Mini Review

Allergens derived from shrimp

Mary Margaret, P.D.S., Jinap, S. and Ahmad Faizal, A.R.

Food Safety Research Centre (FOSREC), Faculty of Food Science and Technology, Laboratory of UPM-MAKNA Cancer Research, Institute of Bioscience, Universiti Putra Malaysia, 43400, UPM Serdang, Selangor, Malaysia

Abstract

Allergy caused by food is usually type 1 allergy of four types of allergic reactions. One of the most widespread allergenic is those that are caused by crustacean shellfish. Crustaceans are classified among arthropods which include crab, crayfish, lobster, prawn and shrimp. Shrimp which are broadly consumed as nutritional food is one of the most important food that contribute to allergy. Thus, reducing the allergenicity of shrimp allergen will be helpful to individuals who are sensitive to shrimp and for this reason the characteristics of each allergen need to be studied. Those sensitized individuals can develop urticaria, angioedema, laryngospasm, asthma and life threatening anaphylaxis. To date, four main allergens contribute to allergic reactions. They are tropomyosin (TM), a highly conserved and heat stable myofibrillar protein of 35-38 kDa followed by arginine kinase (AK) which is also known as Pen m 2 or Lit v 2 with 40 kDa. Two other contributing allergens are sarcoplasmic calcium-binding protein (SCP) also known as Lit v 4 with 22 kDa and myosin light chain (MLC) which is also termed as Lit v 3 with 20 kDa. This mini-review will provide a better understanding of each allergen derived from shrimp which subsequently will help to reduce the allergenicity.

Introduction

Food allergy or hypersensitivity disorders are defined as unfavorable immune responses to food proteins and differ from many adverse food reactions that have non immune causes or origins (Sicherer and Sampson, 2009). Food allergy is also the fastest growing allergy than any other allergic disorder (Gupta et al., 2007). Crustacean shellfish, peanuts, fish and tree nuts are the common foods that cause allergic reaction in adults while children are mostly affected by consumption of cow’s milk, egg white, wheat and soy (Ebo and Stevens, 2001; Thong et al., 2007; Ben-Shoshan et al., 2010). However, the most widespread IgE mediated food allergies which will cause severe reactions are allergies caused by crustacean shellfish (Crespo and Rodriguez, 2003; Vilalta et al., 2010). According to a research conducted in 2011, shellfish refers to those with a shell like exoskeleton like crustacean and mollusks that are classified among arthropods which include crab, crayfish, lobster, prawn and shrimp (Woo and Bahna, 2011). Shrimp which are broadly consumed as nutritional food is one of the most important crustacean shellfish that contribute to allergy (Lu et al., 2007). Thus, reducing the allergenicity of shrimp allergen will be helpful to those who are sensitive to shrimp (Zhenxing et al., 2006). Those sensitized individuals can develop urticaria, angioedema, laryngospasm, asthma and life threatening anaphylaxis (Yu et al., 2003).

There are four allergens from shrimp that have been discovered to be the major contributor to allergenicity including tropomyosin (TM), arginine kinase (AK), sarcoplasmic calcium-binding protein (SCP) and myosin light chain (MLC). Hoffman’s study revealed that TM, a highly conserved and heat stable myofibrillar protein serves as a major allergen from crustaceans (Liang et al., 2008; Zheng et al., 2011; Zailatul et al., 2012). Tropomyosin also present in other crustaceans (Motoyama et al., 2007), mollusks (Leung et al., 1996), house dust mites, cockroach and squid (Luis and Nathalie, 2011). Whereas, in a study conducted by Yu et al., (2003) on black tiger shrimp (Penaeus monodon) they encountered that Pen m 2, an AK represents a new class of shrimp allergen and serves as a cross-reactive crustacean allergen with 40 kDa allergen protein. On the other hand, Lit v 2 was disclosed as arginine kinase from pacific white shrimp (Litopenaeus vannamei) species with 96% identity to Pen m 2 from black tiger shrimp (Garcia-Orozco et al., 2007). Subsequently, researchers have come across another two new allergens, MLC also known as Lit v 3 derived from pacific white shrimp species (Ayuso et al., 2008) and SCP also known as Lit v 4 which is also from the same species of shrimp (Ayuso et al., 2009).

Keywords

Allergen
Shrimp
Tropomyosin
Arginine kinase
Sarcoplasmic calcium-binding protein
Myosin light chain

© All Rights Reserved
Four major allergens

Tropomyosin (TM)

Tropomyosin, a muscle protein is the major shrimp allergen identified and also termed as Pen a 1 (identified in brown shrimp, *Penaeus aztecus*) (Reese *et al.*, 1997), Pen i 1 (identified in Indian prawn, *Penaeus indicus*), Pen m 1 (identified in black tiger shrimp, *Penaeus monodon*), Lit v 1 (identified in pacific white shrimp, *Litopenaeus vanamei*) (Gamez *et al.*, 2011) and Cra c 1 (identified in North Sea Shrimp) (Woo and Bahna, 2011). This heat-stable allergen initially was found in crustacean in the year 1981 by Hoffman and his team (1993) and Shanti *et al.* (1993) found it has 86% of similarity in amino acid sequence with muscle protein, TM from fruit fly, *drosophila melanogaster*. Tropomyosin is a diverse group of protein with different isoforms which are found in both muscle and non-muscle cells. The tissue-specific functions of TM are seen in both vertebrates and in crustaceans (Smillie, 1979; Miyazaki *et al.*, 1992). Detailed studies on this allergen showed that TM is a major cross-reactive allergen among crustaceas and mollusks (Leung *et al.*, 1996). In a study done by Motoyama *et al.* (2007) concluded that tropomyosin can be classified into three categories which are fast, slow-twitch and slow- tonic (based on muscle fiber) and majority of shrimp tropomyosin is known as fast type and they do not have much alteration in their amino acid sequences. The molecular weight is between 34 kDa to 38 kDa and it serves as the major allergen in almost all crustaceans (Zheng *et al.*, 2011; Zailatul *et al.*, 2012). Moreover, mite allergen patients who consumed shrimp can experience severe asthma symptoms and patients treated with immunotherapy with mite extracts can become sensitized with mite tropomyosin and react to shrimp (Luis and Nathalie, 2011). The characterization of this allergen was mainly used by using three main techniques which radioallergosorbent test (RAST), Molecular genetics (MG) and mass spectrometry (MS) (Garcia-Orozco *et al.*, 2007; Abdel Rahman *et al.*, 2012).

Arginine kinase (AK)

Arginine kinase is a monomeric phosphagen ATP phosphotransferase which is generally found in invertebrates and is the key to energy metabolism (Yao *et al.*, 2005). Pen m 2, an allergen from black tiger shrimp, is an AK obtained from shrimp which is anticipated to play an essential role as a cross-reactive crustacean allergen and in rousing hypersensitivity responses (Yu *et al.*, 2003). AK is also rich in pacific white shrimp muscle and is anticipated to be the next major allergen (Garcia-Orozco *et al.*, 2007). It has been reported AK from pacific white shrimp is known as Lit v 2 and has 96% identity to Pen m 2 from black tiger shrimp. Both researchers disclosed that AK is located at 40 kDa. Characterization of AK can be done by Molecular genetics and Mass spectrometry techniques (Garcia-Orozco *et al.*, 2007; Abdel Rahman *et al.*, 2012).

Sarcoplasmic calcium-binding protein (SCP)

Sarcoplasmic calcium-binding protein is acquired from pacific white shrimp. It is known as Lit v 4 with 22 kDa allergen, 194 amino acids, isoelectric point of 4.7 and also a muscle protein (Ayuso *et al.*, 2009). The research team also revealed that sensitization to SCP appear to be involved in cross-reactivity among crustaceans only and SCP is the major culprit in pediatric population. In other study, during the process of purification of arginine kinase, it has been discovered that SCP is also found in black tiger shrimp (Pen m 4), kuruma shrimp (*Penaeus japonicus*), American lobster (*Homarus americanus*),

Table 1. Allergenic proteins characterized in shrimp

<table>
<thead>
<tr>
<th>Group</th>
<th>TM</th>
<th>AK</th>
<th>SCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustacean (Shrimp)</td>
<td>North Sea Shrimp (Cra c 1)</td>
<td>Pacific white shrimp (Lit v 2)</td>
<td>Pacific white shrimp (Lit v 3)</td>
</tr>
<tr>
<td></td>
<td>Pacific white shrimp (Lit v 1)</td>
<td>Black tiger shrimp (Pen m 2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brown shrimp (Pen a 1)</td>
<td>Black tiger shrimp (Pen m 4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indian prawn (Pen i 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Black tiger shrimp (Pen m 1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characterization technique</th>
<th>RASt; MG, MS</th>
<th>MG, MS</th>
<th>ELISA, Edman, WB, LC-MS/MS, MS</th>
<th>MS, Edman, MG, WB, Peptide microarray</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantification technique</td>
<td>ELISA, MS</td>
<td>MS</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

AK = Arginine kinase, ELISA = Enzyme-linked immunosorbent assay, LC-MS/MS = Liquid chromatography-tandem mass spectrometry, MG = Molecular genetics, MLC = Myosin light chain, MS = Mass spectrometry, N/A = Not available, RAST = Radioallergosorbent test, SCP = sarcoplasmic calcium-binding protein, TM = Tropomyosin, WB = Western blotting. Adapted from Woo and Bahna (2011).
pink shrimp (Pandalus eous), king crab (Paralithodes camtschaticus) and snow crab (Chionoecetes opilio) (Shiomi et al., 2008). To characterize this allergen few methods can be employed such as ELISA, Edman, Western blotting, Liquid chromatography-tandem mass spectrometry (LC-MS), Mass spectrometry or Molecular genetics (García-Orozco et al., 2007; Abdel Rahman et al., 2012).

Myosin light chain (MLC)

Myosin light chain from pacific white shrimp termed as Lit v 3 was recognized as a new shrimp allergen (Ayuso et al., 2008). In their study, they concluded that despite TM being the major allergen, some patients are exclusively sensitive to MLC only; hence MLC is also a major shrimp allergen. It is a muscle protein with 20 kDa (Ayuso et al., 2008). Due to the fact that MLC has a similar molecular weight, 20 kDa and similar isoelectric point, 4.2 to SCP, provoking difficulties to recognize which protein is responsible for allergic reactions in particular patient’s IgE antibodies by using standard laboratory methods. Ayuso et al. (2008) also found that patients with IgE binding to the boiled form of MLC appear to be greater in adults compared with children who tend to recognize the MLC in the raw extract with higher intensity. But, interestingly some children has asthmatic episodes when exposed to the steam boiling shrimp; suggesting that MLC is aerosolized and might contribute to respiratory symptoms in such patients. However, they recommended for further studies to be done finding out if MLC played the most important role in causing asthmatic reactions. Table 1 summarizes four major shrimp allergens and the proposed characterization and quantification techniques.

Conclusions

Nowadays, the seafood allergy is becoming more common and increasing among the adults. However, the identification and characterization of clinically relevant seafood allergen are still incomplete and thus limiting the understanding of their role in the immunopathogenic mechanisms involved in hypersensitivity reaction. In addition, it is essential that the correct diagnosis of food allergy is made to avoid false positive diagnosis which will lead to unnecessary dietary intake restriction that will cause nutritional deficiency.

References


Lu, Y., Ohshima, T., Ushio, H., Hamada, Y. and Shiomi, K. 2007. Immunological characteristics of
monoclonal antibodies against shellfish major allergen tropomyosin. Food Chemistry 100: 1093-1099.


