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Impact of magnetic assisted freezing in the physicochemical and functional properties of egg components. Part 2: Egg yolk

F. Fernández-Martín[a,*], M. Pérez-Mateos[a], S. Dadashi[b], C.M. Gómez-Guillén[a], P.D. Sanz[a]

[a] Instituto de Ciencia y Tecnología de Alimentos y Nutrición (ICTAN-CSIC), José Antonio Nováis 10, 28040 Madrid, Spain
[b] Department of Food Science and Technology, Faculty of Agriculture, University of Tabriz, P.O. Box 51666-16471, Tabriz, Iran

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ABSTRACT

Effects of freezing assisted with magnetic fields (MFs) in a commercial Cell Alive System (CAS) unit at − 50 °C, with a static MF only (0% CAS) and with a static MF plus oscillating MF (10% CAS), on egg yolk (Y) was investigated. Y samples were obtained from commercial eggs laid by three hen strains (two of them in fortified cages and the third one free outdoors). The main goal was to study the thermal denaturation of protein involved in MF processing. Results showed that freezing treatment was the factor with the highest influence. Thermal denaturation enthalpy of Y was markedly affected (~45% total protein in comparison with Fresh sample), but similar for the two MF processes, where 0% CAS was taken as the Control freezing treatment. MF effects were predominantly thermal in nature and were the factor with the highest influence on the thermal behavior (which ran parallel to that of egg white, as described in Part 1), as well as on most of the functional properties exhibited by the MF samples. Rheology and free Sulfhydryl content were studied complementarily to Differential Scanning Calorimetry (DSC) data. Some important functional properties such as Emulsion Ability and Emulsion Stability were also determined. The hen strain feeding factor had practically no influence on the physical or functional behavior of both untreated and processed Y samples, except on their color parameters.

1. Introduction

Eggs are generally considered as tasty, wholesome, nutritious food. Their protein value is high while their calories and fat content are moderate. Eggs are also easy to digest. They are very good potential sources of fresh materials for health-promoting derivatives, the so-called functional foods (Garcés Rimón, Sandoval, Molina, López-Fandiño, & Miguel, 2016), as well as an ingredient for the food industry in general. They are also suitable for nutritional improvement (fortification) of several kinds of foods because they have four major nutritional components: proteins, lipids, all necessary vitamins (except vitamin C), and minerals. Hens' eggs have been used as a food by human beings since antiquity and they are used in the food industry because of their nutritional value and organoleptic characteristics, but also, and widely, for their functional properties. Some of these functional properties are foaming, thickening, binding, and emulsifying; in addition, the coloring ability and aroma of egg should also be mentioned.

All eggs have two main edible parts: White (or Albumen) (W), and Yolk (Y). White egg proteins have already been dealt with in Part 1, so this section is restricted to egg yolk (Y). The total dry matter of freshly laid Y is about 52%, of which 65% is fat, 31% is protein, and 4% is composed of carbohydrates, vitamins, and minerals. The largest variation in egg yolk dry matter takes place during storage of the egg in its shell, owing to transfer of water from the white into the yolk (Guilmineau & Kulozik, 2006, 2007). In other words, as the pH of W increases during storage, the physical properties of the Y membrane are modified, allowing a slow diffusion of water and other small molecules from W into Y (Silversides & Budgell, 2004). Egg yolk dry matter is composed of complex lipids and proteins in a ratio of around 2:1. In fact, Y is an emulsion of lipid droplets (microscopic particles of high structural complexity) dispersed in an aqueous protein medium, the droplets being of three types: spheres, granules (lipoprotein drops), and profiles (low-density lipoproteins), which have been shown to be chemically constituted by complex mixtures of phospholipids and low-density lipoproteins (LDL) (Chang, Powrie, & Fennema, 1977). Another way of describing the composition of Y is to say that it consists of two main fractions: Plasma (80%), which contains LDL and soluble proteins (livetins), and Granula (20%), richer than plasma in proteins, such as lipovitellins (HDL), phosvitin, and Granular LDL (Ibanoglu & Erçelebi, 2007). LDL is the largest constituent of egg yolk. It has a typical lipoprotein structure, comprising a core of neutral lipids (triglycerides and

* Corresponding author.
E-mail address: fermarfer@ictan.csic.es (F. Fernández-Martín).

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cholesterol esters) surrounded by an interfacial layer of phospholipids and proteins (LDL apoproteins) (Burley & Vadehra, 1979; Kiosseoglou & Paraskevopoulou, 2005). According to Guilmineau & Kulozik, 2007, and references therein), native egg yolk consists of a dispersion of low-density lipoproteins (LDL) and insoluble granules in an aqueous solution of soluble glycoproteins (vitellins), where the granules consist of a complex of high-density lipoproteins (HDL) and a phosphoprotein (phosvitin) bound by phosphocalcic bridges. Egg Yolk is appreciated for its emulsifying properties, which are of particular value for the preparation of hot and cold sauces (e.g. mayonnaise, dressings, hollandaise sauce), as well as in the production of biscuits, cakes, and ice cream.

Egg yolk (Y) is capable of being treated by the new processing technologies for various purposes, mainly for inactivation of microorganisms and enzymes for safe consumption within a short time or extended shelf life for long storage periods. Among these technologies we are particularly interested in the application of magnetic assisted freezing (MF) because it is a recently introduced treatment method that has not yet been applied to egg products, as far as we know. MF combines the application of a variety of magnetic fields with a temperature below the freezing point of the samples. Its commercial development is noticeable, but so far clear evidence of its promised effects has not yet been found (Xanthakis, Havet, Chevallier, Abadie, & Le-Bail, 2013; Xanthakis, Le-Bail, & Ramaswamy, 2014). According to commercial advertisements, equipment of this kind is able to generate tiny ice crystals throughout the frozen product, preventing cell destruction and keeping the quality of the fresh product intact after thawing (Otero, Rodríguez, Pérez Mateos, & Sanz, 2016). However, the number of studies reported in the literature is still very small, particularly concerning the effects of MF on protein denaturation in treated egg substrates. This novel technology is of considerable local interest because it is currently in a phase of commercial introduction in Spain and in several other countries.

The main goal of the present work was to study the effect of MF treatments, performed in a commercial unit, on various physicochemical and functional properties of separated egg yolk (Y) from three classes of commercial eggs laid by three types of hens living in different conditions. Furthermore, the thermal denaturation of the respective proteins involved in MF treatments were studied by Differential Scanning Calorimetry (DSC), mainly complemented by Textural and Rheological analysis. It is interesting to note that rheological properties are among the most important characteristics of food products, determining their functional properties and shelf life; they are useful in process design.

The collection of all these data is intended to help to understand the changes that this new freezing technology could induce in physicochemical and functional properties such as foaming or gelling. This would make it possible to present a general evaluation of MF performance in egg component treatment in comparison with the corresponding fresh egg components: Part 1, Egg white (Fernández-Martín, Pérez-Mateos, Dadashi, Gómez-Guillén, & Sanz, 2017) and Part 2, Egg yolk.

2. Materials and methods

2.1. Sample preparation

Three different classes of brown eggs, laid within 7 days, all from *Gallus gallus* hen flocks fed compound feed, were obtained from a local producer. The three hen strains corresponded to Lohmann Brown (A), Hn Brown (B), and Isa Brown (C), respectively. While A and B hens lived in fortified/enriched cages, C hens remained free outdoors and also ate grass.

Fresh egg yolk (Y) was manually separated from each egg; chalazae and spots and defects were then removed from them (Manzocco, Panozzo, & Nicoli, 2013). Not < 20 eggs from each strain were broken for the preparation of each Y sample batch. The Fresh Y that was obtained was very gently homogenized by hand and then immediately processed.

2.2. Composition and pH

Compositional data were determined in triplicate according to AOAC (1984) methods. Moisture was evaluated by desiccation of ~5 g using a Selecta 2000367 air-forced oven (JP SELECTA, SA, Spain) at 105 °C until a constant weight was reached. Fat was determined by the Soxhlet method with a Soxtec system (Tecator AB, Höganäs, Sweden). Protein was measured by the Dumas method with a LECO TruMac analyzer (LECO Corporation, St. Joseph, MI, USA). Ash content was assessed with a Select Horn oven (JP SELECTA, SA, Spain) working at 550 °C for 5 h.

The pH was determined at room temperature with a pH-meter (Crison, pH Burette 24 1S) in triplicate.

2.3. MF treatments

They were performed as described in Part 1 (Fernández-Martín et al., 2017) for W samples. Briefly, a freezer (ABI, Corporation Ltd., Chiba, Japan) equipped with both static and oscillating magnetic field generators (Cell Alive System – CAS) was used. Details of its characteristics are given in Otero, Pérez-Mateos, Rodríguez, and Sanz (2017). Among the possibilities of the freezer, the two that corresponded to the minimum and the maximum magnetic intensity field were chosen, i.e., one with only static MF (0.14 mT, 0 Hz; 0% CAS) and the other at the maximum intensity of 0.14 mT static MF plus 1.52 mT oscillating MF (10% CAS) working at 6 Hz. The temperature of the freezer was programmed to be − 50 °C. Both MF treatments were applied for ~75 min processing time; cooling rates (°C/min) ranged between ~0.04 and 0.05 (in the initial step, before the phase change) and between ~0.02 and 0.03 (in the final step, after the phase change), with the higher and lower values corresponding to 0% CAS and 10% CAS, respectively.

As explained in detail in Part 1 (Fernández-Martín et al., 2017), Conventional Freezing was not chosen as Control because this process is usually performed at a given temperature but at very high cooling rates that are not accessible in MF processing. Therefore 0% CAS was considered the current Control for the MF treatments (Wowk, 2012).

In the case of DSC and Rheology, the procedure used for analysis was: Fresh Y (YA, YB, YC) samples were prepared in the morning and subsequently subjected to MF freezing treatment; the frozen samples were then kept in the refrigerator (2–4 °C) overnight for thawing and then immediately encapsulated for DSC runs or rheological measurements, keeping the operating conditions always at temperatures lower than 20 °C to avoid undesirable protein denaturation. This was explained in Part 1. However, in those cases in which it was not appropriate to apply this procedure, we followed the same methodology as for W in some of the physicochemical determinations, i.e., a total of 72 Y individual 100 mL portions for each CAS condition from the abovementioned Y (YA, YB, YC) sample batch were deep-frozen at − 80 °C with a Forma − 86 °C ULT Freezer (Thermo Fisher Scientific, Waltham, MA, USA) at a cooling rate of 1 °C/min. Successively, samples were thawed for two hours at room temperature for daily analytical use. Only determinations such as emulsifying properties were affected, and fortunately their results (see corresponding Results headings) seemed not to present inconsistent values in relation to the general study, as in the W samples. This was expected because the MF frozen samples were already completely crystallized.

2.4. Color

Color was evaluated with a CM-3500d spectrophotometer (Konica Minolta, Tokyo, Japan) managed by CM-S100w SpectraMagic™ data software using the CIE Lab scale (D65/10°). Objective CIE-LAB