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Egg yolk granules: Separation, characteristics and applications in food industry

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ABSTRACT

Egg yolk is a multifunctional ingredient in many food applications, as it binds interesting functional attributes (foaming, coagulative, emulsifiying, colouring, etc. properties). Last years, numerous extensive studies characterizing egg components have been carried out. This has led to the development of new promising technologies to expand the egg-processing industry into new applications. Individual constituents of yolk are difficult to separate; thus, nowadays, only plasma and granules can be easily fractionated from yolk at an industrial scale. Recently, different works have reported the interesting composition and properties of granules to be used as ingredient in food industry, some of these works have even developed applications at pilot scale. Afterwards, this review provides an update on the different methods employed to obtain egg yolk granules, with a description of their constituents and functionalities and finally the future possibilities to employ them as ingredient in food industry.

1. Introduction

Hen egg yolk is a key ingredient in a wide variety of food emulsions, as it combines excellent emulsifying properties and appreciated organoleptic characteristics (Anton, Le Denmat, Beaumal, & Pilet, 2001). In native conditions, yolk is constituted of a continuous aqueous phase (plasma) and insoluble denser structures with a size ranging from 0.3 to 2 μm (granules) (Guilmineau & Kulozik, 2006). Plasma is composed of LDLs and livetins, whereas granules are mainly constituted by HDLs, phosvitin and LDLs (Anton, 2013).

Currently, as an increase in the added value of egg products is pursued, it is important to explore new technological applications. One of the main approaches accompanying these new innovative applications is the fractionation of egg components. However, individual constituents of yolk are difficult to separate due to different practical and economic reasons, so, nowadays only plasma and granules can be easily fractionated at an industrial scale (Anton, 2007).

Last years, different works (Anton, 2013; Freschi, Razafindralambo, Danthine, & Blecker, 2011; Laca, Paredes, & Díaz, 2010a; Laca, Paredes, & Díaz., 2011; Navidghasemizad, Temelli, & Wu, 2014; Strixner & Kulozik, 2013) have reported interesting composition and properties of granules and plasma. Specifically, granules show many interesting characteristics to be employed as ingredient in food industry, providing some advantages in relation with the use of egg yolk. Even some applications of granules at a pilot scale have lately been developed (Laca, Paredes, & Díaz, 2010b; Laca, Sáenz, Paredes, & Díaz, 2010; Orcajo, Marcet, Paredes, & Díaz, 2013). This work focuses on literature knowledge regarding functionalities of granules in food applications; although it is necessary to keep on carrying out further research in this field.

2. Production methods

Since the 1970s it is well known that egg yolk can be easily separated into two fractions by centrifugation. The major fraction is plasma (supernatant), whereas granules (pellet) represent the smallest part of the yolk dry matter (19–29% depending basically on the fractionation method employed (Anton, 2007; Dyer-Hurdon & Nnanna, 1993; Freschi et al., 2011; Laca et al., 2010a; Le Denmat, Anton, & Beaumal, 2000)).

Table 1 summarizes egg yolk granule production methods found in literature, the fractionation procedure is always based on two basic steps: dilution and centrifugation (Fig. 1). Some works (Dyer-Hurdon & Nnanna, 1993) included a dialysis step before centrifugation, but it is not a common procedure. Until now the McBee and Coterill (1979) method is the most popular. Different authors

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Table 1
Comparation of egg yolk granules production methods.

Yolk dilution	Dilution agent	Pretreatment	Centrifugation conditions	References
1:1	0.17 M NaCl	–	4 °C/10,000 *g*/15 min	McBee and Coterill (1979)
1:10	Deionized water	Keep yolk solution overnight at 4 °C	4 °C/10,000 *g* /15 min	Kwan et al. (1991)
1:1	0.16 M NaCl	Stirred yolk solution for 5 min and dialysed against distilled water at 4 °C for 12 h	10 °C/13,000 *g* /1 h	Dyer-Hurdon and Nnanna (1993)
1:4	0.16 M NaCl	–	4 °C/8000 *g* /30 min	Aluko and Mine (1998)
1:1	0.17 M NaCl	Mix yolk solution with a magnetic stirrer for 1 h at 10 °C	10 °C/10,000 *g* /45 min	Le Denmat et al. (2000), Jin et al. (2013)
1:1	0.17 M NaCl	Mix yolk solution with a magnetic stirrer for 1 h at 4 °C	4 °C/10,000 *g* /45 min	Le Denmat et al. (2000), Anton et al. (2003), Moussa, Martinet, Trimeche, Tainturier, and Anton (2002), Castellani et al. (2003), Sousa et al. (2007), Freschi et al. (2011)
1:3	0.17 M NaCl	Mix yolk solution with a magnetic stirrer for 1 h at 4 °C	4 °C/10,000 *g* /45 min	Kiosseglou and Paraskevopoulou (2005)
1:1	Phosphate buffer	Mix yolk solution with a magnetic stirrer for 1 h at 4 °C	4 °C/10,000 *g* /45 min	Rojas et al. (2006)
1:1.5	Deionized water (adjust yolk solution to pH 7 with 1 N NaOH)	Keep yolk solution overnight at 4 °C	4 °C/10,000 *g* /45 min	Laca et al. (2010a, 2010b), Laca, Sáenz, et al. (2010)
1:1	Deionized water	Mix yolk solution with a magnetic stirrer for 1 h at 4 °C	4 °C/10,000 *g* /45 min	Lei and Wu (2012)
1:2	0.15 M NaCl	Mix yolk solution with a magnetic stirrer for 1 h at 10 °C	10 °C/10,000 *g* /45 min	Strixner and Kulozik (2013)
1:10	MilliQ water (adjust yolk solution to pH 6 with 1 M HCl)	Mix yolk solution with a magnetic stirrer for 1 h at 4 °C	4 °C/10,000 *g* /15 min	Navidghasemizad et al. (2014)

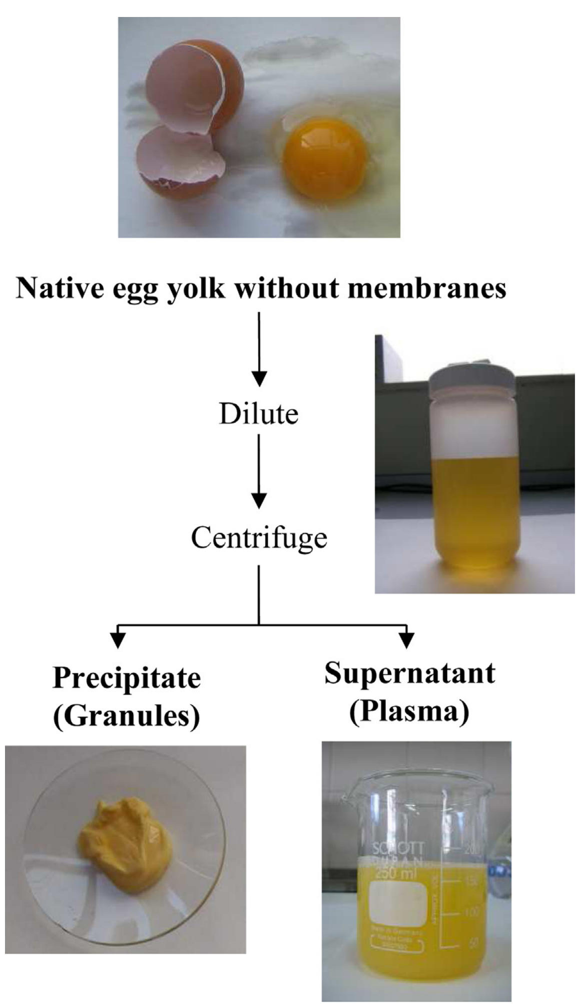

Fig. 1. General scheme for obtaining egg yolk granules.

employed this procedure modifying yolk dilution and/or centrifugation conditions (Anton, Beaumal, & Gandemer, 2000; Anton et al., 2003; Castellani, Martinet, David-Brand, Guerin-Dubiard, & Anton, 2003; Freschi et al., 2011; Kiosseglou & Paraskevopoulou, 2005; Le Denmat et al., 2000; Sousa et al., 2007); whereas, another researchers, additionally, employed other alternatives instead of NaCl solution as dilution agent, such as phosphate buffer (Rojas, Coimbra, & Minim, 2006) or deionized water (Kwan, Li-Chan, Helbig, & Nakai, 1991; Laca et al., 2010a; Lei & Wu, 2012; Merkle & Ball, 2000).

Although the fractionation procedure is most frequently based on a discontinuous lab scale method, some attempts have been carried out in order to deal with an industrial scale separation (Corlay, Causeret, & Lorient, 1991; Ulrichs & Ternes, 2010). In fact, a recent study has obtained promising results in relation to the continuous fractionation of liquid egg yolk at industrial scale (Strixner & Kulozik, 2013).

3. Composition

Table 2 compares the granules composition found in the literature. It is important to observe that granules are mainly constituted by proteins and present low cholesterol content as compared to whole egg yolk or plasma (Anton, 2007; Dyer-Hurdon & Nnanna, 1993; Jin, Huang, Ding, Ma, & Oh, 2013; Laca et al., 2010a). The differences in egg yolk granule composition detected are mainly due to the fractionation procedure employed (yolk dilution, disrupting agent, pretreatment …), but also to other factors like egg age (Freschi et al., 2011) or hen species, feeding or age (Li-Chan & Kim, 2008).

Finally, and regarding composition, it is remarkable that phosvitin is the main protein found in granules. It is one of the most highly phosphorylated proteins in nature, showing very strong metal binding capability. This protein and its derived phosphopeptides have recently been demonstrated to possess a variety of functional and biological properties including antioxidant, antibacterial, anti-inflammatory and anticancer activities (Castellani et al., 2003; Lei & Wu, 2012; Xu, Yang, Yin, Liu, & Mine, 2012).