Relationships between eggshell matrix proteins and egg quality

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The chicken eggshell is a perfectly ordered structure formed in the uterus of the laying hen, during 3 stages of formation: i) initial when the first crystals are deposited on mammillary knobs, ii) the active calcification phase when there is a rapid deposition of shell (0.32 g/h), and iii) the terminal phase when there is an arrest of mineralization 2 hours before the oviposition during the cuticle deposition. The eggshell is composed of 95 % of calcium carbonate on calcite form. It also contains a low percentage (3.5 %) of organic matter present in the eggshell membranes and cuticle, but also in the calcified part of the shell where it is named organic matrix. The previously identified matrix proteins can be divided into three groups according to their characteristics: i) Egg white proteins also localised in the shell, ii) ubiquitous proteins widely expressed in other tissues, iii) and proteins unique to the process of shell calcification.

The egg possesses two major natural defence systems. The first one is the eggshell, together with the cuticle and membranes, which constitutes a physical barrier against bacteria penetration. Defects in the mineralized shell are directly related to increasing risk of egg contamination. Eggshell matrix proteins are involved in the fabric of the eggshell and consequently determine its resulting mechanical properties. This hypothesis was confirmed by experimental observations: i) Presence in eggshell of novel proteins only secreted by tissues where eggshell calcification takes place and that are highly stimulated during the calcification process. ii) Modification of calcite crystal morphology in presence of matrix components showing an interaction of mineral and organic compounds in the shell (Gautron et al., 1996; Dominguez-Vera et al., 2000). iii) Different uterine fluid composition for eggshell matrix proteins at various stages of eggshell calcification that demonstrated an adaptation of the matrix composition depending of the calcification process (Gautron et al., 1997). Furthermore a relationship between eggshell mechanical properties and level of matrix components were established (Ahmed et al., 2005).

The second natural defence of the egg is a chemical barrier composed of proteins found in the eggshell and in the albumen that exhibit anti-microbial activity. Some egg white proteins (ovotransferrin and lysozyme), well known for their antimicrobial properties, have been identified in egg shell (Gautron et al., 2001; Hincke et al., 2000). They may explain some of the anti-microbial activity observed in eggshell extracts (Mine et al., 2003). Recently we have cloned Ovocalyxin-36, a novel eggshell specific matrix protein (Gautron et al., 2005) that showed significant identities with lipopolysaccharide binding proteins (Schumann et al., 1990), bactericidal permeability increasing proteins (Gray et al., 1989) and the PLUNC family of proteins (Bingle and Craven, 2002). These proteins are often described as "first-line host defence proteins" and could be involved in the innate immune response.

These data demonstrates that the chicken eggshell is a sophisticated structure which contains a number of proteins that have been identified and characterized during the past decade. Our experimental data shows that these proteins regulate shell mineralization and may influence its mechanical properties. These matrix proteins could also act as anti-bacterial agents to protect the egg contents against microbial challenge. The authors thank the European commission (egg defence, QLRT-2001-01606), NSERC and the Poultry Industry Council for financial support of some of this work.

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