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Egg yolk plasma: Separation, characteristics and future prospects

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ABSTRACT

Egg yolk is a complex system comprising a variety of particles in suspension in a clear yellow fluid (plasma). Although the individual constituents of yolk are difficult to separate, hen egg yolk can be easily fractionated by simple dilution and centrifugation into sedimented granules and plasma. Each egg yolk fraction could possibly offer new pathways in applied science. In fact, the observed differences between plasma and granules indicate that there is scope for more efficient or more specific use of these fractions compared to whole egg yolk. This review provides an update which focuses specifically on egg yolk plasma, providing a description of its constituents and functionalities and future possibilities for its use in the egg industry.

1. Introduction

As one of the most versatile of products, egg yolk is widely used in the medical, pharmaceutical, cosmetics and food industries on account of its multifunctional properties. It is a natural oil-in-water emulsion containing approximately 52% dry matter, about 65% of which is fat, 31% proteins and the remaining 4% carbohydrates, vitamins and minerals (Guilmineau, Krause, & Kulozik, 2005).

As egg yolk is a major source of active ingredients, one of the main purposes is the separation of its components. However, nowadays only plasma (supernatant) and granules (pellet) can be easily fractionated from yolk by centrifugation at an industrial scale (Huopalahti, Lopez-Fandiño, Anton, & Schade, 2007). Based on the current state of the art, separate usage of each egg yolk fraction in food processing could possibly offer new approaches, for instance, in emulsification technology (Strixner & Kulozik, 2013).

Plasma forms the aqueous phase in which yolk particles are in suspension. It is composed of 85% low-density lipoproteins (LDLs) and 15% globular glycoproteins, mainly α-, β- and γ-livetins (Anton, 2013; Strixner & Kulozik, 2013). LDLs are large spherical particles of 17–60 nm in diameter with a core of triglycerides and cholesterol esters surrounded by a monofilm of apoproteins (called lipovitellenins) and phospholipids. The chemical and structural properties, adsorption kinetics and emulsifying properties of egg yolk plasma have been investigated previously (Erçelebi & Ibanoglu, 2010). Plasma is also an abundant source of many bioactives, such as egg yolk immunoglobulin Y (IgY) and phospholipids (Navidghasemizad, Temelli, & Wu, 2014). This paper provides an update on egg yolk plasma characteristics and its possible uses in applied science, mainly in the food industry.

2. Production methods

It is widely known that the individual constituents of egg yolk are difficult to separate (Erçelebi & Ibanoglu, 2010; Strixner & Kulozik, 2013). However, since McBee and Coterill (1979) reported a method to easily fractionate egg yolk into plasma and granules by dilution and centrifugation, different authors have typically employed this procedure, modifying yolk dilution conditions and/or centrifugation speed and time. Laca, Paredes, Rendueles, and Díaz (2014) have recently summarized the egg yolk granule production methods found in literature, which are the same methods used to obtain plasma. The fractionation procedure is always based on two basic steps: dilution and centrifugation. Although some publications and patents employ industrial-scale separation of egg yolk, it should be noted that recent studies still use discontinuous fractionation methods (Strixner & Kulozik, 2013).

3. Composition

Plasma makes up approximately 80% of total yolk and consists primarily of lipids (Table 1). However, the composition of plasma

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can change with the hen's diet (Li-Chan & Kim, 2008; Pillet et al., 2011). Although other factors like egg age (Freschi, Razafindralambo, Danthine, & Blecker, 2011) or hen species (Li-Chan & Kim, 2008) can also affect plasma composition, the reported differences in yolk plasma composition can mainly be attributed to the fractionation procedure employed (yolk dilution, disrupting agent, pretreatment, etc.) (Lei & Wu, 2012; Strixner & Kulozik, 2013). A comparison between egg yolk, plasma and granules composition is shown in Table 2.

4. Protein profile

As previously mentioned, plasma contains 85% LDLs and 15% globular glycoproteins, mainly α-, β- and γ-livetins. Livetins correspond to chicken blood serum proteins, with IgY being the predominant fraction of γ-livetins (Guilmineau et al., 2005; Huopalahti et al., 2007). LDLs represent a heterogeneous group of spherical particles with a lipid core stabilised by an outer layer of phospholipids and apoproteins (lipovitellenins) (Huopalahti et al., 2007; Strixner & Kulozik, 2013). Although Huopalahti et al. (2007) reported that there are six major LDL apoproteins ranging between 15 and 130 kDa, different studies can be found in the literature describing up to 18 polypeptides ranging between 15 and 240 kDa (Guilmineau et al., 2005).

The SDS-PAGE protein profile of plasma generally reveals the presence of nine bands corresponding to LDL apoproteins and livetins (Anton, Beaumal, & Gandemer, 2000; Anton et al., 2003; Freschi et al., 2011; Huopalahti et al. 2007; Le Denmat, Anton, & Beaumal, 2000; Mine, 1998; Naderi, House, & Pouliot, 2014; Navidghasemizad et al., 2014; Strixner & Kulozik, 2013). However, as can be seen in Table 3, there is little agreement among different studies concerning the molecular weight of LDL apoproteins and livetins. This may be due to several factors: more than 100 apoproteins from hen egg yolk have been identified to date (Rao, Fisher, Guo, & Labuza, 2013); proteins can exist in different polymorphic forms (Hatta, Kapoor, & Juneja, 2008; Raikos, Hansen, Campbell, & Euston, 2006); method protocol (delipidation of proteins prior to analysis, electrophoresis under reducing or nonreducing conditions, etc.) (Guilmineau et al., 2005; Naderi et al., 2014; Strixner & Kulozik, 2013).

5. Functional properties

Plasma exhibits better emulsifying activity than granules (Anton, 2013) and major similarities have been observed between the emulsifying properties of yolk and plasma (Jolivet, Boulard, Beaumal, Chardot, & Anton, 2006). This is due to the fact that LDLs are considered to be the main contributors to the exceptional emulsifying activity of egg yolk (Anton et al., 2003). Emulsifying properties are closely related to protein solubility and plasma is solubilized at any ionic strength (Li-Chan & Kim, 2008). As regards emulsion stability, different tools have been used to determine this parameter, such as oil droplet diameter measurement. A summarized review of the literature related to the emulsifying properties of egg yolk plasma is given in Table 4.

The rheological properties of plasma have not been widely studied, as most papers study the rheological behaviour of plasma dispersions or emulsions. However, Le Denmat, Anton, and Gandemer (1999) reported that plasma flow curves were characteristic of Newtonian liquids with low viscosity, as also occurs with plasma dispersions (Anton, 2013). With regard to plasma emulsions, Sirvente et al. (2007) found that they exhibited mild viscosity at low shear stress which then rapidly dropped with increasing shear stress, demonstrating the presence of a flocculated system. Rheological properties are determining factors in processing and technical aspects; for instance, in the continuous fractionation of liquid egg yolk into granules and plasma (Strixner & Kulozik, 2013).

It is a well-known fact that, with equal dry matter, plasma exhibit better properties than yolk. In fact, plasma proteins have been shown to play a prominent role in egg yolk gelation (Guilmineau et al., 2005; Kiosseglou & Paraskevopoulou, 2005; Kiosseoglou, 2003).

The effect of different treatments on plasma has likewise been investigated. Dyer-Hurdon and Nnanna (1993) found that spray-drying may affect the sensory and functional properties of plasma. Sirvente et al. (2007) reported that high pressures had a significant effect on plasma emulsifying properties, while practically did not affected its rheological behaviour in terms of apparent viscosity. More recently, Jin, Huang, Ding, Ma, and Oh (2013) concluded that enzymatic modifications only slightly affected plasma emulsifying properties, while Strixner, Würth, and Kulozik (2013) found that enzymatic treatment significantly improved the surface activity of spray-dried plasma. Anton (2013) also demonstrated that plasma is more sensitive to heat treatments (55–76 °C) than granules. More precisely, above 69 °C plasma protein solubility was found to drop sharply and apparent viscosity rose noticeably (Le Denmat et al., 1999). In particular, the emulsifying activity of plasma was shown to decrease drastically after heating at 72 °C (Sirvente et al., 2007).

The synergistic effects of plasma are also of major interest in the egg industry, as reported by Paraskevopoulou, Amvrosiadou, Biliaderis, and Kiosseglou (2014), who studied the effect of yolk plasma addition on the rheological properties and flavour characteristics of heat-set gels based on whey protein isolate.

Table 2
Comparison of egg yolk, plasma and granules composition.

	Egg yolk[a]	Plasma[b]	Granules[c]
Dry matter content (%)	51	32	44
Protein content (% dry weight basis)	31	23	58
Lipid content (% dry weight basis)	70	76	33
Cholesterol (% dry weight basis)	2.5	3	0.7

[a] Values adapted from Laca, Paredes, and Díaz (2010).
[b] Average data of values found in Literature (see Table 1).
[c] Average data of values found in Literature (Adapted from Laca et a. (2014)).

Table 1
Comparison of egg yolk plasma composition according to different papers.

Yolk dry matter (%)	Dry matter content (%)	Protein content (% dry weight basis)	Lipid content (% dry weight basis)	Ash (% dry weight basis)	Cholesterol (% dry weight basis)	References
75	–	24	79	–	2.4	Dyer-Hurdon and Nnanna (1993)
–	24	–	–	–	–	Le Denmat et al. (1999).
77–81	–	25	73	2	3.6	Huopalahti et al. (2007)
78	51	18	80	2	–	Li Chang & Kim (2008)
77–81	–	23	80	–	–	Freschi et al. (2011)
77–81	–	25	73	2	–	Navidghasemizad et al. (2014)
–	22	19–22	71–76	–	–	Naderi et al. (2014)