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Review

Effect of processing on conformational changes of food proteins related to allergenicity

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ABSTRACT

Background: Food allergy is one of the major health concerns worldwide that has been increasing at an alarming rate in recent times. Foods undergo various processing steps before consumption that could affect conformation of food proteins, their digestion and thereby allergenicity.

Scope and approach: This review summarizes the effect of various processing methods on structural changes of major food allergens and how these changes affect their digestibility as well as allergenicity. This information could be a base line for selecting suitable food processing parameters for management of food allergies.

Key findings and conclusions: Most physical processes (heat, pressure, radiation, and ultrasound) affect conformational epitopes (destroy, mask or expose) of food proteins by altering their secondary and tertiary structures whereas the linear/sequential epitopes are affected mainly through bio-chemical (fermentation and enzymatic hydrolysis) treatments. Processing may also influence the interaction of food proteins with other ingredients via Maillard reaction and give rise to formation of new allergenic compound (neo-allergens). Processing induced changes to food proteins can largely affect their susceptibility to gastrointestinal digestion, absorption kinetics and consequently their allergenic response to immune system. Therefore, allergenic potential of food proteins may be minimized by selecting appropriate parameters during processing. Allergenicity of certain food proteins can also be modulated through optimized formulation with other food matrices. However, depending on the method of processing, intensity of treatment and molecular characteristics of allergen food proteins, allergenicity can be increased, decreased or remain unaltered.

1. Introduction

Food allergy is one of the major health concerns worldwide affecting 1–3% of adults and 4–6% of children, and in the last two decades the rate has increased considerably (Lack & Du Toit, 2014). It can seriously affect the quality of life of both, patients and their family, even more than chronic childhood diseases (Arasi et al., 2014). Food allergies are the adverse immune reactions to specific foods that result in either instant severe life threatening symptoms such as acute urticaria, angioedema, bronchospasm and anaphylaxis or delayed symptoms including atopic dermatitis and allergic gastrointestinal disorders. Although many foods are reported for their allergic reactions, more than 90% of food allergies are caused by cow's milk, egg, fish, crustaceans, peanuts, tree nuts, wheat and soybeans, which are referred as "The Big Eight" (Török et al., 2014).

In the early history of food allergy, a report of sensitivity to cooked but not raw fish (Mills & Mackie, 2008) created an interest to know whether processing affected food allergy or not. It is now understood that processing may either reduce or enhance the allergic potential of food proteins or sometimes have no effect at all. For example, Chinese traditional water boiling and frying of egg showed higher allergenic potential than steamed egg and tea-boiled egg (Liu et al., 2013). In addition, some treatments can induce formation of new allergenic compounds (neo-allergens) by prompting interactions between different ingredients (Verma, Kumar, Das, & Dwivedi, 2012).

Foods are processed in diverse ways before consumption in order to improve functional, nutritional and sensory attributes, as well as for preservation and detoxification. Commonly applied processing techniques include thermal, high pressure, radiation, high intensity ultrasound, and bio-chemical approaches. Different processing methods alter the structure of food proteins in different

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ways and possible structural modifications include unfolding, aggregation, cross-linking between the ingredients and chemical modifications such as oxidation and glycosylation (Lepski & Brockmeyer, 2013). Such processing induced conformational changes can directly influence the allergenicity by disrupting conformational or linear epitopes. Conformational epitopes can be exposed or hidden by unfolding or aggregation of proteins (Rahaman, Vasiljevic, & Ramchandran, 2015), respectively, whereas sequential epitopes can be affected by acidic or enzymatic hydrolysis (Kasera, Singh, Lavasa, Prasad, & Arora, 2015) and extreme Maillard reactions (Toda, Heilmann, Ilchmann, & Vieths, 2014). Processing induced physico-chemical changes of food proteins may further affect gastrointestinal digestibility, absorbance kinetics through mucosa as well as their presentation to the immune system and thereby influence their allergenicity (Table 1). However, the degree of structural alteration and allergenicity depends on the processing method used, extent and exposure time, and presence of other ingredients for example salt, sugar etc. (Verma et al., 2012).

Avoidance of allergic foods is the most common management strategy for sensitive individuals which may consequently lead to a number of nutritional deficiency syndromes. Although oral and subcutaneous desensitization therapies have also been practiced for a long time, their efficacies are not always satisfactory (Patriarca et al., 2007). Thus, there is a need to seek alternate strategies such as selective processing for minimizing the allergenic severity of foods. To select appropriate processing methods, it is very important to understand how these procedures alter the structure of food proteins both at a microscopic and macroscopic level and their subsequent gastrointestinal digestibility, all of which can influence their allergenicity. Several reviews (Lepski & Brockmeyer, 2013; Mills, Sancho, Rigby, Jenkins, & Mackie, 2009; Paschke, 2009; Shriver & Yang, 2011; Verhoeckx et al., 2015) have compiled the effect of processing on allergenicity of various foods but it is not well explained how the processing induced conformational changes affect digestibility. Resistance to gastrointestinal digestion is one of the main characteristics that allow food proteins retaining intact epitopes to invoke allergic reaction. Therefore the present review focuses on processing induced conformational changes of major food proteins and its relation to their digestibility and allergenicity. Such information is critical in the selection of appropriate parameters during food processing as an effective alternate in the management strategies of food allergies.

2. Various processing and their effect on food protein structure, digestibility and allergenicity

2.1. Effect of thermal treatments

Thermal treatment is the conventional and most commonly used processing technique for many foods in order to reduce their

Table 1
Summary of effect of different processing methods on conformation, digestibility and allergenicity of food allergens.

Allergen	Processing methods	Conformational change	Digestibility and allergenic consequence	References
Ara h1 and Ara h2 from peanut	Roasting	Compact globular covalent aggregates and Maillard products (neo-allergen)	Less susceptible to protease and enhanced allergenicity	(Blanc et al., 2011; Maleki & Hurlburt, 2004)
	Boiling	Loss of β barrel with adopting random coil and formation of branched rod-shaped aggregates	More susceptible to hydrolysis and decreased allergenicity	
Wheat protein allergen	Baking	Formation of aggregates through Maillard reaction and inter-peptide linkage	Decreased digestibility and enhanced allergenicity	(Pasini et al., 2001)
β-lg in cow milk	Sterilization	Unfolding followed by covalent aggregation and Maillard reaction	Increased susceptibility to peptic hydrolysis and reduced allergenicity	(Bu et al., 2009; Peram et al., 2013)
	Pasteurization	Exposure of conformational epitopes	Enhanced uptake through epithelium with increased allergenicity	(Bu et al., 2009)
	Heating with wheat matrix	Complex structure formation between wheat and β-lg	Reduced digestibility and bio-availability to immune system	(Bloom et al., 2014)
	High pressure	Unfolding of protein molecule with exposure of cleavage site	Enhanced digestibility and reduced allergenicity	(López-Expósito et al., 2012)
	Radiation	Protein agglomeration	Unaltered	(Lee et al., 2001)
	Ultrasound	Formation of oligomers and β sheet to α helix transition	Increased digestibility but allergenicity is unaltered	(Stanic-Vucinic et al., 2012)
Casein in cow milk	Pasteurization, Sterilization	Rheomorphic, no conformational change	Unaffected	(Morisawa et al., 2009)
Egg ovalbumin	Moist heat	Denaturation and aggregation	Lower permeability through enterocyte resulting in reduced allergenic potential	(Shin et al., 2013; Watanabe et al., 2014)
	High pressure	Loss of conformational and sequential epitopes	Enhanced digestibility and reduced allergenicity	López-Expósito et al., 2008
Egg ovomucoid	Moist heat	Heat stable	Unaltered	(Julià et al., 2007; Shin et al., 2013)
	Heating with wheat flour in pasta	Formation of insoluble aggregates	Reduced allergenicity	(Kato et al., 2001)
Tropomyosin from shrimp	Moist heat	Formation of new allergic compound through Maillard reaction	Digestibility remain unaltered and allergenicity increased	(Kamath et al., 2013)
	High Pressure	Unfolding of protein with loss of α helix	Improved digestibility and reduced allergenicity	(Jin et al., 2015)
	Ultrasound	Denaturation and fragmentation	Increased digestibility but allergenicity remain unaltered	(Li, Lin, Cao, & Jameel, 2006)
Walnut	Moist heat	Fragmentation of protein molecules	Enhanced susceptibility to digestion and reduced allergenicity	(Cabanillas et al., 2014)
Soy allergen (glycicnin)	Moist heat	Formation of soluble aggregates	Slight decrease of peptic digestibility but no change of allergenicity	(van Boxtel, van den Broek, Koppelman, & Gruppen, 2008)
	High pressure	Increased hydrophobicity, SH and α helix content	Increased digestibility and reduced allergenicity	(Penas et al., 2006)