Trends in Food Science & Technology 78 (2018) 188–196

Contents lists available at ScienceDirect

Trends in Food Science & Technology

journal homepage: www.elsevier.com/locate/tifs

Review

Impact of food processing on the structural and allergenic properties of egg white

Yao Zhu*, Sai Kranthi Vanga, Jin Wang, Vijaya Raghavan

Department of Bioresource Engineering, Faculty of Agricultural and Environmental Sciences, McGill University, Sainte-Anne-de-Bellevue, QC H9X 3V9, Canada

ARTICLE INFO

Keywords:
Egg white proteins
Avidin
Thermal processing
Non-thermal processing
Novel processing
Egg allergy

ABSTRACT

Background: Egg is one of the most nutritious foods that is easily available and it has become a favorite source of major nutrients like lipids and proteins around the world. However, eggs can trigger severe allergic reactions, especially in infants and children. The reactions are mostly IgE-mediated with a range of symptoms related to nose and throat and further can lead to life-threatening anaphylaxis. A total of ten allergens have been recognized to date and researchers are actively working on understanding their structure-function relationship which could help reduce the allergy incidences. Major egg allergens are abundant in egg white which include ovalbumin (OA), ovomucoid (OVM), ovotransferrin (OVT) and lysozyme (Lys). In addition to allergens, avidin present in egg white is also extensively studied due to its anti-nutritional properties. Avidin is known to form a complex with biotin which makes it unavailable for absorption.

Scope and approach: This review focuses on the effects of thermal and non-thermal processing methods on the structure and functional properties of various egg proteins including a wide range of allergens and anti-nutrients.

Key findings and conclusions: Novel processing techniques including various non-thermal techniques show promising results in reducing the allergic reactions of egg. Anti-nutrients like avidin can be partly inactivated under combined high-pressure processing and heat treatment.

1. Introduction

Eggs are abundant in nutrients which are beneficial to human health. The nutritional composition not only includes proteins and lipids but also contains various vitamins like thiamin, riboflavin, vitamin A, B, D, E and minerals like Ca, P, K, Na, Mg, Fe, Zn. However, beside cow milk, eggs are the other most important allergy-causing food item in children (Gray et al., 2015; Savage, Matsui, Skripak, & Wood, 2007). Exposure to egg in sensitive children can result in hives, rashes which are the symptoms of anaphylaxis. Most of egg allergens are presented in egg white, including ovomucoid (Gal d 1), ovalbumin (Gal d 2), conalbumin (Gal d 3) and lysozyme (Gal d 4) (Poulsen et al., 2001). The best way to manage egg allergy is complete abstinence from any food products containing eggs. However, eggs are incorporated in many food applications and complete avoidance is impossible (Mine & Yang, 2008).

Egg proteins are important in several functional properties, eg, emulsification, foaming, and flavor. The coagulative properties which lead to solidification upon heating and aeration play a key role in baking. Eggs also possess emulsification properties which are important in salad dressings and sauces that are widely consumed around the world as part of various cuisines. They also have binding properties and can greatly improve texture and acceptability of products like health bars and baked products (Stadelman, 1999). An egg consists of 8–11% shell, 27–32% yolk and 56–61% albumen (Poulsen et al., 2001). Albumen comprises 88.5% water, 10.5% protein, 0.5% carbohydrate (Stevens, 1991). The protein composition of albumen is summarized in Table 1.

Recent research has also shown that eggs contain significant quantities of carotenoids like lutein and zeaxanthin that could play an important role both in well-being and in prevention of various diseases. The egg yolk contains high antioxidants which could provide further health benefits. They are also considered to be an important source of anti-bacterial and bioactive compounds which find their application in various industries including food, pharma and biotechnology (Lesnierowski & Stangierski, 2018). Egg is also a vital source of choline nutrient (680 mg/100 g) which plays a major role in memory development and brain health (Applegate, 2000; Handelman, Nightingale, Lichtenstein, Schaefer, & Blumberg, 1999; Mellott, Williams, Meck, & Blusztajn, 2004). For example, research conducted on rat pups showed that the group treated with choline developed abilities in spatial memory three days sooner compared to control group. The choline was

* Corresponding author.
E-mail address: yao.zhu2@mail.mcgill.ca (Y. Zhu).

https://doi.org/10.1016/j.tifs.2018.06.005
Received 9 November 2017; Received in revised form 30 May 2018; Accepted 9 June 2018
0924-2244/

Acronyms

ELISA	Enzyme-linked immunosorbent assay
IgG	Immunoglobulin G
IgE	Immunoglobulin E
CD	Circular dichroism spectroscopy
UV	Ultraviolet absorption spectroscopy
SDS-PAGE	Sodium dodecyl sulfate polyacrylamide gel electrophoresis
Ci-ELISA	Competitive indirect enzyme-linked immunosorbent assays
HABA	2-Hydroxyazobenzen-4′-Carboxylic Acid
MTS	Manothermosonication
PBS	Phosphate-buffered saline

applied to rat dams in their embryonic days of 12–17 (Mellott et al., 2004). Despite their health and nutritional profile, eggs contain few compounds that could cause adverse reactions in human body especially in form of allergic reactions. In this review, we outline the components of the egg proteins and the effects of various processing methods on their structure-functional relationship which could be of great interest to researchers and the industry.

2. Major egg white proteins

2.1. Ovalbumin

Ovalbumin is a phospho-glycoprotein composed of 385 amino acids with molecular weight of 45 kDa (Abeyrathne, Lee, & Ahn, 2014). Further, the ovalbumin molecular sequence contains a total of four thiol groups and one disulphide bond formed between the cystine residues 87–133. This molecule is generally linked with a carbohydrate chain at the amide nitrogen belonging to asparagine 298 residue (Stein, Leslie, Finch, & Carrell, 1991). The heavy glycosylation leads to the allergenicity of ovalbumin (Aalberse, 2000). Ovalbumin is an acidic molecule with an isoelectric point (pI) of 4.5. Half of the residues present in the molecule are hydrophobic in nature and one-third of them are charged amino acid residues (Huopalahti, Anton, López-Fandiño, & Schade, 2007). Although ovalbumin has certain attributes that make it heat stable, it can be denatured or aggregated by proteolysis due to exposure of the air-water interfaces during thermal processing (Huopalahti et al., 2007; Stevens, 1991). According to its structure, ovalbumin shows certain homology with serpin family proteins, but it does not exhibit any protease inhibitory activity (Huntington & Stein, 2001). Furthermore, ovalbumin plays a major role in immunological and nutritional studies. Ovalbumin acts as a standard protein in several experiments including protein assay, structural properties, animal testing on inhalant and dietary allergies (Abeyrathne et al., 2014; Mine & Yang, 2008).

2.2. Ovomucoid

Ovomucoid is a heat-stable glycoprotein containing 186 residues and a molecular weight of 28 kDa and pI of 4.1 (Julià et al., 2007; Winiarska-Mieczan & Kwiecień, 2007). The structure of ovomucoid consists of three domains: domain I and domain II (defined as α-type) and domain III (β-type). It contains both sulfated oligosaccharides and sialyloligosaccharides and a total of nine disulfide bonds (Huopalahti et al., 2007). Further, intra-domain disulfide bonds exist in each domain that contributes to its stability (Stevens, 1991). Domain III is different from domain I and domain II because it has shorter disulfide bonds between the first and second cysteine residues. The disulfide bonds not only contribute to the higher heat stability, but also are responsible for increasing difficulty in digestion and hence it is classified as a protease inhibitor which is also observed in other molecular like soy inhibitors (Vagadia, Vanga, & Raghavan, 2017; Vagadia, Vanga, Singh, & Raghavan, 2016; Winiarska-Mieczan & Kwiecień, 2007). Hen egg ovomucoid can only bind to one molecule of protease every time, which is different from ovomucoid in duck and turkey egg (Huopalahti et al., 2007). This is due to the flexible enzyme-inhibitor contact position resulting in varying inhibitory activity of ovomucoid present in different species. This phenomenon is beneficial to prevent a wide range of bacterial proteinases (Stevens, 1991).

Researchers also found that ovomucoid is the most allergic protein in egg (Dhanapala, Withanage-Dona, Tang, Doran, & Suphioglu, 2017). The allergic activity of ovomucoid remains stable under thermal treatment or enzymatic hydrolysis (Julià et al., 2007). However, this unique property can be used as a tool for detection of egg in a food products even after thermal processing.

Table 1
Composition of egg white proteins (Desert et al., 2001; Forsythe & Foster, 1950; Mine, 1995; Stevens, 1991).

Protein	Amount in egg white (%)
Ovalbumin	54–66
Ovotransferrin	12–13
Ovomucoid	9.5–11
Lysozyme	2.3–4.5
Ovomucin	1.5–3.5
Ovoinhibitor	0.1–1.5
Ovoglobulin G2	1.0–6
Ovoglobulin G3	1.0–6
Riboflavin binding protein	1.0
Avidin	0.05–0.5
Ovostatin	0.5

2.3. Ovotransferrin/conalbumin

Conalbumin, also known as ovotransferrin, is a monomeric glycoprotein and one of the most allergic proteins found not only in egg white but also in the yolk. Its molecular weight is found to be 76 kDa, with a total of 686 amino acids and 15 disulfide bonds (Abeyrathne et al., 2014). Since each molecule of ovotransferrin can bind to two Fe^{3+} ions, they play a key role in iron transportation from the hen oviduct to the developing embryo (Huopalahti et al., 2007; Stevens, 1991). This property contributes to its applications in iron-fortified products like iron-fortified beverages and iron supplements. It has two different forms: apo-ovotransferrin (iron free) and holo-ovotransferrin (iron bound). After binding to iron, the stability of ovotransferrin was enhanced due to its increased resistance to physical and chemical stresses. Further, researchers also found that ovotransferrin has antimicrobial, antiviral and antioxidant properties (Abeyrathne et al., 2014). The iron-transferrin complex can effectively prevent both gram-positive or gram-negative bacteria from growing in different foods. Moreover, apart from Fe ion, bicarbonate ions can also enhance the antimicrobial activity (Huopalahti et al., 2007). At the same time, bacteriostatic ability due to the bicarbonate ion can be reversed by adding other Fe^{3+}. Other studies proposed different mechanisms on the origin of antimicrobial activity of ovotransferrin. They suggested ovotransferrin might have the ability to bind with bacterial cell membrane which in turn would affect the functional property (Huopalahti et al., 2007). The two opinions are both reasonable and can contribute to the strong antimicrobial activity of ovotransferrin as observed in various food products.