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Effect of spray-drying and storage conditions on the physical and functional properties of standard and n−3 enriched egg yolk powders

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ABSTRACT

This study aimed to evaluate the effect of the processing and storage conditions on the physical and functional properties of egg yolk (EY) powders. The spray-drying temperature (160 °C vs. 180 °C), storage temperature (15 °C vs. 30 °C) and time (1, 2, 4 and 8 months) and n−3 enrichment through hen diet were investigated.

The spray drying temperature and storage conditions modified the water content, water activity and the particle size distribution of EY powders. Flowability of the powders and the emulsifying properties were not significantly affected from an industrial point of view. On the opposite, the viscosity increased with the spray-drying temperature as well as the temperature and time of storage in rehydrated powders. Powders prepared with n−3 enriched egg yolks exhibited lower melting peaks temperatures, a marked yellow colour and higher fluidity of the solutions, but the overall properties remained unchanged. This study clearly attests the possibility of an industrial production of n−3 enriched EY powders.

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1. Introduction

Egg products are widely used in various food preparations for their functional, sensorial and nutritional properties (Watkins, 1995). Egg yolk is particularly recommended for its emulsifying and thickening properties in mayonnaise, salad dressings, ice creams and bakery products, joined to its colouration effect. Egg products are often employed as functional ingredients in the form of powders that offer numerous advantages: reduction of transport and storage costs, protection against microbial growth and easier dosage during industrial manufacture. Spray-drying is the most commonly process used to obtain powders from liquid foods. The industrial treatment of whole egg and egg yolk differs from the one used for egg white: whole egg and egg yolk require a pasteurization step before drying, that is not necessary for egg white because this operation is realised in the dry state (Galet et al. 2010).

The overall conditions encountered during the thermal treatments are susceptible to modify the functional properties of egg products, mostly by decreasing the protein solubility, on a way that may be damaging or beneficial, conferring new functionalities to the powders (Galet et al., 2010).

During spray-drying, the temperature of the droplets remains under the temperature of the outlet air, i.e. under 90–100 °C, and the drying occurs within a few seconds limiting thermal denaturation, particularly in the three-stage drying process. This process is equipped with two fluid beds, an integrated one at the bottom of the drying chamber and an external one, with agglomeration, additional drying and cooling functions (Schuck et al. 2005). The drying parameters are interdependent: the outlet air temperature can be adjusted to the powder characteristics, by regulating the inlet air temperature and the concentrate and air flow rates; usual moisture content and water activity of EY powder are around 3–4%

Abbreviations: EY, egg yolk; EW, egg white; HV, Haenni value; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid; WE, whole egg.

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and 0.2–0.3 respectively. The storage conditions, time and temperature, over periods corresponding to the shelf life of powders have also to be considered.

While the effect of thermal treatment of liquid EY on the emulsifying properties has been investigated (Le Denmat et al. 1999; Campbell et al. 2005; Guilmineau and Kulozik, 2006), there are only few studies concerning the effect of spray-drying and storage parameters and even more seldom on EY powders. Franke and Kiessling (2002) demonstrated on a pilot spray dryer that the increase of inlet air temperature improved the capacity of whole egg powders to stabilise emulsions. Ayadi et al. (2008) came to the same conclusion but on a laboratory-scale spray dryer and with milder conditions: 125 °C compared to 190 °C for the previous study. Some authors like Jaekel et al. (2008) favoured freeze-drying to preserve the functional properties of EY, and Koc et al. (2011) found a lower capacity of emulsion stabilisation and impaired colour for whole egg powder during storage.

Hen egg yolk contains high proportions of lipids (around 30% w/w fresh basis) whose nutritional quality is related to the content of saturated- (SFA), monounsaturated- (MUFA) and polyunsaturated (PUFA) fatty acids. There is nowadays a strong interest to lower the ratio of n−6/n−3 fatty acids in the human diet, in order to reduce the risk of chronic diseases, which are prevalent in the western societies (AFSSA, 2010; EFSA, 2010). The supplementation of hen diet with flax seeds, fish oils… has been proved to reduce this ratio, thus increasing the proportion of n−3 PUFA in egg yolk (Baucells et al. 2000; Fraeye et al. 2012; Milinsk et al. 2003).

The production of egg powders with n−3 enriched eggs could be a way to diversify the supply and enlarge the market of egg products, but their susceptibility to the drying and storage conditions regarding their functional properties have to be investigated.

The objectives of the present work were:

- to study the effect of spray-drying temperature at a semi-industrial scale, and storage conditions, on the physical and functional properties of EY powders particularly the flowability of the powder, the viscosity of the reconstituted EY and the emulsifying capacity,
- to evaluate the impact of processing and storage on the properties of powders prepared from n−3 enriched eggs.

2. Materials and methods

2.1. Preparation of egg powders

Eggs were obtained from hens fed with standard or PUFA-enriched diet. The PUFA-enriched diet was supplemented with extruded flax seeds, according to the French label "Bleu Blanc Coeur".

Two batches of eggs were selected for the study: control egg yolk referred to as standard (Std) and PUFA enriched egg yolk (ω_3).

After industrial pasteurization at 65 °C- for 5 min, spray-drying was conducted on a three-stage pilot plant of the Gea-Niro society (Saint-Quentin-en-Yvelines, France) at Bionov (Rennes, France) whose evaporation capacity is 80 kg h^{-1}. The atomizer was equipped with a pressure nozzle (0.73 mm diameter orifice) providing a 60°spray angle. The spray-drying parameters were determined according to the desorption method of Schuck et al. (2009). Dry air flow rate and nozzle pressure were of 2570 ± 50 kg h^{-1} and 14 MPa respectively; the temperature of the integrated bed was 65 ± 1 °C. Two drying conditions were applied on the control (Std) and PUFA enriched (ω_3) egg yolk: 160 °C/62 °C and 180/80 °C for inlet/outlet air temperatures respectively, noted Std160–Std180 or $\omega_3$160–$\omega_3$180) (Table 1).The inlet flow rate was maintained constant in order to avoid any modification of the particle size distribution due to the spray-drying conditions, with the disadvantage of increasing the outlet temperature. Immediately after drying, powders were packaged in polyethylene bags, and put into kraft bags.

All the powders were stored at 15 °C during 1, 2, 4 and 8 months except an aliquot of the control egg yolk powder dried at 160 °C which was stored at 30 °C (Std160/30). The physical and biochemical characteristics of the powders were determined after drying.

2.2. Physicochemical characteristics

2.2.1. Moisture content and water activity

The moisture content was determined in triplicate by drying 2 g of powder at 105 °C during 5h30 in a forced air oven.

The water activity (a_w) was measured at 25 °C ± 0.1 °C by using the Novasina a_w-meter (Novasina, Switzerland). A replicate was assessed for each sample.

2.2.2. Chemical composition

Total protein was determined by Kjeldahl method with a 6.38 conversion factor using the Tecator equipment (Humeau, Nantes, France) and ashes measured after incineration at 550 °C for 5 h. A replicate was assessed for each sample.

The lipid composition of standard and n−3 enriched EY powders, as well as the tocopherols, lutein and zeaxanthin content were reported previously (Meynier et al., 2014).

2.2.3. Colourimetry

The colour of egg yolk powders was analysed using the Minolta Chroma Meter CR-400 (Minolta, Osaka, Japan). Before analysis, the apparatus was calibrated with the white CR-400 calibration plate. The EY powders were placed in plastic Petri dishes to measure the colour. The illuminant and colour space were D65 and CIE $L^*a^*b^*$ system respectively. The colour characteristics were L^* (lightness: $L^* = 0$ black and $L^* = 100$ white), a^* (red–green axis: $-a^*$ = green and $+a^*$ = red/magenta), and b^* (yellow–blue axis: $-b^*$ = blue and $+b^*$ = yellow). All the analyses were performed in triplicate.

Table 1
Spray drying parameters and physico-chemical characteristics of the powders immediately after drying.

	Spray drying conditions				Physicochemical characteristics				
Powder type	Temperature of the concentrate (°C)	Concentrate mass flow rate (L h^{-1})	Inlet air temperature (°C)	Outlet air temperature (°C)	Moisture content (% dry basis)	a_w (25 °C)	Total protein (% dry basis)	Ashes (% dry basis)	Lipid content (% EY)*
Std160	48.0	115	160.0	62	2.7	0.32	35.7	3.7	33.4 ± 0.6
$\omega_3$160	48.9	112	160.0	61.9	3.1	0.28	34.5	4.8	–
Std180	48.6	105	185.2	80.5	1.5	0.17	35.3	3.8	32.8 ± 0.4
$\omega_3$180	49	110	185	80.6	2.1	0.15	34.6	5.2	–

* From Meynier et al., 2014.

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