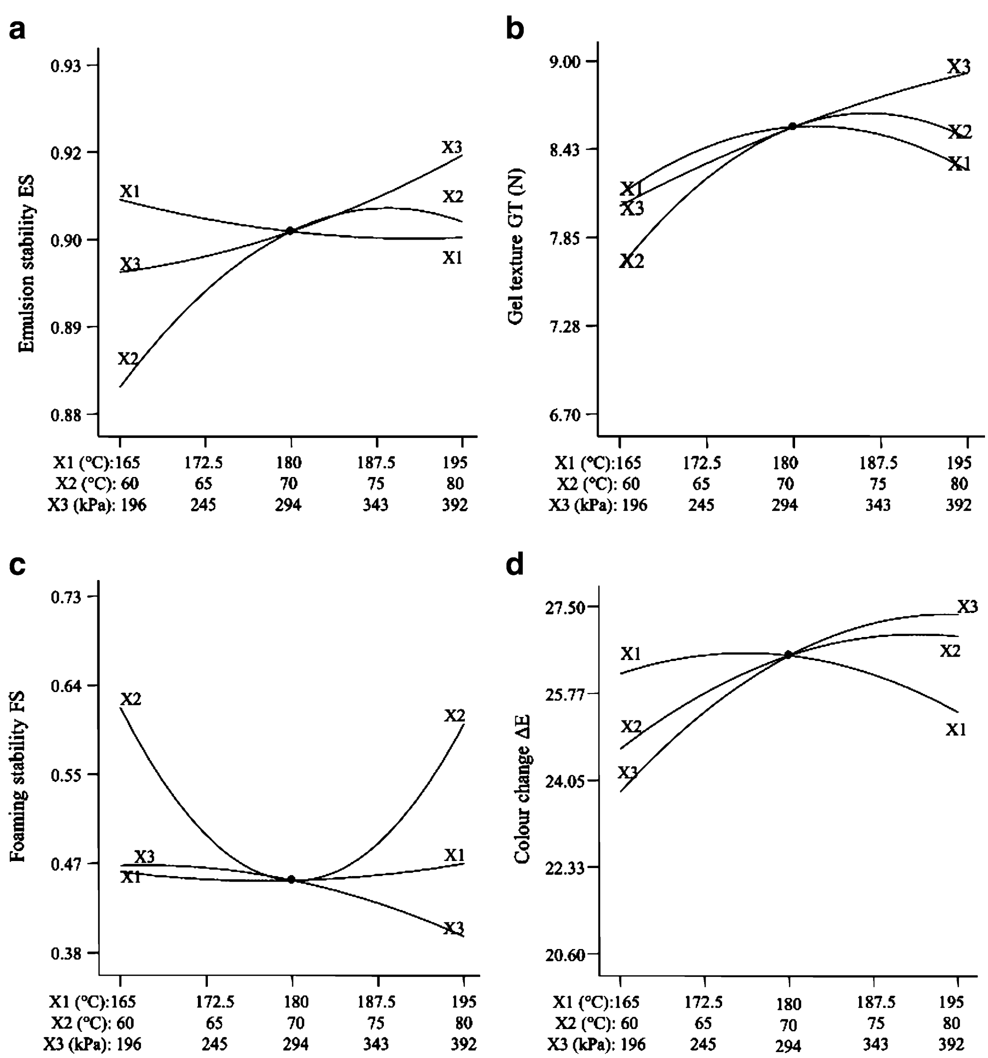

Fig. 1 Perturbation plots. (X1) Inlet air temperature, (X2) Outlet air temperature, (X3) Atomization pressure

maximum emulsion stability value was observed to be 0.928 at outlet air temperature of 70 °C, inlet air temperature of 165 °C and atomization pressure 392 kPa (Table 1). Perturbation plots (Fig. 1a) showed that the emulsion stability of the egg powder increased with the increase in outlet air temperature and atomization pressure whereas, a little change in emulsion stability was observed with the inlet air temperature. The effect of outlet air temperature and atomization pressure on the emulsion stability further revealed by 3-D graph (Fig. 2a) from which it is clear that increase in outlet air temperature and atomization pressure led to an increase in an emulsion stability of egg powder. Drying process has improved the emulsion properties of whole egg as reported also by Chapin (1951). The better stabilisation effects of powders dried at higher temperatures may be attributed to the changes in protein conformation which contribute to the stability of boundary surfaces, as also reported earlier by Franke and Kießling (2002) and Kato et al. (1990). The ANOVA results showed that (Table 2) that the outlet air temperature, atomization pressure and inlet air temperature were the significant parameters affecting the emulsion stability ($p<0.05$).

Spray drying process and conditions have also the influence on the gel texture of whole egg powder. The gel texture strongly depends on protein denaturation (Franke and Kießling 2002; Campbell et al. 2003). The maximum force obtained during compression was used as the quality parameter for gelling property. The highest gel texture value, 8.8 N was observed at the outlet air temperature of

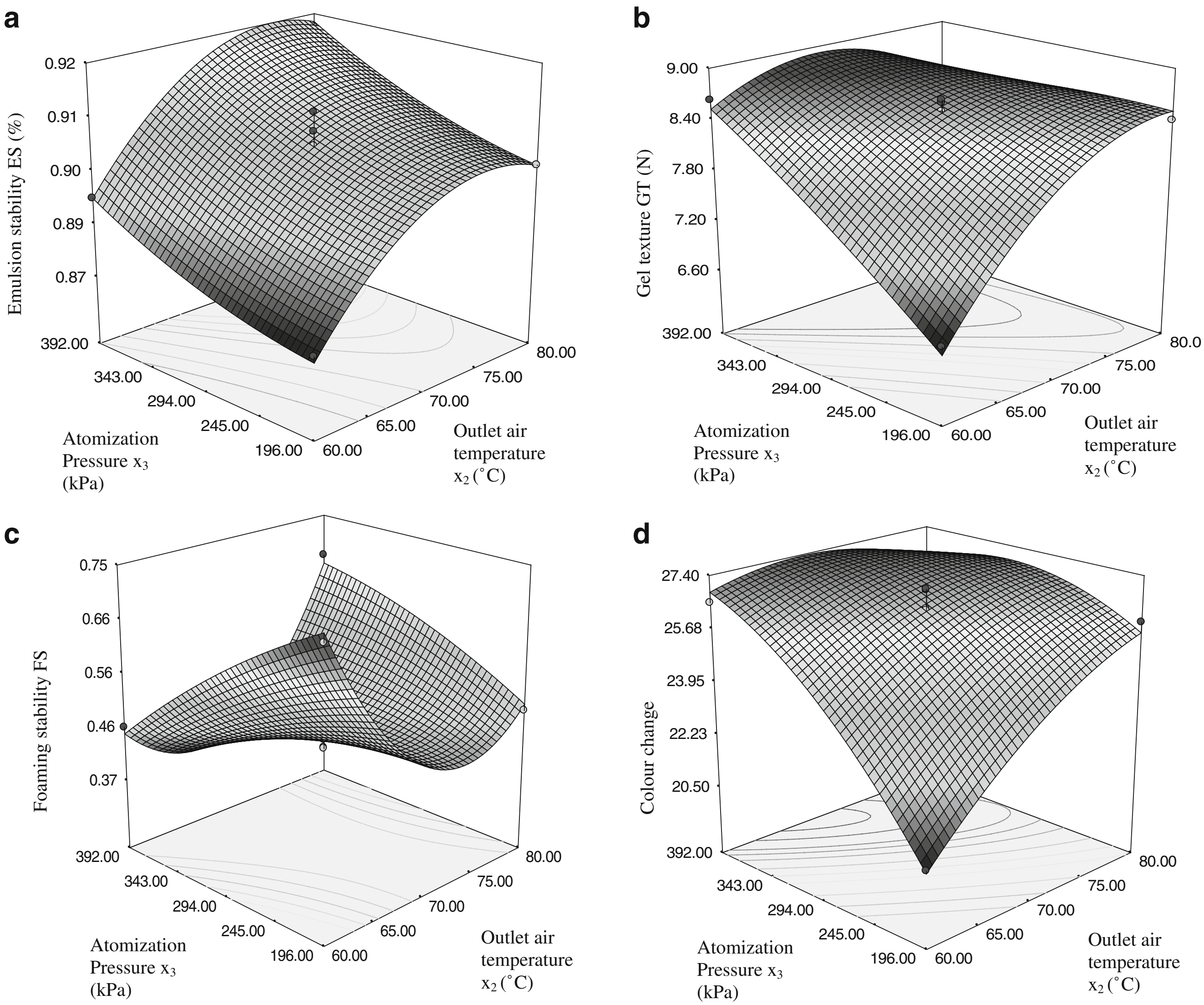

Fig. 2 Calculated effect of outlet air temperature (°C) and atomization pressure (kPa) on functional properties; **a** Emulsion stability, **b** Gel texture, **c** Foaming stability, **d** Colour change of spray dried whole egg

Table 3 Optimum spray drying conditions according to usage of the whole egg powder

	Process Variables			Responses			
Type of product	Inlet air temperature X_1(°C)	Outlet air temperature X_2(°C)	Atomization Pressure X_3(kPa)	ES (%)	GT (N)	FS (%)	ΔE
Bakery foods	171.9	72.5	392.0	Max	Max	Acceptable	Acceptable
Mayonnaise or salad dressing	195.0	64.5	196.0	Max	Min	Min	Acceptable
Omelet	195.0	66.4	196.0	Acceptable	Min	Min	Min

70 °C, inlet air temperature of 195 °C and atomization pressure of 392 kPa, while the lowest value, 6.7 N was monitored at the outlet air temperature of 60 °C, inlet air temperature of 180 °C and atomization pressure of 196 kPa during spray drying (Table 1). As seen from Fig. 1b, higher atomization pressure and outlet air temperature provide to a certain improvement in gelling properties. In general, surface hydrophobicity increases during drying of egg and has a beneficial effect on the gel texture (Kato et al. 1990; Handa et al. 2001; Baron et al. 2003). It was found that the gel texture was not affected significantly by the air inlet temperature (Table 2). The results of Franke and Kießling (2002), Hammershøj et al. (2006) and Ayadi et al. (2008) were in similar manner. Figure 2b shows the interaction effects of outlet air temperature (x_2) and atomization pressure (x_3) on the gel texture values. It can be inferred from Fig. 2b decreasing in outlet air temperature and atomization pressure caused reducing the applicable compression force on gel which obtained from whole egg powder.

When whole egg is beaten, air bubbles are trapped in the liquid albumen, and the foam is formed. The foam is defined as a colloidal dispersion in which a gaseous phase is dispersed in liquid or solid phase. Stadelman and Cotterill (1995) reported that the foaming stability of egg is affected by drying process and conditions. It was found that the foaming stability of whole egg powders altered between 38.7% and 73.0%, and it was influenced by the outlet air temperature and atomization pressure that can be seen in Fig. 1c. The foaming stability decreased with increasing atomization pressure, fundamentally due to physical denaturation of proteins. As seen in Fig. 2c a saddle system was found out because of the interaction of outlet air temperature and atomization pressure. This was explained by the foaming stability which was the highest value at maximum and minimum levels of the outlet air temperature. These findings were inconsistent with the results of the ANOVA (Table 2).

The visual impression of egg colour determines the acceptability of products containing egg powder. It is well known that high temperature and long drying time caused a significant decrease in the quality of dried materials; e.g., by change of colour. The net change in colour (ΔE) was calculated as the change in L, a, b values between the whole egg powder and pasteurized liquid egg. As seen in Figs. 1d and 2d a decrease in outlet air temperature and atomization pressure caused a decrease in the colour change. The minimum change in colour, (ΔE) (20.7), was recorded at the lowest outlet air temperature and atomization pressure, whereas the maximum change in colour, (ΔE) (27.5), was recorded at the outlet air temperature of

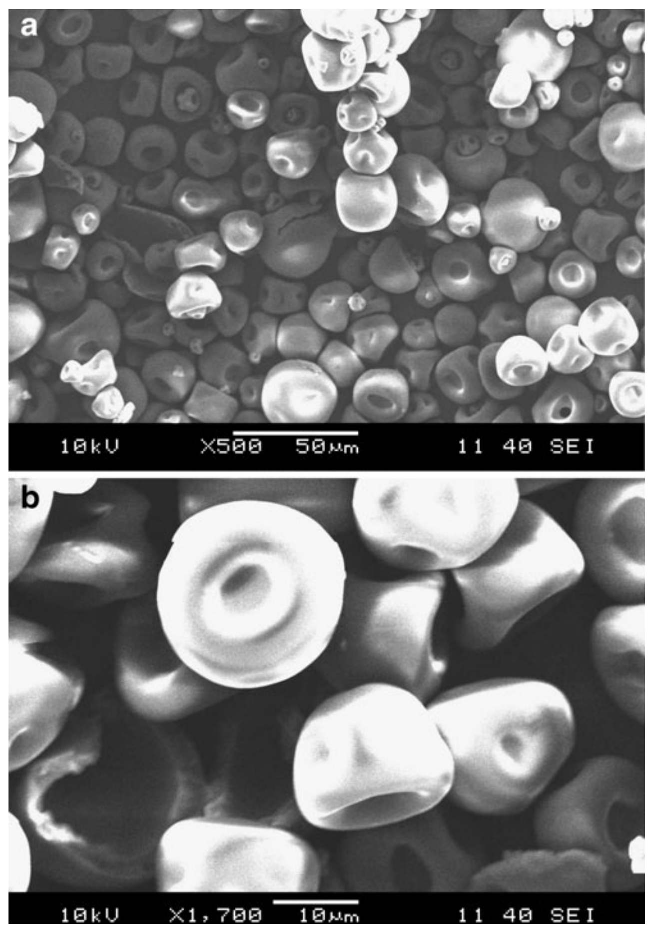

Fig. 3 Scanning electron microscopy images of whole egg powder, produced at X_1:172.9 °C; X_2:72.5 °C; X_3:392 kPa

70 °C and atomization pressure of 392 kPa. In spray drying process, higher temperature and atomization pressure applications which lead to oxidation of colour pigments (xanthophylls, lutein and zeaxanthin) and formation of smaller particles after atomization caused a bleaching of colour of whole egg powder (Stadelman and Cotterill 1995). It was observed that Hunter L value, as lightness index, increased during the drying process. On the other hand, the low a_w value of the egg powder prevented the formation of excessive Maillard reaction, also preventing the increase in Hunter b value, since the optimal range of a_w is known as 0.520–0.750 for that reaction (O'Brien and Morissey 1989).

Optimization

Spray dried whole egg powder with desired functional properties are used by many segments of the food industry especially for bakery foods, fast food (omelette), mayonnaise and salad dressing. For these products, optimum spray drying conditions were determined for targeting to obtain the desired value of functional properties, i.e.; emulsion stability, gel texture, foaming stability and colour change, separately, for the area of use or specific end-product requirement. While maximum emulsion stability and gel texture and acceptable foaming stability and colour change were objected for bakery foods, for the fast food (omelette) minimum gel texture, foaming stability and colour change and acceptable emulsion stability were the selected goals. For mayonnaise and salad dressing type products maximum emulsion stability, minimum gel texture and colour change and acceptable foaming stability were targeted. At the optimization stage, the air inlet temperature (165–195 °C), air outlet temperature (60–80 °C) and atomization pressure (196–392 kPa) were selected as independent factors. Numerical optimization was performed for the process parameters of spray drying to obtain the optimum quality whole egg powder for bakery foods, fast food and mayonnaise and salad dressing. To perform this operation, Design Expert–version 7.0 software (Statease Inc., MI, USA) was utilized for simultaneous optimization of the multiple responses.

The desired goals for each variable and response were chosen and different weights were assigned to each goal to adjust the shape of its particular desirability function. Table 3 shows software generated optimum conditions of independent variables for each area of use of the egg powder with the maximum desirability (>0.70). Outlet air temperature and atomization pressure were observed to get high values for producing whole egg powder which would be used in bakery foods were higher than other type of products' (mayonnaise and salad dressing; omelette). Nearly the same spray drying conditions of whole egg powder production were defined for mayonnaise and salad dressing, and omelette.

In the following stage of the study, which was given elsewhere (Koç 2009), the sensorial analysis was conducted for testing the use of egg powder in a cake formulation. The sensorial test results (in terms of appearance, taste and texture) showed that the egg powder produced at the selected optimum condition was satisfactorily used instead of liquid egg. Parihar et al. (2001) also reported that the overall acceptability of the omelette made from the egg powder was the second best in their samples.

Particle morphology (SEM analysis)

Figure 3a and b show scanning electron micrographs of the spray dried whole egg powder at optimum conditions. Through the scanning electron microscopy, the whole egg powder particles were observed as amorphous and shrivelled appearance. If the skin remains moist and supple for longer than the hollow particles can deflate and shrivel as they cool (Birchal et al. 2005). Fast formation and expansion of the crust or skin can also damage the particle surface.

Conclusion

Spray drying conditions (outlet air temperature; atomization pressure) in the transformation of pasteurized liquid whole egg into whole egg powder have effect on functional, physical and chemical properties of the powder. The outlet air temperature has the most pronounced effect on all analysed properties except the foaming stability, whereas only the emulsion stability was influenced by the inlet air temperature. Furthermore, no significant impact of atomization pressure was found on the water activity and peroxide value. In the optimization study, optimum spray dryer conditions were determined as the inlet air temperature of 171.9 °C, outlet air temperature of 72.5 °C and atomization pressure of 392 kPa, for whole egg powder as to be used as an ingredient in bakery foods. Similar spray drying conditions were obtained for whole egg powder which would be used in mayonnaise and salad dressing, and omelette products. This study can be used as a reference for further studies planned to develop dried egg products with the desired levels of functional properties.

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