Allergen Data Collection:
Shrimps *(Natantia)*

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Abstract

Among crustaceans, such as shrimp, crab, crawfish and lobster, shrimp is frequently identified as a cause of IgE mediated adverse reactions in food allergic individuals. According to different studies the prevalence of shrimp allergy can be estimated to be about 0.6 to 2.8% in food allergic individuals. Ingestion and occasionally inhalation of shrimp allergens can induce allergic reactions such as pruritus, urticaria, angio-edema, gastrointestinal symptoms, asthma, and life-threatening anaphylaxis.
For diagnosis of shrimp allergy a thorough clinical and occupational history is the initial evaluation step. No single test can be used for a definite diagnosis of shrimp allergy, while the combination of skin tests and shrimp-specific serum-IgE is highly predictive. Reactions could be confirmed by oral challenge procedures, when anaphylactic reactions are not expected.

Up to 13 IgE binding proteins have been detected in shrimp meat. The muscle protein tropomyosin (34-39 kDa) is the only major allergen identified in several shrimp species: Met e 1 (Metapenaeus ensis), Pen a 1 (Penaeus aztecus), Pen i 1 (Penaeus indicus), and Pen o 1 (Penaeus orientalis). Cross-reactive tropomyosins are found in invertebrates such as crustaceans (shrimp, lobster, crab, crawfish), mollusks (e.g. squid), arachnids (house dust mites), and insects (cockroaches). However in general IgE antibodies from crustaceae allergic individuals do not bind to tropomyosins from vertebrates (poultry, mammalians).

Most common edible shrimp species in Asia are Penaeus indicus, Penaeus monodon (black tiger shrimp), Penaeus orientalis and Metapenaeus ensis (greasyback shrimp), in North America Penaeus setifecus (white shrimp) and Penaeus aztecus (brown shrimp), and in Europe shrimps from the families Crangonoidea (Crangon crangon), Palaemonoidea (Leander adspersus), and Pandaloidea (e.g. Atlantic shrimp - Pandalus borealis). The so-called Gammarus shrimp (Gammaridae family) commonly used in pet fish food is not included in the present data collection.

The present data collection gives an overview of prevalence data, symptoms, and diagnostic features of shrimp allergy as well as molecular biological and allergenic properties of the major shrimp allergens in tabular form. The term "natantia" collectively describes the species of crustaceae that are swimmers such as shrimps and prawns (bigger shrimps). "Reptantia" describes the opposite, crustaceae which are walkers such as crabs, crawfish, and lobsters.
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The reference lists of the Allergen Data Collections are based mainly on searches of Medline and FSTA (Food Science & Technology Abstracts) databases up to the related dates of publication. The scientific rigor of the studies listed is variable and not subject of critique or evaluation by the authors or the editor of the Allergen Data Collections. The reader should be aware of considerable problems in comparing data from different studies (eg. patient cohorts, diagnostic performances, possible flaws in allergen preparations and methodologies for allergen characterization) and is encouraged to review the original publications.

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1 Prevalence of Shrimp Allergy

Prevalence data are based on different diagnostic procedures. While the prevalence of sensitization (sensitivity) can be estimated by SPT, RAST, and immunoblot, a clinical relevant sensitization (allergy) is evaluated by convincing history (anamnesis) or food challenge tests (ideally by DBPCFC).

1.1 Subjects with Atopic or Other Diseases

Country / Subjects	Allergy / Sensitivity	References
France, Nancy and Toulouse 544 food allergic children	shrimp 2.2% (labial food challenge)	Rance et al. 1999
France, Pierre Benite 580 patients with adverse reactions to food (study period 1984-92)	shrimp 14% (RAST)	Andre et al. 1994
France, Toulouse 142 food allergic children	shrimp 2.8% (labial food challenge)	Rance & Dutau 1997
Japan, Okinawa 127 atopic patients (with bronchial asthma, allergic rhinitis and/or atopic dermatitis)	shrimp 14% (MAST)	Kosugi et al. 1992
Malaysia, Kuala Lumpur 148 adults with symptoms of nasal congestion and rhinorrhea	shrimp 48% (SPT)	Gendeh et al. 2000
Spain, Gran Canaria 120 food allergic adults	shrimp 40% (case history, SPT, RAST)	Castillo et al. 1996
Switzerland, Bern 22 patients with severe food-induced anaphylaxis (study period 1994-96)	shrimp 14% (case history)	Rohrer et al. 1998
Thailand 100 asthmatic children	shrimp 14% (SPT)	Kongpanichkul et al. 1997
USA, Denver, CO food allergic children (DBPCFC) a) 74 age of <3 years b) 111 age of 3-19 years	a) shrimp 0% b) shrimp 1.8% (DBPCFC)	Bock & Atkins 1990
USA, Durham, NC 113 food allergic children with atopic dermatitis	16% (SPT)	Sampson & McCaskill 1985
USA, Little Rock, AR 165 patients with atopic dermatitis	shrimp 0.6% (SPT, DBPCFC)	Burks et al. 1998
USA, Memphis, TN 89 patients with food-induced anaphylaxis (age of 12-75 years, study period 1978-92)	crustaceae (shrimp, scallop, crab) 29% (case history)	Kemp et al. 1995

1.2 Prevalence of Associated Allergies

Country / Subjects	Allergy / Sensitivity			References
		RAST	**SPT**	
Canada, Montreal, Quebec	shrimp	14%	16%	
57 food processing workers exposed to clam and shrimp as inhalant allergens	clam	7.0%	7.0%	Desjardins et al. 1995
	crab	11%	8.8%	
	crawfish	12%		
	lobster	8.8%	8.8%	
Japan, Tokyo 161 asthmatic children	Cluster group: shrimp and crab (20 inhalants and 15 foods allergens, MAST, cluster analysis)			Iwasaki & Baba 1992
		a)	**b)**	
USA, New Orleans, LA	shrimp	83%	39%	
36 patients with history of shrimp allergy	soybean	31%	0%	
a) atopic individuals with and b) non-atopic individuals without respiratory atopic symptoms	peanut	13%	0%	
	corn	17%	7.7%	
	beef	13%	7.7%	Morgan et al. 1989a
	rice	8.7%	15%	
	milk	4.4%	15%	
	wheat	4.4%	0%	
	egg	0%	0%	
	(SPT)			

2 Symptoms of Shrimp Allergy

Symptoms & Case Reports	References
systemic reactions anaphylaxis (1, 4, 5, 8, 9, 10), hypotension (9) symptoms on skin and mucous membranes angio-edema (1, 6, 9), rhinoconjunctivitis (7), eczema (1), pruritus (9), rash (1), urticaria (1, 6, 9), contact urticaria (2, 11), generalized urticaria (9) gastrointestinal symptoms laryngeal symptoms (9), nausea (9), oral allergy (9), swelling of lips (9), vomiting (6, 9) respiratory symptoms asthma (3, 7, 11), cough (9), dyspnoea (9), wheeze (6) other symptoms eosinophilic granuloma (1)	(1) Hoffman et al. 1981 (2) Nagano et al. 1984 (3) Carino et al. 1985 (4) Stricker et al. 1986 (5) Sorensen et al. 1989 (6) Daul et al. 1990 (7) Desjardins et al. 1995 (8) Kemp et al. 1995 (9) Hess Schmid & Wüthrich 1997 (10) Rohrer et al. 1998 (11) Goetz & Whisman 2000

Percentage of Reactions

Symptoms / Ref.	(1)	(2)	(3)	(4)
Anaphylaxis / Shock		21%*		
Fainting	14%			
Cutaneous				
Angioedema	57%		33%	72%
Pruritus		6%	100%	75%
Urticaria	86%		11%	56%
Urticaria / Angioedema	%	85%		%
Gastrointestinal	43%	40%	44%	42%
Respiratory	29%	27%	44%	39%
No. of patients	14	33	9	36

(1) reported symptoms in shrimp allergic individuals
(2) reported symptoms in shrimp allergic individuals
*anaphylaxis occurred in atopic patients only (atopic = personal or family history of allergy and positive SPT to common inhalant allergens)
(3) shrimp allergic individuals, symptoms after DBPCFC (n=6) or open challenge (n=3)
(4) reported symptoms in shrimp allergic individuals

(1) Waring et al. 1985
(2) Daul et al. 1987
(3) Daul et al. 1988
(4) Morgan et al. 1989a

Onset of Symptoms

Onset of symptoms after ingestion of shrimps:
<60 min in 75% (group a) and 83% (group b) of 14 shrimp allergic individuals, and within 60-120 min in 25% (group a) and 17% (group b) (group a = atopic, group b = non-atopic)

(1) Waring et al. 1985

Threshold for Elicitation of Symptoms

Amounts of boiled shrimp inducing symptoms ranged from 16 to 64 g (4 to 16 shrimps) (DBPCFC, 6 shrimp allergic adults) (1)

(1) Daul et al. 1988

3 Diagnostic Features of Shrimp Allergy

Parameters / Subjects	Outcome	male	age	References
Gender and Age				
36 patients with history of shrimp allergy a) atopic individuals with and b) non-atopic individuals without respiratory atopic symptoms	a) atopic 64%	52%	32 years (11-46)	Morgan et al. 1989a
	b) non-atopic 36%	31%	38 years (22-57)	
SPT, IgE and Clinical Relevance				
33 patients with history of shrimp allergy a) atopic individuals with and b) non-atopic individuals without history and skin test reactivity to common inhalant allergens	Positive skin test to shrimp in 85% Elevated shrimp specific RAST in a) 81% and b) 41% of shrimp allergic individuals			Daul et al. 1987

SPT, IgE and Clinical Relevance 30 patients with history of shrimp allergy	Positive immediate response to challenges with shrimps in 30% (6 DBPCFC + 3 open challenge), generalized pruritus in 40% after challenges and remaining 30% challenge negative; positive SPT strongly associated with challenge symptoms (p <0.001), shrimp specific RAST significantly higher in positive challenge group (p <0.02); combination of a positive SPT and elevated specific IgE demonstrated a correct predictive value of 87%	Daul et al. 1988
SPT and Pulmonary Symptoms 36 patients with history of shrimp allergy (39% reported pulmonary symptoms)	Higher incidence of SPT reactivity to shrimp extract in patients who reported pulmonary symptoms (86% vs. 55% in patients without pulmonary symptoms)	Morgan et al. 1989a
Ig-Classes 11 patients with history of shrimp allergy (follow-up of 24 months)	Shrimp-specific IgE and IgG, but not IgM and IgA, significantly higher in shrimp allergic individuals as compared to controls; DBPCFC positive subjects had higher levels of both shrimp-specific IgE and IgG, levels of IgG correlated with IgE	Daul et al. 1990
IgG-Subclasses 31 patients with history of shrimp allergy	Shrimp-specific IgG2 and IgG4 significantly higher in shrimp allergic individuals as compared to shrimp-tolerant individuals; none of the subclasses were significantly predictive of a positive response to DBPCFC	Morgan et al. 1990

4 Composition of Shrimp

4.1 Distribution of Nutrients

For other shrimp products see: USDA Nutrient Database

Nutrients: Content per 100 g		
Energy 369 kJ (87 kcal) Water 78.4 g Protein 18.6 g Lipids 1.4 g Minerals 1.4 g **Minerals** Sodium 145 mg Potassium 265 mg Magnesium 65 mg Calcium 90 mg Manganese 30 µg Iron 1760 µg Copper 240 µg Zinc 2310 µg Phosphorus 225 mg Fluoride 160 µg Iodine 130 µg Selenium 40 µg	**Vitamins** Vitamin A traces Vitamin B1 50 µg Vitamin B2 35 µg Nicotinamide 2430 µg Pantothenic acid 370 µg Vitamin B6 130 µg Biotin 1 µg Folic acid 7 µg Vitamin B12 830 ng **Amino Acids** Arg 1740 mg His 410 mg Ile 1000 mg Leu 1970 mg Lys 2020 mg Met 670 mg Phe 880 mg	Thr 850 mg Trp 210 mg Tyr 650 mg Val 990 mg **Lipids** Palmitic acid 150 mg Stearic acid 25 mg Oleic acid 180 mg Linolic acid 13 mg Linoleic acid 13 mg Arachidonic acid 13 mg Eicosapentaenoic acid 215 mg Docosahexaenoic acid 150 mg Cholesterol 140 mg **Other** Purines 145 mg

Reference: Deutsche Forschungsanstalt für Lebensmittelchemie, Garching bei München (ed), **Der kleine "Souci-Fachmann-Kraut" Lebensmitteltabelle für die Praxis**, WVG, Stuttgart 1991

5 Allergens of Shrimps

Proteins / Glycoproteins	Allergen Nomenclature	References
Tropomyosins [34-39 kDa]	a) Met e 1 *(Metapenaeus ensis)* b) Pen a 1 *(Penaeus aztecus)* c) Pen i 1 *(Penaeus indicus)* d) Pen o 1* (*Penaeus orientalis*)	a) Leung et al. 1994 b) Daul et al. 1994 c) Shanti et al. 1993 d) Miyazawa et al. 1996
39 kDa Allergen	Par f 1* *(Parapenaeus fissurus)*	Lin et al. 1993
Allergens: 21** and 38 kDa***		Hoffman et al. 1981
7 Allergens		Lehrer et al. 1985
13 Allergens (<16 to 166 kDa)		Daul et al. 1994

* not listed in the official WHO/IUIS list of allergens
** 21 kDa: 189 aa residues, pI 4.75-5.0, carbohydrate moieties 0.5%
*** 38 kDa: 341 aa residues, pI 5.4-5.8, carbohydrate moieties 4%

Other Allergens	References
tRNA from boiled whole shrimp *(Peneaus indicus)**	Nagpal et al. 1987

* existence of tRNA allergen not confirmed by other investigators

5.1 Sensitization to Shrimp Allergens

Country / Subjects	Sensitivity to	References
Taiwan, Tapei 10 shrimp allergic patients	**Allergens from *Parapenaeus fissurus*** 86 kDa in 20% 74 kDa in 40% 50 kDa in 10% 47 kDa in 20% 41 kDa in 10% 39 kDa (Par f 1) in 70% (SDS-PAGE immunoblot)	Lin et al. 1993
USA, New Orleans, LA 34 shrimp allergic patients	**Allergens from *Penaeus aztecus*** 166 kDa in 15% 105 kDa in 24% 66 kDa in 3% 55 kDa in 3% 45 kDa in 18% 42 kDa in 15% 36 kDa (Pen a 1) in 82% 33 kDa in 21% 29 kDa in 6% 24 kDa in 3% 20 kDa in 18% 16 kDa in 6% <16 kDa in 12% (SDS-PAGE immunoblot)	Daul et al. 1994

USA, NC 11 shrimp allergic patients	38 kDa allergen in 100% 21 kDa allergen in 64% (RAST)	Hoffman et al. 1981

5.2 Properties of Tropomyosins

5.2.1 Molecular Biological Properties

Tropomyosins	References
Allergen Nomenclature Met e 1 *(Metapenaeus ensis)* Pen a 1 *(Penaeus aztecus)* Pen i 1 *(Penaeus indicus)* Pen o 1* (*Penaeus orientalis*) * not listed in the official WHO/IUIS list of allergens	(1) Larsen & Lowenstein 2000
Molecular Mass **Met e 1** / **Pen a 1** / **Pen i 1** / **Pen o 1** SDS-PAGE: 36 kDa (2) / 34 kDa (1) / 39 kDa (4) calculated: 34 kDa (3)	(1) Shanti et al. 1993 (2) Daul et al. 1994 (3) Leung et al. 1994 (4) Miyazawa et al. 1996
Isoelectric Point **Met e 1** / **Pen a 1** / **Pen i 1** IEF-PAGE: pI 5.2 (2) / pI 4.8-5.4 (1)	(1) Shanti et al. 1993 (2) Daul et al. 1994
Amino Acid Sequence, mRNA, and cDNA **Met e 1** / **Pen a 1** / **Pen o 1** **GenBank:** U08008 / AAB31957 (1)* **SWISS-PROT:** Q25456 **Amino Acids:** 281 (2) / 265 and 229 (4) 284 (5) / ps** (3) **mRNA:** 843 bp (partial) **cDNA** *21aa peptide from endoproteinase Lys-C digest (1) ** partial sequence, 3 peptides from Acromobacter protease digest (3)	(1) Daul et al. 1994 (2) Leung et al. 1994 (3) Miyazawa et al. 1996 (4) Reese et al. 1997 (5) Reese et al. 1999b
Recombinant Proteins Expression cDNA library: cDNA library from the shrimp *Metapenaeus ensis* in lambda gt 11 screened with patient's sera, identified IgE-reactive clone (cDNA) purified and expressed in plasmid pGEX (1) Screening of cDNA library from shrimp tail muscle (*Penaeus aztecus*) with a Pen a 1 specific mAb, expression of 4 recombinant proteins in *Escherichia coli* (2)	(1) Leung et al. 1994 (2) Reese et al. 1997
Posttranslational Modification Acetylation: blocked N-terminus (Pen o 1) (2) Glycosylation: Carbohydrate moieties (Pen a 1): 2.9% (1)	(1) Daul et al. 1994 (2) Miyazawa et al. 1996

Biological Function Tropomyosin belongs to a highly conserved family of proteins in both muscle and non-muscle cells of all species of vertebrates and invertebrates (2); tropomyosin is associated with the troponin complex which plays a central role in calcium dependent regulation of muscle contraction (1)	(1) SWISS-PROT (2) Reese et al. 1999b
Sequence Homology Amino acid sequence identities of Met a 1 and Pen a 1 to tropomyosins from 22 sources (1): **Met e 1 / Pen a 1** Met a 1 - 99% Hom a 1 (Atlantic lobster) 98% 98% Pan s 1 (spiny lobster) 98% 98% Per a 7 (American cockroach) 82% 82% Der p 10 (house dust mite) 81% 81% DromTM (fruit fly *Drosophila melanogaster*) 77% 77% ChlnTM (Japanese scallop) 57% 57%	(1) Reese et al. 1999b

5.2.2 Allergenic Properties

Tropomyosins	References
Frequency of Sensitization IgE-binding to tropomyosins in 82% of patients (1)	(1) see 5.1 Sensitization to Shrimp Allergens
Allergenicity of Natural Proteins IgE-binding to nPen a 1: Pen a 1 inhibited about 85% of IgE binding to whole shrimp protein extract (1)	(1) Reese et al. 1999b
Allergenicity of Recombinant Proteins IgE-binding to rMet e 1: demonstrated for recombinant shrimp protein with human sera from shrimp-allergic subjects (SDS-PAGE immunoblot) (1) complete inhibition of IgE binding by rMet e 1 to recombinant crab tropomyosin (sera from crustaceae allergic patients) (3) complete inhibition of IgE binding by rMet e 1 to lobster muscle extract (sera from crustaceae allergic patients) (4) IgE-binding to rPen a 1: demonstrated for all 4 recombinant shrimp proteins with human sera from shrimp-allergic subjects (2)	(1) Leung et al. 1994 (2) Reese et al. 1997 (3) Leung et al. 1998a (4) Leung et al. 1998b

B-Cell Epitopes IgE-binding regions of Met e 1: aa 47-63 (5) aa 150-158 (5) IgE-binding regions of Pen a 1: CNBr cleavage and enzymic digestion (Lys-C, Glu-C, trypsin, Arg-C, chymotrypsin) (c) recombinant peptides (d): synthetic peptides (a, e): IgE-binding regions of Pen i 1: aa 47-63 (trypsin digest) (a) (1,5)* aa 150-158 (trypsin digest) (a) (1,5)*	 4-20 kDa fragments (2, 3) aa 136-148 (4, 6)* aa 157-169 (4, 6)* aa 167-179 (4, 6)* aa 262-282 (4, 6)* aa 1-15 (6) aa 79-93 (6) aa 109-123 (6) aa 121-135 (6) aa 133-147 (6) aa 187-201 (6) aa 217-231 (6) aa 241-255 (6) aa 253-267 (6)	(1) Shanti et al. 1993 (2) Reeese et al. 1995 (3) Reeese et al. 1996 (4) Reese et al. 1997 (5) Subba Rao et al. 1998 (6) Reese et al. 1999a (a) Dot-immunoblot (b) ELISA inhibition (c) SDS-PAGE immunoblot (d) coding plasmid randomly cleaved by DNase 1, library screened with serum pool (e) SPOTs membrane technique *note differences in aa sequence designation in references
IgE-Binding: Critical Amino Acids Phe-150 in Pen i 1 assumed to be essential for IgE binding since peptide aa 150-158 showed IgE binding while peptide aa 151-171 did not (1)		(1) Subba Rao et al. 1998
T-Cell Epitopes Putative T-cell epitopes deduced from Pen i 1 sequence by computer algorithm, in vitro proliferative activity of 6 synthetic peptides tested with splenocytes from mice; none of the peptides bound patients' IgE (1)		(1) Subba Rao et al. 1998

5.3 Properties of 39 kDa Allergen (Par f 1)

5.3.1 Molecular Biological Properties

39 kDa Allergen	References
Allergen Nomenclature Par f 1* *(Parapenaeus fissurus)* * not listed in the official WHO/IUIS list of allergens	(1) Lin et al. 1993
Molecular Mass 39 kDa (SDS-PAGE) (1)	(1) Lin et al. 1993
Isoelectric Point pI 5.1-5.6 (1)	(1) Lin et al. 1993
Amino Acid Sequence, mRNA, and cDNA Sequences of 6 peptide fragments from endopeptidase Lys-C digest of Par f 1 with 5 to 26 aa in length (1)	(1) Lin et al. 1993
Genetic Variants / Isoforms 6 isoforms in 2D-electrophoresis (1)	(1) Lin et al. 1993
Biological Function unknown, but similar amino acid composition to serum albumins from different animals (1)	(1) Lin et al. 1993
Sequence Homology 62% to 83% sequence homology among 3 different pairs of peptide fragments of purified 39 kd components of shrimp and crab (2)	(1) Lin et al. 1993

5.3.2 Allergenic Properties

39 kDa Allergen	References
Frequency of Sensitization IgE-binding to Par f 1 in 70% (1)	(1) see 5.1 Sensitization to Shrimp Allergens

6 Isolation & Preparation

Extract / Purified Allergens	Methods	References
Protein Extract	Meat from boiled shrimp homogenized in PBS (pH 7.2), mixing overnight at 4°C, centrifuged, supernatant concentrated by membrane filtration, centrifuged, and dialyzed	Lehrer 1986
Protein Extract	Whole shrimp cooked in distilled water for 10 min, supernatant decanted, cooled, and centrifuged, followed by ammonium sulfate precipitation, precipitate redissolved in Tris-HCl buffer (pH 8) and dialyzed	Nagpal et al. 1987
Protein Extract	Meat from boiled shrimp homogenized in PBS (pH 7.2), mixing overnight with agitation, centrifuged, supernatant dialyzed, and freeze-dried	Crespo et al. 1995
Muscle Protein Fractions	Shrimp meat homogenized with cold PBS (pH 7.2), centrifuged, and supernatant filtered (filtrate = sarcoplasmic protein solution); precipitate washed, redissolved in high-salt buffer, centrifuged and filtered (filtrate = myofibrillar protein solution)	Byun et al. 2000

21 and 38-kDa Allergens	38 kDa allergen isolated from fresh extract of boiled shrimp by gel filtration and from raw shrimp by gel filtration and agarose electrophoresis; 21 kDa allergen isolated from raw shrimp	Hoffman et al. 1981
34 kDa Allergen (Pen i 1)	Isolation from boiled shrimp protein extract by successive ion exchange chromatography (DEAE-sephacel) and gelfiltration (BioGel, Sepharose columns)	Nagpal et al. 1989
Pen a 1	Isolation of 36 kDa band from SDS-PAGE gels by electroelution	Daul et al. 1994
Pen a 1	Isolation of Pen a 1 by preparative SDS-PAGE / fraction collection	Reese et al. 1995
Tropomyosin	Cut shrimp meat boiled in distilled water for 10 min, followed by ammonium sulfate precipitation, centrifugation, precipitate redissolved in Tris-HCl buffer (pH 8.0) and dialyzed; major shrimp allergen isolated by column chromatography (DEAE-Sepharose, hydroxylapatite, and Sephacryl S-300)	Miyazawa et al. 1996
Major Heat Stable Protein (36 kDa)	Boiled shrimp peeled and deveined, meat homogenized, extracted with PBS (pH 7.2) at 4°C overnight and centrifuged; supernatant filtered and followed by ammonium sulfate precipitation; precipitate redissolved in PBS, dialyzed, followed by isoelectric precipitation at pH 4.5 (repeated 3 times)	Byun et al. 2000

7 Cross-Reactivities

Cross-Reacting Allergens	Subjects / Methods	References
Shrimp *(Species)* *Penaeus setifecus* (white shrimp) and *Penaeus aztecus* (brown shrimp)	Positive SPT to both in 77% of 30 patients with shrimp allergy, 1 individual reacted to brown shrimp extract only; elevated RAST values to both extracts in 52%, 1 subject reacted only to white shrimp and 2 subjects to brown shrimp alone; 2 sera recognized qualitatively different allergens in brown and white shrimp extracts by RAST inhibition	Morgan et al. 1989b
Shrimp *(Crustaceae)* crab, crawfish, and lobster *	18 precipitating antigens in shrimp extract by CIE; 5 cross-reacted with crawfish, 3 with lobster and 1 with crab extract in CLIE; 7 shrimp allergens identified by CRIE with 6 sera from shrimp allergic patients, 3 allergens reacted with most of 6 sera, 2 precipitins present in shrimp, crawfish, lobster, and crab, while 1 precipitin were present only in shrimp	Lehrer et al. 1985
Shrimp *(Crustaceae)* crab, crawfish, and lobster	Inhibition of IgE binding to shrimp extract by crab (42%), crawfish (67%), and lobster extracts (82%), inhibition of IgE binding to crab (85%), crawfish (90%), and lobster extracts (78%) by shrimp extract (RAST inhibition)	Lehrer 1986
Shrimp *(Crustaceae)* crab, crawfish, and lobster and Pen a 1	Strong inhibition of IgE binding to Pen a 1 by crab, crawfish, and lobster protein extracts, similar inhibition potency to shrimp extract (RAST inhibition, serum pool from shrimp sensitive individuals)	Daul et al. 1994
Shrimp *(Crustaceae)* crab and rMet e 1	Complete inhibition of IgE binding to recombinant crab tropomyosin by recombinant shrimp tropomyosin (rMet e1) (SDS-PAGE immunoblot, 10 patients with crustaceae allergy)	Leung et al. 1998a

Shrimp *(Crustaceae)* lobster and rMet e 1	Complete inhibition of IgE binding to lobster muscle extracts by recombinant shrimp tropomyosin (rMet e 1) (SDS-PAGE immunoblot, 10 patients with crustaceae allergy)	Leung et al. 1998b
Shrimp *(Mollusca)* oyster	52-88% inhibition of IgE binding to oyster extracts by shrimp extracts (RAST inhibition, serum pool from 4 oyster sensitive individuals)	Lehrer & McCants 1987
Shrimp *(Mollusca)* clam	Inhibition of IgE binding to shrimp extract by clam extract, similar inhibitory potency as shrimp (RAST inhibition, serum pool from 3 patients with clam and shrimp specific IgE)	Desjardins et al. 1995
Shrimp *(Mollusca)* squid (*Todarodes pacificus*) and shrimp (*Penaeus orientalis*) tropomyosins	Significant cross-reactivity between squid tropomyosin (Tod p 1, 38 kDa) and shrimp tropomyosin (RAST inhibition)	Miyazawa et al. 1996
Shrimp *(Mollusca)* scallop	17% inhibition of IgE-binding to shrimp by scallop and 28% to scallop by shrimp extracts; Significant inhibition of 35 to 39 kDa bands of shrimp by scallop extract and vice versa (ELISA inhibition, SDS-PAGE immunoblot, 1 shrimp and scallop allergic individual)	Goetz & Whisman 2000
Shrimp *(Caddis Fly)* caddis fly	IgE reactivity of sera of 1 patient: cross-reacting homologous 13 kDa proteins in extracts of shrimp and caddis fly (RAST inhibition, SDS-PAGE immunoblot inhibition, caddis fly sensitvie patients)	Koshte et al. 1989
Shrimp *(Mite)* boiled shrimp (*Crangon crangon*) and mite (*Dermatophagoides pteronyssinus*)	100-fold higher inhibition of IgE binding to mite extract by shrimp extract as compared to tropomyosin depleted shrimp extract (RAST inhibition, 3 sera from mite sensitive and shrimp allergic patients)	Witteman et al. 1994
Shrimp *(Cockroach)* boiled Atlantic shrimp (*Pandalus borealis*) and German cockroach (*Blattella germanica*)	Inhibition of IgE binding by shrimp extract to cockroach extract, and vice versa (RAST inhibition); strongest IgE binding for both at 30 to 43 kDa, binding capacity of cockroach was totally abolished by shrimp extract, while cockroach extract only partially inhibited IgE binding to shrimp (SDS-PAGE immunoblot inhibition) (sera from 89 shrimp and/or cockroach sensitive patients)	Crespo et al. 1995

* multiple sensitization / reactivity (not proven by inhibition-tests)

8 Stability of Shrimp Allergens

Treatment	Effects	References
Shrimps *(Heat)* boiled and raw shrimp extracts from white shrimp (*Penaeus setifecus*)	Similar reactivity of boiled and raw shrimp in SPT, higher specific IgE to boiled shrimp as compared to raw shrimp in 9 from 14 shrimp allergic individuals (RAST)	Waring et al. 1985
Shrimps *(Heat)* boiled and raw shrimp extracts from white shrimp (*Penaeus setifecus*)	85% and 88% inhibition of IgE binding to raw and cooked oyster extracts, respectively, by cooked shrimp extract; 56% and 52% inhibition of IgE binding to raw and cooked oyster extracts, respectively, by raw shrimp extract (RAST inhibition, serum pool from 4 oyster sensitive individuals)	Lehrer & McCants 1987
Shrimps *(Heat)* allergens from boiling water and extracts from boiled shrimps	Both shrimp extracts contained acidic proteins (pI <3.5-6.0) and demonstrated similar allergenic activity (IEF-PAGE immunoblot, RAST, RAST inhibition, 14 shrimp allergic individuals)	Lehrer et al. 1990

Major Allergen *(Heat)* 38 kDa allergen isolated from boiled and raw shrimp	38 kDa allergen gave a correlation coefficient of 0.98 with whole cooked shrimp extract and of 0.66 with raw shrimp extract; strong inhibition of boiled and raw extracts by 38 kDa allergen (RAST, RAST inhibition, 11 shrimp allergic patients)	Hoffman et al. 1981
Shrimps, Major Protein *(gamma Irradiation)* Isolated shrimp heat-stable protein (HSP) gamma irradiated at 0, 1, 3, 5, 7, or 10 kGy in solution, fresh shrimp also irradiated	Dose-dependent reduction of IgE binding to irradiated HSP, and sarcoplasmic and myofibrillar protein extracts from irradiated shrimp ; reduction of HSP amount; in SDS-PAGE the main band (36 kDa) disappeared and traces induced from coagulation appeared at higher Mr (ELISA, SDS-PAGE, sera from 20 shrimp allergic individuals)	Byun et al. 2000

9 Allergen Sources

Reported Adverse Reactions	References
Shrimp Symptoms after ingestion of shrimp in various forms (e.g. whole shrimps, food compound, challenge test)	see 2 Symptoms of Shrimp Allergy
Shrimp-Meal Occupational asthma due to shrimp meal inhalation	Carino et al. 1985
Dust Samples Occupational asthma in food processing workers due to exposure to dust containing corn starch, guar gum, cellulose, shrimp (1%), and traces of clam	Desjardins et al. 1995
Shrimp Boiling Steam Occupational asthma in a seafood restaurant worker (shrimp allergy evaluated by RAST, SPT, and inhalation challenge): shrimp allergens were identified in boiling water distillates by SDS-PAGE immunoblot	Goetz & Whisman 2000
Fish Food 27-year-old patient with bronchial asthma who kept fish showed strongly positive reactions in skin tests for Chironomus and Culex larvae, as well as several kinds of Crustacea species, such as Daphnia and brine shrimps which are common ingredients in pet fish food	Dietschi & Wüthrich 1987

Allergens in Seafood Products	Content / Results	References
Pen a 1 in 4 commercial shrimp extracts, crab and lobster extracts	Commercial shrimp extracts demonstrated a 40-fold difference in Pen a 1 levels (24 to 920 µg/ml); crab and lobster extracts contained detectable levels of Pen a 1-like proteins; no detection in cockroach, house dust mite, oyster, codfish, or peanut extracts (ELISA, Pen a 1 specific mAb)	(1) Jeoung et al. 1997

Other Allergen Sources	References
House Dust Mite Immunotherapy Sensitization to shrimp during mite immunotherapy might occasionally occur probably due to cross-reactive allergenic tropomyosins from mite and shrimp; 17 patients receiving mite immunotherapy: 2 patients with antitropomyosin IgE also had a positive SPT for shrimp, and demonstrated oral allergy syndrome (OAS) after eating shrimp	van Ree et al. 1996

10 Food Allergen Labeling

Food Allergen	Labeling / Regulation Status	References
International Regulations Crustaceae* and crustaceae products	mandatory labeling of prepackaged food / advisary status (1)	(1) Codex Alimentarius Commission 1999
European Regulations Crustaceae* and crustaceae products	labeling appropriate / recommendation (1)	(1) Bousquet et al. 1998

* Including shrimps, crawfish, crabs, and lobsters

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