

Occupational allergy and asthma in the seafood industry

– emerging issues

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ABSTRACT

Increased demand for seafood and its functional by-products has been associated with a concomitant rise in fishing and aquaculture activities. This increased consumption and processing of seafood is associated with more frequent allergic health problems among seafood processors. This overview of occupational allergies and asthma in seafood exposed workers illustrates the changing nature of the fishing and seafood processing industry in the midst of ecological degradation and globalisation. It provides detailed insights into the major and minor allergens that have been identified and other pathophysiological mechanisms that have been implicated in airway inflammation. More refined exposure assessment studies in recent times have enabled detailed characterisation of allergen exposure response relationships, which confirm the increased risk associated with elevated allergen exposures. Directions for future research and preventive strategies are outlined.

Key words: occupational allergy, seafood industry, rhinitis, asthma, dermatitis

INTRODUCTION

Worldwide, food allergies and anaphylaxis are increasing at a faster rate than any other allergic disorder, affecting up to 13% of adults and 12% of children.¹ The World Allergy Organization (WAO) estimates that allergic diseases affect at least 30–40% of the world's population, and are increasingly affecting young people and those in the developing world as the diseases reach their plateau in the industrialised world.² Most allergic reactions to foods can be attributed to a few food groups including seafood, which form important sources of protein for populations from developing countries.

In industrialised countries, increased demand and consumption for seafood and its functional by-products has been associated with a concomitant rise in fishing and aquaculture activities. Aside from the potential depletion of marine stocks resulting from these activities, recent studies suggest that this increased consumption and processing of seafood has resulted in more frequent reports of allergic health problems among consumers as well as processors of seafood.³ This overview provides an update on the state of knowledge and understanding of occupational allergies and asthma in seafood exposed workers with a particular focus on the changing nature of the fishing and seafood processing industry, insights into the pathophysiological mechanisms that underlie the disease and the allergens implicated. It also identifies the risk factors that could be earmarked for preventive strategies. Emerging issues and directions for future research are outlined.

A MEDLINE search was undertaken for studies on occupational seafood allergy during the period 2000–2010 following a similar review published in 2001.³

FISHING AND THE SEAFOOD PROCESSING INDUSTRY

Recent data from the Food and Agriculture Organization indicates that in 2008, fishery capture and aquaculture production activities produced 142 million tonnes of fish.⁴ While fish capture remained around 90 million tonnes since 2001, aquaculture production has continued to increase at an average annual growth rate of 6% p.a. Aquaculture currently constitutes just under 50% of the total global fish supply. It is estimated that 80% of seafood harvests are used for direct human consumption and the remainder for non-food sources such as fishmeal and fish oil (Figure 1).

With this increase in harvesting in the last three decades, employment in the primary fisheries sector has grown faster than the world's population and employment in traditional agriculture. The number of fishers and fish farmers has been growing at an average rate of around 4% per year.⁴ In 2008, this sector provided direct employment and revenue for 45 million people worldwide, 98% of whom are from developing countries, especially from the Asian continent. While developing countries increase their share of fishery exports with increasing globalisation, the number of fishers in industrialised countries has declined primarily due to ageing of the workforce.

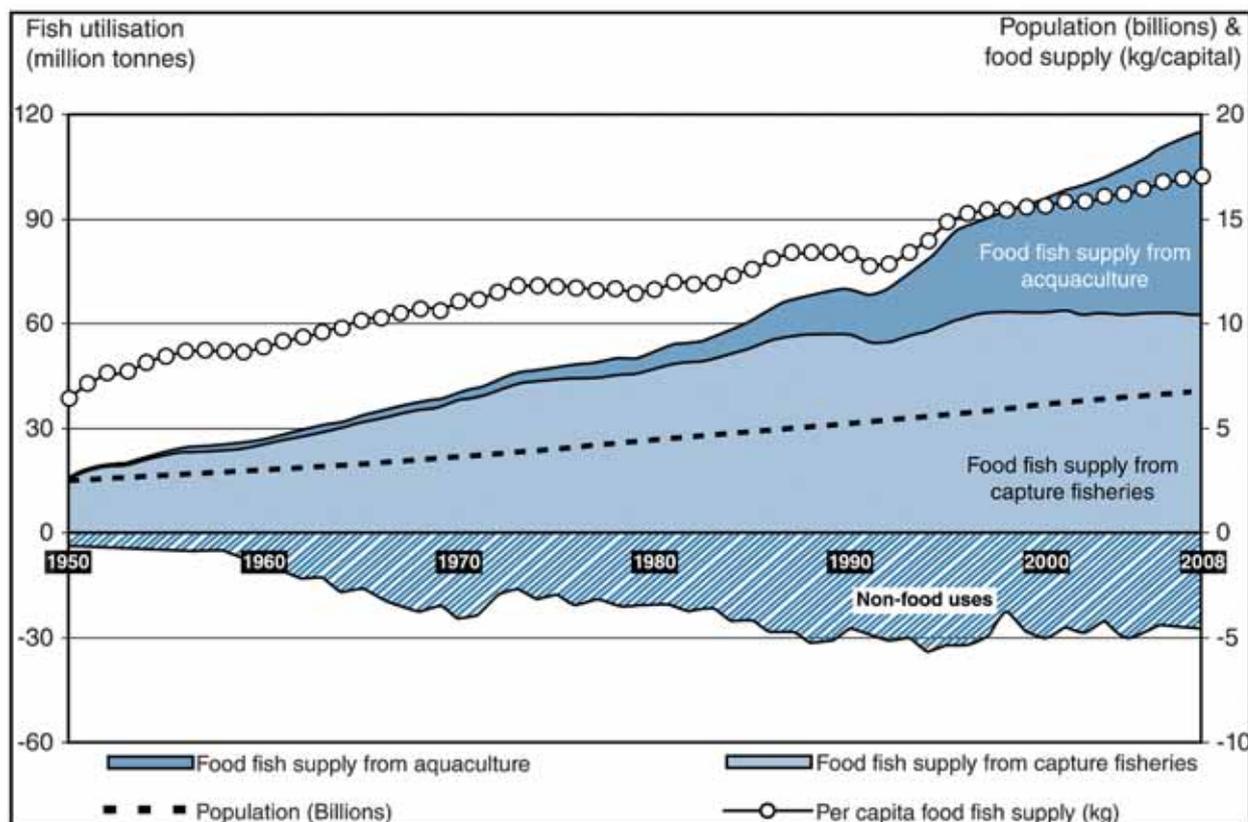


Figure 1. World fish utilisation and supply⁴

The International Labour Organization (ILO) estimates that approximately 50% of the fishing population work aboard fishing trawlers, 30% in aquaculture production (marine and freshwater), and 20% work inland as capture fishers or in other land-based activities such as processing.⁵ A characteristic feature of employment in the fishing industry is the seasonal nature of the work due to seasonal weather variations and the migratory nature of marine species. As a result, the number of full-time fishers has declined while the number of part-time fishers has grown quite rapidly in Asian countries. In many countries, labour in the fishing industry is divided along gender lines with men almost exclusively involved in harvesting and some processing of the seafood at sea and women doing most of the processing ashore and some inland capture.⁶

THE SEAFOOD MATRIX

The three most important seafood groupings of marine species frequently consumed and processed are Arthropods, Molluscs, and Pisces (sub-phylum Chordata).

It is estimated that in most developing countries at least 70–80% of seafood is eaten fresh.⁷ However, based on trends over the last decade in China, this proportion of fresh seafood eaten is on the decline towards trends seen in industrialised countries as the marine seafood stocks are decreasing and aquaculture and processing activities take

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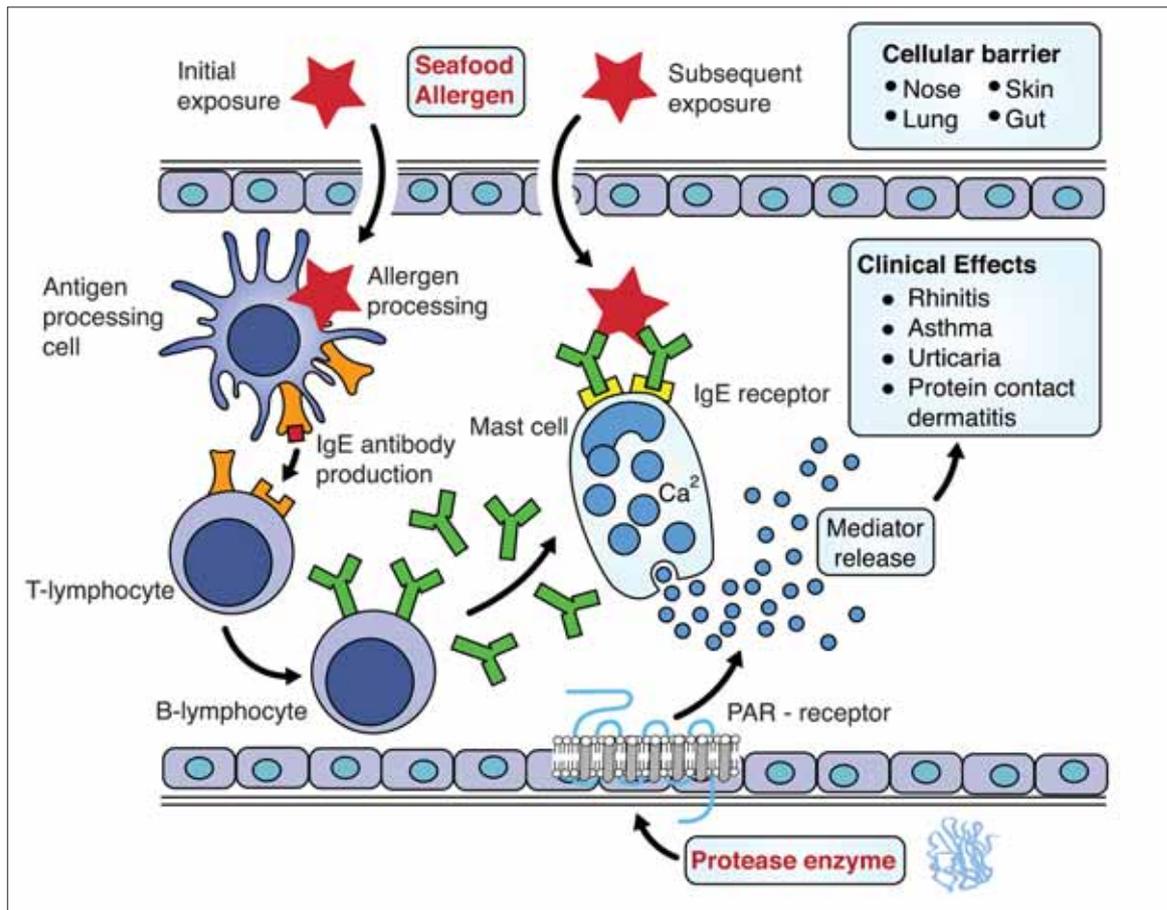


Figure 2. Mechanisms of allergic and non-allergic inflammation in seafood exposed individuals (Modified and adapted)¹⁴

hold. The processed aquatic products are mainly filleted frozen products, as well as dried, salted, canned products, surimi products, additives and fishmeal.

Studies in crab processing plants demonstrate that the aerosols generated in these factories contain mainly crab exoskeleton containing chitin, meat primarily muscle protein, gills and kanimiso/internal organs.³ Fish juice produced in fish filleting and canning plants has various biogenic amines, degradation compounds associated with postmortem

changes, digestive enzymes, skin slime/mucin, collagen and fish muscle proteins.

Aside from the actual seafood, various non-seafood contaminants and additives have been detected in the seafood matrix. These include parasites (*Anisakis simplex*), protochordates (*Hoya* or sea-squirt), red soft-coral, algae (dinoflagellates – *Hematodinium*), bacteria (*Vibrio*), viruses (hepatitis A), marine or bacterial toxins (saxitoxins, scombroid toxin, histamine, endotoxin), gases produced

Table 1. Seafood and associated agents causing occupational allergy and asthma in seafood workers

Phylum	Class	Family species (common name)
Arthropoda	Crustacea	Crabs, lobsters, prawns, shrimp, scampi, shrimpm meal
Mollusca	Gastropoda	Abalone
	Bivalvia	Clams, oysters, mussels, scallops
	Cephalopoda	Cuttlefish (and bone), octopus, squid
Pisces (sub-phylum Chordata)	Osteichthyes (bony fish)	Salmon, plaice, tuna, hake, cod, herring, pilchard, anchovy, trout, swordfish, sole, pomfret, yellowfin, turbot, fishmeal (flour)
	Chondrichthyes (cartilaginous fish)	Shark (cartilage)
	Other agents	Hoya (Sea-squirt), Anisakis, Red soft coral, Daphnia, Marine sponge, Algae

by anaerobic decomposition of fish (hydrogen sulphide), polyphosphates, nitrosamines and residues of drugs used in aquaculture (e.g. antibiotics or hormones), chemical additives (sulphites), spices (mustard, paprika, flour additives, garlic), and hidden ingredients (casein) in canned or processed fish products.³

PATHOPHYSIOLOGICAL MECHANISMS

Aside from the ingestion route commonly encountered in the domestic setting, seafood also finds its way into the human body through inhalation and skin contact in domestic and recreational settings and is the main route of exposure in workplace settings. Adverse reactions have been reported in all these exposure contexts in individuals consuming, handling and processing seafood.

The adverse reactions associated with seafood could be a toxic or non-toxic individual reaction that may be due to an allergy or intolerance to an additive or contaminant of seafood.⁸ In seafood exposed individuals, both allergic and irritant reactions have been observed. The allergy is commonly mediated by specific IgE antibodies in response to a seafood allergen or associated agent present in the seafood matrix (Figure 2). There is also evidence that seafood digestive enzymes such as trypsin can activate protease activated receptor-2 on epithelial cells of the airways and cause airway inflammation through the expression of IL-8 in in-vitro models.⁹

HEALTH EFFECTS ASSOCIATED WITH SEAFOOD

Seafood allergy was first reported in 1937 by Arent de Besche in a fisherman who developed allergic symptoms and asthma when handling codfish.¹⁰ Various seafood species, from all three major seafood groupings, have subsequently been reported to cause occupational allergy and asthma (Table 1).^{3,11}

Rhinitis

Various epidemiological studies and case reports indicate that ocular-nasal symptoms and allergic rhinitis occur commonly in seafood exposed workers. Frequently, this is the first indicator that there is underlying allergic disease. A large proportion of individuals with occupational asthma also report co-existing occupational rhinitis.¹² The prevalence of occupational rhinitis associated with fish and seafood proteins is reported to be between 5–24%.¹³ However, the true incidence of occupational rhinitis in this setting has yet to be characterised.

Asthma

Epidemiological studies indicate that the prevalence of occupational asthma is between 2 and 36%.¹¹ These

differences in prevalence are partly due to varying definitions of occupational asthma used; the allergenic potential of the seafood proteins of the species implicated; and the type of work process causing excessive exposure such as steam, organic dust, air blowing and water jets. What is notable, however, is that various studies show that occupational asthma is more commonly associated with shellfish (4–36%) than with bony fish (2–8%).¹¹ Rhinitis, conjunctivitis and less frequently urticaria, are often associated and may precede

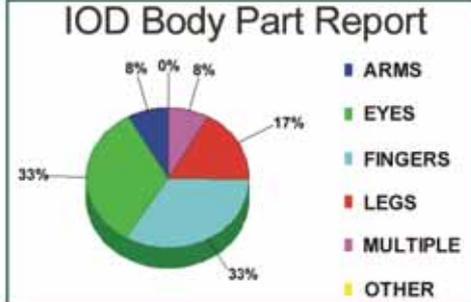
“ . . . inhalation of seafood muscle proteins and digestive enzymes such as trypsin can cause respiratory allergy or inflammation. ”

the development of chest symptoms. There have also been isolated case reports of workers with work-related asthma symptoms who subsequently developed ingestion-related allergic symptoms.³



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The natural history of occupational asthma is outlined in Figure 3, commencing from entry into the workplace as a healthy individual, and passing on to the allergic sensitisation phase with the development of specific IgE antibodies following inhalation to the seafood allergen, followed by the rhinitis phase and finally the development of occupational asthma with continued exposure. The latency period between the onset of exposure and the onset of asthma symptoms is highly variable, however a large proportion of workers develop asthma within the first 2 years of exposure. If the asthma is detected early, it could be “cured” since the mainstay of management is interrupting the progression of the disease through avoidance of exposure to the offending allergen.¹²

Dermatoses

Allergic dermatoses to seafood, in contrast to respiratory allergy, have been studied to a lesser extent. The major skin manifestations associated with seafood are contact urticaria and eczematous contact dermatitis of various types. Contact urticaria is associated with direct contact with raw seafood proteins. At least 75% of eczematous dermatitis in the fish processing industry is of an irritant nature commonly due to contact with water and fish products (fish juice, slime, skin, fillet).³ Contact with the proteinacious material such as seafood also causes a chronic recurrent dermatitis commonly known as protein contact dermatitis (PCD).¹⁶ However, biochemical sensitisers (e.g. garlic, onion, spices) added to seafood can also cause a delayed allergic contact dermatitis.³ Various reports have indicated that these dermatological outcomes can also co-exist in affected individuals.

In the seafood industry, the reported prevalence of occupational protein contact dermatitis (PCD) is between 3–11%.³ Protein contact dermatitis (PCD) initially manifests as itchy, erythematous and vesicular lesions. PCD usually goes on to present as a chronic eczema with episodic acute exacerbations a few minutes after repeated contact with the offending allergen.¹⁶ The development of immediate contact reactions usually requires repeated skin contact although prior sensitisation through ingestion or inhalation and subsequent dermal contact can also result in PCD. Predominantly affected areas are the volar aspect of the forearm and dorsum of the hands. In the more severe form, local skin contact with seafood may result in generalised urticaria and/or systemic symptoms (angioedema, wheezing). The diagnosis can be made by means of skin prick tests since patch tests with the responsible allergen are usually negative. Occasionally, specific IgE antibodies can be detected in the sera.

RISK FACTORS FOR OCCUPATIONAL ALLERGY AND ASTHMA ASSOCIATED WITH SEAFOOD

Various studies show that the aetiology and development of allergic disease is due to an interaction between genetic, environmental and host factors giving rise to different allergic disease phenotypes. The seafood industry provides an ideal context to analyse both upstream and downstream risk factors for occupational allergy and asthma associated with seafood.

(a) Environmental factors

Working populations with seafood contact

Occupational exposure to seafood allergens occurs mainly

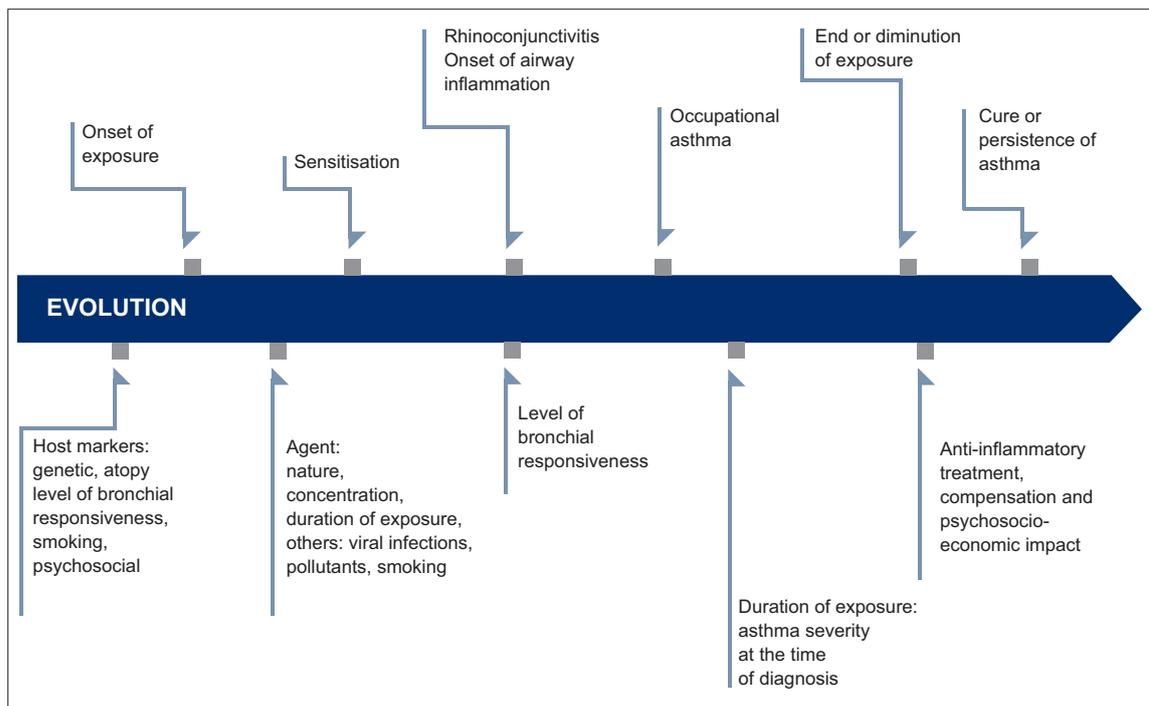


Figure 3. Natural history of occupational asthma, risk factors for disease onset and progression

(Reproduced with permission from Jean-Luc Malo)¹⁵



Figure 4a. Pilchard heading



Figure 4b. Salmon degutting



Figure 4c. Crab scrubbing



Figure 4d. Lobster cleaning and washing

in the food and fishing industry. Seafood processing plants in particular vary in technology levels, with some of the smaller workplaces relying entirely on manual handling of the seafood and larger companies using modern highly automated processes. There is great variation in processing procedures and preservation techniques for the different types of seafood including filleting, freezing, drying, cooking, smoking and high pressure techniques.¹⁷ Workers are involved in either manual or automated processing of crabs, prawns, mussels, fish, and fishmeal in factories. Other occupations associated with exposure to seafood include harvesting activities (fishermen, aquaculture, oyster shuckers, fishmongers, truck drivers, maintenance), food preparation activities (restaurant chefs and waiters), laboratory and pharmaceutical technicians and researchers, pet food production and value added (shell grinders, jewellery polishers).^{3,11}

Work processes generating seafood aerosols

Studies among fish processors demonstrate that common work processes causing bioaerosol production include butchering or grinding; degilling, "cracking" and boiling of crabs; cleaning and brushing of crab; "tailing" of lobster; "blowing" of prawn meat through shells; washing or scrubbing of shellfish; degutting, heading, and cooking/boiling of fish; mincing of

seafood; and cleaning of the processing line or storage tanks with high pressured water hoses (Figures 4a–d).³ Processes that generate dry aerosol particulates such as prawn blowing operations using compressed air and fishmeal loading/bagging appear to generate higher levels of particulate than wet processes (prawn blowing with water jets). It is these aerosolised wet or dry particulates produced from seafood during processing operations that are inhaled by workers.

Environmental exposure assessments in seafood processing plants demonstrate a wide range of airborne concentrations of aerosols from the lower limits of assay detection to as high as 11 mg/m³ for total inhalable particulates, 6 mg/m³ for protein and 75 µg/m³ for allergen levels (Table 2).¹¹ Particulates and allergens reach very high levels during dusty fishmeal operations and crab processing aboard vessels at sea since processing occurs in very confined spaces with poor ventilation systems. Recent studies also suggest that particle concentrations are higher in factories with old seafood processing machines. Aerodynamic studies of these particles in crab processing environments indicate that at least 30% of airborne particulates are <5 µm and almost 100% are <1 µm in herring fish filleting environments.^{3,18} This suggests that most of these particles are capable of being inhaled and reaching the small airways.

Food processing techniques

Aerosols and particulates produced in the seafood processing industry are not inert but are biologically active. There is increasing evidence that food processing techniques such as heating, freezing and high pressures have the ability to change the nature, dose and allergenicity of food.¹⁹ During processing, the seafood is concentrated into major allergen source compartments from muscle, visceral contents, skin slime/mucin or collagen.³ The allergenic potential of these proteins is dependent on the seafood type, with crustacean proteins being more allergenic than fish proteins. In addition, other by-products such as protease enzymes from the gut, chitin from shellfish, and endotoxin from gram negative bacteria, also promote airway inflammation when present in high concentrations. Furthermore, it has been shown that storage conditions may also influence the allergenicity of seafood extracts by influencing the relative distribution of various IgE reactive proteins.²⁰ Fish kept on ice for several days showed additional high molecular weight allergens and higher IgE binding capacity than fresh fish. Codfish stored for several days (at 4°C) displays a much higher IgE reactivity than very fresh fish. These changes may be attributed to the natural development of components such as formaldehyde in fish tissue, which might affect the allergenicity of some proteins.²⁰ This is confirmed by recent studies suggesting that processing raw crustaceans or fish may be less sensitising than the cooked seafood.^{11,21}

Seafood allergens in aerosols

Molecular characterisation studies show that aerosolised

seafood proteins are primarily high molecular weight proteins.^{8,20} Immunological studies of serum obtained from crab processing workers with occupational asthma identified the major allergen in shellfish responsible for inhalant-related seafood allergy to be tropomyosin, a 34–39 kDa muscle protein, which is important for muscle contraction.^{22,23} This is the same allergen that has been identified in patients with ingestion-related allergy. Another minor inhaled seafood allergen, arginine kinase (40 kDa) has also been recently identified.²⁴ Studies among fish processing workers also suggest that a highly cross-reactive allergenic isoform of pilchard parvalbumin, the major allergen causing ingestion-related seafood allergy, is also one of the allergens responsible for the symptoms observed in workers.²⁵ Parvalbumin is a 12 kDa calcium binding protein also involved in muscle contraction. In contrast to ingestion sensitised patients, who recognise mainly the monomer, occupationally sensitised workers appear to recognise higher molecular weight proteins, including parvalbumin dimers and oligomers. Furthermore, another novel allergen (36 kDa), identified as fish glyceraldehyde-3-phosphate dehydrogenase has also been characterised.²⁶

Cross-reactivity of pan-allergens is an important mechanism that may result in allergic reactions in individuals. Tropomyosin is a pan-allergen because it is a highly conserved protein among crustacean species. Individuals, allergic to one seafood type such as crab, who have cross-reactive allergies can experience similar symptoms as a result of a common allergen found in a range of other sources such as crustaceans (shrimp, lobster) as well as molluscs

Table 2. A summary of various exposure assessment studies of seafood processing workers on land and aboard vessels reported in the literature

Seafood category	Particle fraction measured	Particulate conc. (mg/m ³) range	Protein conc. (mg/m ³) range	Allergen (µg/m ³) range
<i>Crustaceans</i>				
- crabs (snow, Tanner, common, King)	total inhalable	0.001-0.680	0.001-6.400	0.001-5.061
- crabs (snow)*	total inhalable	ND	ND	0.079-21.093
- prawns	total inhalable	0.100-3.300	ND	ND
- shrimp	total inhalable	ND	ND	1.500-6.260
- rock lobster	thoracic	LOD-0.661	LOD-0.002	ND
- scampi	total inhalable	ND	ND	0.047-1.042
<i>Finfish</i>				
- salmon	respirable	0.040-3.570	ND	0.100-1.00
- pollock	total inhalable	0.004	ND	ND
- whiff megrim/hake	total inhalable	ND	ND	0.002-0.025
- pilchard	thoracic	LOD-2.954	LOD-0.006	0.010-0.898
- cod	total inhalable	ND	ND	3.800-5.100
- salmon	total inhalable	ND	ND	LOD-1.600
- herring	total inhalable	ND	ND	0.300-1.900
- fishmeal (anchovy)	thoracic	LOD-11.293	LOD-0.004	0.069-75.748
- shark cartilage**	respirable	0.920 - 5.140	ND	ND
	total inhalable	26.400 - 44.700	ND	ND

Reproduced with permission from Jeebhay and Cartier¹¹

ND: Not done, LOD: Limit of detection

* processing aboard vessels; ** non-food-handling environment

(snails), insects (cockroach), roundworms (*Anisakis*) and house dust mites.⁸ While there appears to be very little or no cross-reactivity between shellfish and bony fish, again there exists a high degree of cross-reactivity between fish species, due to the presence of parvalbumin and similarly between crustaceans due to the presence of tropomyosin.^{8,25}

Exposure-response relationships

There is increasing evidence that the risks of sensitisation and occupational asthma are increased with higher exposures of seafood aerosols. Gaddie et al. reported that a substantial proportion of prawn processors experienced relief of allergic symptoms including asthma when compressed-air jets were replaced by cold-water jets for prawn meat extrusion, the wet weight of material filtered in the air decreasing from 1,8–3,3 mg/m³ to 0,1–0,3 mg/m³.²⁷ Similarly, Douglas et al. reported that adding an exhaust ventilation over gutting machines in a salmon processing facility reduced respirable aerosol levels from a mean of 3,14 mg/m³ to <0,01 mg/m³.²⁸ As a result no new cases of occupational asthma occurred over 24 months versus a prevalence of 8% over an 18 month period prior to this. Recently, Gautrin et al. showed that cumulative exposure to snow crab allergens is positively associated with occupational asthma and allergy in a dose-response manner.²⁹ Studies among pilchard and anchovy fish processors have also found that workers with work-related asthma symptoms had a twofold increased risk of being exposed to pilchard-antigen concentrations >30 ng/m³ at the time of onset of their symptoms.³⁰ Similar positive relationships for incident work-related asthma symptoms and increasing concentrations as well as cumulative exposures have also been observed.³¹ This risk is further modified in atopic individuals, who demonstrate a higher risk.

Workplace organisation factors mediating exposure to seafood

Recent studies also suggest that industrial change (linked to ecological degradation and globalisation) and associated ecological and global shifts in production interact with rurality, migrancy, seasonality, gendered and racialised divisions of labour, as well as shortcomings in occupational health and safety interventions to mediate hazardous exposures and worker vulnerability.³² All these factors have the potential to contribute to substantial long-term negative physical health, economic hardship and poor quality of life of the affected workers and their families due to the potential under-diagnosis, under-reporting and under-compensation of workers with occupational allergy and asthma.

(b) Host factors

Atopy

Atopy among seafood processors is the most important host factor associated with the development of allergic

sensitisation and asthma to seafood allergens from crabs, prawns, cuttlefish, pilchard and anchovy. Studies among food handlers and caterers have shown an association between atopy and urticaria and protein contact dermatitis induced by crustaceans.^{3,11}

Smoking

Smoking has been associated with an increased risk of developing sensitisation to prawns, crab and fish (pilchard, anchovy and salmon).^{3,11} It is also a risk factor for developing occupational asthma in salmon and crab processing workers. Various reasons have been postulated including disruption of the natural epithelial barrier of the respiratory tract facilitating allergen entry or smoking acting as an adjuvant enhancing the allergenicity of the inhaled allergen.³³

“Atopy is associated with an increased risk of sensitisation to various seafood.”

Upper airway disease – occupational rhinitis

Many studies show that occupational rhinitis and occupational asthma frequently occur as co-morbid conditions. Rhinoconjunctivitis may precede or coincide with the onset of occupational asthma. The presence of rhinitis has been associated with an increased risk of developing occupational asthma to a number of proteins including seafood. Studies also show that the risk of developing occupational asthma is highest in the year after the onset of occupational rhinitis.¹⁴

Pre-existing skin disease

Skin integrity constitutes an important risk factor for the development of urticaria and protein contact dermatitis.³ Skin integrity and physiological factors (such as temperature below 19°C) also seem to be important in determining the location of skin symptoms (urticaria) and recovery of skin barrier function among workers handling fish.¹⁷

PREVENTION

Legislation, policies and exposure standards

Currently, workplace exposure standards do not exist for seafood allergen exposures. However, these can only be developed and enforced once sampling methods and standardised assays for quantifying these allergens become widely available. Aside from country-specific legislative provisions to promote a healthy and safe working environment on land, the ILO Convention on Fishing will also contribute towards improving occupational health and safety conditions at sea and to ensure social protection for these vulnerable groups of workers.³⁴

Workplace interventions and control measures

Exposure control measures by eliminating exposure or worker relocation are key to reducing the risk of occupational allergy and asthma among workers in the seafood industry. Identifying departments and activities with high aerosol exposure such as fishmeal bagging, gutting machines, cleaning and brushing crabs, and compressed-air jets should lead to the introduction of improved local exhaust ventilation systems and change in work processes to reduce aerosol exposures.³⁵ Preliminary studies suggest that processing (cleaning and brushing) raw crab before it is cooked may help reduce the risk of sensitisation, however further studies are needed to confirm this.¹¹

Medical surveillance of workers

Regular medical surveillance of exposed workers employed particularly in high-risk seafood industries such as crab and prawn processing is another strategy that can be used to reduce the incidence of occupational allergy and asthma and long-term disability. Abbreviated questionnaires may allow early detection of allergic symptoms, which could be investigated further using skin prick tests or allergens specific IgE if available. Prior to work withdrawal, proper evaluation should be conducted to confirm the diagnosis of occupational allergy or asthma. Affected individuals should be transferred to a low allergen exposure environment, while measures are undertaken to reduce allergen exposures in high-risk work processes. Surveillance of workers is also important as it may point to early presentation of allergies to previously unknown allergens that may be newly introduced into the work process before the product is released for broader domestic consumption.^{3,11}

Although studies have shown that atopic individuals are at higher risk of developing occupational asthma, there is no way of predicting which individuals will become symptomatic. As a result there is general consensus that there is no place for pre-screening and exclusion from employment of atopic individuals since studies show that almost 40% of workers are atopic and a residual risk for asthma exists even in non-atopic individuals that are exposed.³⁶ However, what is recommended is advising and counselling atopic apprentices to choose jobs that do not subject themselves to seafood allergens during the course of their work.

Increased worker awareness and training

Workers who are allergic to seafood and workers in high-risk working environments with exposure to seafood need to be educated on the health risks associated with handling seafood containing products.

Immunotherapy modalities

While immunotherapy remains a theoretical possibility, it is still in the experimental stage as it has not yet been studied in seafood exposed working populations.²⁶

CONCLUSIONS

This review has identified some emerging areas and developing trends in relation to occupational allergy and asthma in the seafood industry. These relate to industrial change (linked to ecological degradation and globalisation) and associated global shifts in production that form the basis for continued and increased exposure to vulnerable populations. More detailed insights have emerged into the allergens causing work-related fish and shellfish allergy and asthma, indicating that while the major allergens (parvalbumin and tropomyosin) causing occupational asthma appear to be similar to the allergens causing ingestion-related allergy, there are other allergens that are also implicated. In-vitro studies have also identified serine proteases that cause airway inflammation by upregulating the IL-8 receptor, which may be contributing to the work-related symptoms observed in workers. More advanced laboratory-based techniques have paved the way for detailed exposure characterisation studies of seafood allergen and other contaminants present in seafood aerosols. Evidence from exposure-response relationships emphasise control strategies directed towards reduction of exposures as being the mainstay of prevention.

Areas for future research

- Detailed exposure assessment studies are required using standardised immunoassays for specific seafood allergens and non-immunologically-based approaches (for proteases, sulphites, toxins) to investigate single and mixed exposures.
- Establishing health surveillance programmes for high-risk exposure groups:
 - detailed epidemiological studies of workers aboard vessels;
 - establishing dose-response relationships in order to establish the utility of exposure threshold limits for minimising exposure to seafood allergens; and
 - investigating the interaction of exposures with host factors in modifying the asthmatic response.
- Investigating the relevance of raw versus cooked seafood for inhalant respiratory allergy.
- Identification and characterisation of other major or minor seafood allergens causing inhalant respiratory allergy and asthma.
- Evaluating effective intervention packages (exposure controls / best practice) in seafood processing environments aboard vessels and ashore.

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LESSONS LEARNED

- Seafood processing techniques causes aerosolisation of allergens which are more likely to be inhaled by exposed workers.
- Industrial food processing techniques change the nature, dose and allergenicity of seafood.
- Occupational allergy and asthma due to crustaceans is more prevalent than due to bony fish.
- Atopy, smoking and rhinitis are risk factors for inhalant reactions associated with exposure to seafood.
- Reducing airborne exposures can decrease the risk of developing allergy and asthma associated with seafood.

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