Occupational inhalant allergy in food handling occupations

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Purpose of review

Review article on recent developments on inhalant food allergens associated with occupational respiratory allergy and asthma.

Recent findings

This review has found that occupational inhalant allergy in food handling occupations is a common and recognisable clinical entity (class 3 food allergy) in high-risk food occupations such as bakeries and seafood processing. Aerosolised food proteins from plant or animal food sources, additives and biological food contaminants cause occupational sensitization, rhinitis and asthma. The risk of allergy may be enhanced across the food value chain as a result of food processing techniques including the introduction of new food allergens in the food matrix. Occupational food allergy and asthma can be prevented by improved health-based exposure standards, workplace control measures, education and training activities, and early diagnosis accompanied with exposure reduction.

Summary

Future studies need to focus on exposure-response studies to establish improved exposure limits especially for flour dust, the relevance of cooked vs raw foods in influencing risk, identifying and characterising major inhalant food allergens accompanied with component resolved diagnostic approaches, and evaluating the effectiveness of interventions for common high-risk food sensitizers causing occupational rhinitis and asthma.

Keywords

food handling and processing, inhalant food allergens, occupational asthma, occupational food allergy

INTRODUCTION

Occupational sensitisation due to inhalant food allergens during food handling, classified by the European Academy of Allergy and Clinical Immunology (EAACI) Consensus Statement as a class 3 food allergy (Table 1), is estimated to account for up to 25% of occupational asthma (OA) and occupational rhinitis (OR) [1▪]. The main allergen sources include high molecular weight (HMW) food proteins in plant or animal food sources, additives (enzymes, flavourants, colourants, thickening agents, sulphites) and biological food contaminants (insects, mites, parasites and fungi) in food storage, preparation and processing facilities [1▪,2]. The predominant mechanism of sensitisation is through aerosolisation of allergens during workplace handling and their subsequent inhalation.

METHODS

Published studies were identified from PubMed and MEDLINE for the period 2018–2021, as an update to the comprehensive review published in 2019 by the EAACI FORA Taskforce [1▪]. The following keywords were used in the search strategy: (occupational allergy) or (inhalant food allergy) or (work-related allergy) AND (occupational allergic respiratory disease) or (respiratory allergy or asthma or rhinitis) AND (food processing) or (food handling) or (food industry). Specific searches also included (wheat allergen) or (flour dust or wheat allergens) or (baker's asthma or rhinitis) AND occupational exposure),

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KEY POINTS

- Occupational inhalant food allergy is caused by high molecular weight food proteins in plant or animal food sources, additives and biological food contaminants in food storage, preparation and processing facilities.
- The predominant mechanism of sensitization is through aerosolization of allergens during workplace handling resulting in occupational rhinitis and asthma.
- Occupational food allergy and asthma can be prevented by improved health-based exposure standards, workplace control measures, education and training activities and early diagnosis accompanied with exposure reduction.

(seafood processing or manufacturing or handling or industry) or (seafood allergy or asthma or occupational seafood allergy) or (seafood allergens) or (work-related exposure or occupational seafood exposure or bioaerosol exposure or enzyme exposure), given these two entities are the most commonly studied. References published within the timeframe not otherwise identified in the initial search were added to provide appropriate continuity and context.

OCCUPATIONS AND POPULATIONS AT RISK

Causative agents

There are few prospective studies that follow the development of adult respiratory disease with exposure to occupational asthmagenic agents. In a population-based study, Tagiyeva *et al.* reported an increased risk of adult onset wheezing illness, lung function impairment and excess Forced expiratory volume in one second (FEV_1) decline with occupational exposure to food-related agents in adults without childhood wheeze [3].

A comprehensive list of agents causing occupational allergy, OR or OA is listed in the EAACI Consensus Statement [1▪]. Additional agents that have been reported in this review period are listed in Table 2 [4–19]. Notable newly reported plant agents include an additional allergen *Prunus persica* 9 in peach tree pollen, causing allergic sensitization in peach orchard farm workers [5]. Another is quinoa flour causing wheeze in a mill worker as seeds become popular in wheat allergic or gluten-intolerant individuals [6]. Occupational allergy to donkey milk was reported in a food laboratory analyst that handled both liquid and powdered lyophilized forms [12]. It is rare since it is not widely consumed and is considered to be hypoallergenic.

An unusual allergen in a butcher involved in sausage production, when adding binding agents, containing enzyme transglutaminase from *Streptomyces mobaraensis* to catalyze cross-linking of meat proteins to produce a more stable texture [14]. Psyllium has reemerged in bakers due to the increasing popularity of gluten-free and vegan food as a substitute for gluten or eggs [17]. An exotic rare cause of OA due to saponins from soapnuts and quillaja bark (*Quillaja saponaria*), added to beer was also reported [18].

Finally, two new seafood allergens were reported in workers handling dry shrimp Gammarus powder (*Pen m* 4) and fish (creatine kinase) [7,8].

Epidemiology and risk factors

It is estimated that OA occurs in 3–10% of green coffee bean workers, 4–13% of bakers, 2–8% of bony fish processors and 4–36% of shellfish processors [1▪,20,21]. Occupational risk factors for OA include

Table 1. Classification of food allergy

	Primary route of sensitization	Population affected	Symptoms with food ingestion	Symptoms with food inhalation
Class 1	Gastrointestinal tract, transcutaneous (with disrupted skin barrier)	Commonly children but can also occur in adults	Always	Occasional
Class 2	Cross-reactive allergens present in inhaled sources[a]	Commonly adults but can also occur in children/adolescents	Always	Seldom
Class 3	Respiratory tract, transcutaneous (with disrupted skin barrier)	Commonly adults in the workplace, but can also occur in the domestic setting with food preparation	Seldom	Always

[a]Example: pollen food syndromes.
EAACI consensus statement on food processing and occupational respiratory allergy [1▪].

Table 2. Recent case reports of food handling workers with occupational rhinitis or asthma due to inhalant food allergens

Agent	Occupation	Other Symptoms	Skin prick or intradermal test	Other immunologic evidence	Specific bronchial provocation	Other evidence
Plants/vegetables/fruits/spices						
Carrot [4]	Cook	Sneezing, rhinorrhoea, conjunctivitis	Positive to carrot	IgE positive	ND	ND
Peach tree pollen (*Prunus persica 9*) [5]	Peach orchard farm workers ($n=21$)	Rhinitis, asthma	Positive to peach tree pollen	Immunoblot	ND	Nasal provocation
Seeds						
Quinoa flour [6]	Mill worker	Wheeze	Positive to quinoa	ND	ND	FeNO, methacholine challenge
Buckwheat [7]	Cooks, baker, Grocery store worker ($n=6$)	Recurrent watery rhinitis, cough, dyspnoea	Positive to buckwheat	Specific IgE	ND	Spirometry, FeNO, serial PEF
Mushrooms						
Mushroom *sp.* [8] (*L shimeji, F velutipes, A bisporus/brunnescens*)	Farmer	Nasal, wheezing	Positive for mushroom	Immunoblot positive	ND	Serial FEV_1, PEF
Farm products						
Pork [9]	Slaughterhouse Workers ($n=4$)	Recurrent cough, dyspnoea, watery rhinitis	Positive pork meat	Immunoblot positive	Positive (pork meat and liver)	Nasal provocation, FeNO, spirometry
Shrimp Gammarus Powder [10]	Manufacturing/packaging animal feed worker	Rhinorrhea, dyspnoea, cough, wheezing	Positive to shrimp Gammarus	IgE to shrimp	Positive (shrimp Gammarus)	Spirometry, bronchodilator challenge
Fish Creatine Kinase [11]	Fishmonger	Dyspnoea, pruritis	Positive to raw hake, sole, tuna	IgE to sole, hake Immunoblot Positive	ND	Spirometry, FeNO mass spectrometry for protein identification
Milk derivatives						
Donkey milk [12]	Food analyst	Rhinitis	Positive for donkey milk	Immunoblot positive	ND	ND
Rennet (chymosin) [13]	Cheese maker	Dry cough, wheezing, sneezing	Positive to rennet	IgE to rennet	ND	Bronchodilator challenge, FeNO
Additives and preservatives						
Trans-Glutaminase [14] (*Streptomyces mobaraensis*)	Butcher	Cough, sneezing	Positive to transglutaminase	Immunoblot positive	ND	Spirometry (FEVi)
Gum Arabic [15]	Candy factory	Rhinitis	Negative	Positive to Gum Arabic	ND	Nasal provocation
Locust (carob) Bean Gum [16]	Cheese maker	Rhinitis, wheezing	ND	IgE positive	ND	Serial PEF
Psyllium [17]	Baker	Itchy eyes/nose wheeze, cough	Positive to psyllium	IgE positive	ND	FeNO
Soapnut and quillaja bark [18]	Processing worker	Rhino-conjunctivitis, asthma	Positive to quillaja bark, soapnut	Specific IgE	Positive (soapnut extract)	FeNO, Serial FEV_1
Sodium metabisulphite (SMBS) [19]	Coffee factory worker	Rhinitis	Positive SMBS	Oral provocation	ND	Nasal provocation

FeNO, fractional exhaled nitric oxide; IgE, Immunoglobulin E; ND, not done; PEF, peak expiratory flow.

the allergenicity of food proteins, nature of work processes and allergen exposure levels, whereas atopy, OR and ingestion-related allergy are important host risk factors.

Recent epidemiological studies have focussed mainly on workers in flour mills baking industries and the seafood industry (Tables 3 and 4). OA in these two food sectors have been reviewed in greater detail elsewhere [20,21].

Olivieri *et al.* reported a higher prevalence of work-related nasal (25.7%) than asthma-like symptoms (9.5%) in bakers using only wheat flour in traditional Italian bakeries (Table 3) [22]. The risk of work-related asthma-like symptoms was higher in bakers compared to shop assistants, with higher odds when multigrain flour was used (OR = 3.4, 95% CI 1.1–10.8). In a sub-study, fractional exhaled nitric oxide (FeNO) levels were higher in sensitized bakers with work-related lower airway symptoms compared to nonsensitized bakers as has been reported previously by Baatjies *et al.* [23▪,24]. In another Italian study of bakers, a significant correlation was observed between increasing duration or flour dust exposures $>2\,mg/m^3$ and declining FEV_1/Forced vital capacity (FVC) ratio [25].

In Ethiopian flour mill workers, significant risk factors for work-related respiratory symptoms included employment duration >5 years, flour mixing operations, inadequate workplace ventilation, lack of respiratory protective equipment and bakers having no safety training [26–28]. Two studies of bakeries in the DR Congo and Benin reported the prevalence of OA as 3.6% and 10% respectively [29,30].

Epidemiological studies were reported from Norwegian crab processing workers and Swedish fishers and processors (Table 4). In the former group, atopy was significantly associated with positive Skin prick test (SPT) or raised IgE to king- and edible crab. Workers exhibited differential IgE binding patterns to various forms of crab extracts (raw and cooked meat, intestines, shell) frequently to tropomyosin and arginine kinase as well as to two novel proteins, hemocyanin and enolase [31▪]. More studies are needed to determine their relevance for occupational sensitization through inhalation. In the latter study, the risk of asthma among fish filleting workers increased with employment duration in fish processing and the use of pressured sprayers. Filleters were also more likely to change their work tasks due to respiratory symptoms than other fish processing workers [32]. Mason *et al.* used data from the Surveillance of Work-related and Occupational Respiratory Disease reporting system for 1992–2017 showing an excess incidence of annual OA for UK land-based seafood processors of 70 per 100 000 workers compared to 2.9 in 'all other industries', implicating prawns and salmon/trout processing [33]. These findings are consistent with others, highlighting the need to reduce bioaerosol exposures [34].

In an isolated study of poultry farm workers, Ngajilo *et al.* reported a 3% prevalence of OA [35]. Workers sensitized to chicken-specific allergens (8%) were more likely to be atopic or employed as casual-workers, whereas those with work-related chest symptoms were more likely to work in the rearing-department (OR = 3.2, 95% CI: 1.2–8.4).

EXPOSURE ASSESSMENT

Exposure assessment is important in identifying high-risk exposures and evaluating the effectiveness of interventions. El-Zaemey *et al.* used data from the Australian Work Exposure Study-Asthma, found that among the 4,878 respondents, 12.4% reported occupational exposure to asthmagens derived from animals, fish and/or shellfish, whilst 12.8% reported occupational exposure to asthmagens derived from plants [36,37]. Furthermore, farmers/food handling workers were the most common occupational group exposed to animals/seafood (33%) and plants, mainly to flour (66%).

Exposure studies have been reported mainly for flour dust, since it continues to be associated with a higher incidence of OA and OR. Recent studies have been reviewed in a separate communication [38▪]. Notable is the systematic review of 21 studies, which demonstrated that weighing/mixing and dough forming tasks were associated with the highest inhalable dust ($3.078–4.930\,mg/m^3$) and wheat allergen levels ($37–40\,\mu g/m^3$) [39]. Furthermore, small bakery size was also associated with higher exposures.

Noncompliance with exposure limits continues to be highlighted. Zamani *et al.* reported high mean dust levels of $11.06\,mg/m^3$ in Iranian flour mill workers, with 45% of samples exceeding the American Conference of Governmental Industrial Hygienists (ACGIH) standard of $0.5\,mg/m^3$ [40]. Irish bakeries had 70% of measurements exceeding $1\,mg/m^3$ whereas Norwegian bakeries had 29% of samples exceeding $3\,mg/m^3$ [41,42]. Similarly, dust levels in Canadian bakeries were on average, double the exposure standard [39].

Furthermore, mycotoxin exposures have also been reported in Portuguese fresh bread dough companies [43], documenting exposures to deoxynivalenol (DON) as high as 58.2 ng/g, whilst a study in the Norwegian grain industry reported 1,3-β-glucan concentrations of $32\,\mu g/m^3$ [44]. A study of Irish bakeries and pizzerias reported fungi including *Penicillium* and mycotoxin exposures dominated by

Table 3. Summary of recent epidemiological studies of work-related symptoms, rhinitis and asthma in plant food handling workplaces

Author/ Country	Study design	Subjects (*n*)	Participation rate (%)	Age (yrs.) mean (range)	Workplace	Diagnostic methods for defining rhinitis	Diagnostic methods for defining asthma	Atopy assessment	Risk factors (host and occupational)	Predictors of WRS/rhinitis symptoms/ asthma symptoms/OA: OR (95% CI) (unless otherwise stated)
Olivieri, 2021, Italy [22]	Cross-sectional	727	92	40.7 ± 11.6	Traditional bakeries	Q	Q	Q	*WR rhinitis*: gender, atopy, job task *WR asthma*: gender, atopy, job years, job	*WR nasal sx*: - males 2 (1.4-2.8) - atopy 6.2 (4.1–9.3) - task using wheat only 1.9 (1.2–3.1) - using wheat and additives 2.6 (1.7–4.1) - using wheat, additives and multigrain 2.7 (1.4–5) *WR asthma-like sx*: - gender 2.4 (1.4–4.2) - atopy 4.5 (2.7–7.6) - working ≥5yrs 1.9 (1.1–3.4) - using wheat and additives 3.5 (1.7–7.3) - using wheat, additives and multigrain 5.1 (2.1–12.1)
Olivieri, 2021, Italy [23■]	Cross-sectional	174	92	40.2 ± 11.3	Bakery	Q	Q, BHR, SPT	SPT	Sensitization to occupational allergens, WR nasal, WR lower airway sx, WR asthma	FeNO higher in sensitized vs nonsensitized – 22.8 vs 12.0 ppb FeNO higher in WR nasal and sensitized vs WR nasal and nonsensitized – 25.4 vs 13.4 ppb FeNO higher in WR lower airway sx and sensitized vs WRLA and nonsensitized – 31.2 vs 13.3ppb
Mekonnen, 2021, Ethiopia [26]	Cross-sectional	560 (280 exp, 280 nonexp)	100	Exposed 28 (IQR 20) Nonexposed 31 (IQR 15)	Flour mill	Q	Q	ND	*Flour mill workers*: age, educational status, inadequate ventilation, work years, no safety training	*Flour mill workers:* - age >35yrs 2.0 (1.3 – 5.5) - No education 1.5 (1.3 – 3.1) - inadequate ventilation 2 (1.2–3.6) - >5yrs work yrs 1.9 (1.2–4.7) - no safety training 2.5 (1.5–4.8)
Kitenge, 2021, DR Congo [29]	Cross-sectional	389 (276 bakers, 113 nonexp)	Not stated	32 (17–59)	Bakeries	Q	Q, PEF	Not stated	ND	bakers vs controls: WR rhinitis –31% vs 2%, WR asthma –5% vs 0%
Ade, 2020, Benin [30]	Cross-sectional	210	91	25.5 (22–32)	Bakeries	Q	BHR	Q	Rhino-conjunctivitis	*Probable OA* - rhino-conjunctivitis ($P < 0.05$)
Lagiso, 2020, Ethiopia [27]	Cross-sectional	406 (196 mill, 260 nonexp)	97	NR	Flour mill	Not reported	Q	Not stated	Mixing dept, work years, working>8hrs,	*Flour mill workers: with respiratory sx* - mixing dept 5.3 (1.7–16.6) - work years 6–9 yrs 5.1 (2.1–12.5) - work years ≥ 10 yrs 2.5 (1.0–6.1) - working >8hrs 2.4 (1.2–5.1)

Table 3 (*Continued*)

Author/Country	Study design	Subjects (n)	Participation rate (%)	Age (yrs.) mean (range)	Workplace	Diagnostic methods for defining rhinitis	Diagnostic methods for defining asthma	Atopy assessment	Risk factors (host and occupational)	Predictors of WRS/rhinitis symptoms/asthma symptoms/OA: OR (95% CI) (unless otherwise stated)
Crivellaro, 2020, Italy [25]	Cross-sectional	142	Not stated	39.9 ± 11.3	Bakeries	Q	Q	SPT	Flour dust, duration of employment,	- FEV_1/FVC declined with increasing dust >2mg/m^3 ($P<0.017$), duration of exposure in yrs ($P=0.02$)
Alemseged, 2019, Ethiopia [28]	Cross-sectional	424	97.8	29.7 ± 8.5	Flour mills	Q	Q	Not stated	Age group, monthly income, work experience, past exposure use of respiratory protective equipment	*Respiratory sx:* - age 24–45 yrs 1.9 (1.2–3.2) - age >45 yrs 12.3 (4.4–36.6) - monthly income 1.7 (1–2.8) - work experience >10 yrs 2.6 (1–6.6) - past exposure 1.9 (1.1–3.2) - no respiratory protective equipment 2.3 (1.3–4.1)

BHR, bronchial hyperresponsiveness; FeNO, fractional exhaled nitric oxide; HR, hazard ratio; IQR, interquartile range; ND, not done; NR, not reported; OA, occupational asthma; PEF, peak expiratory flow; Q, questionnaire; sIgE, serum-specific immunoglobulin E; SPT, skin prick tests; sx, symptoms; WR, work-related.

DON [41]. A study of swine production workers, also reported high levels (272 ng/g) of exposure to DON [45].

Exposure to bioaerosols in fish processing areas on board Norwegian fishing trawlers were reported to have high levels of proteins, trypsin, parvalbumin and endotoxin [46]. Exposures varied depending on the age and type of fish processed and high endotoxin levels were associated with high-pressure water cleaning of machines and floors. Sauvé *et al.* also reported higher endotoxin levels during bedding work, hog handling and working in barn/confinement buildings, grain bins and grain elevators among farmers in Iowa [47]. Increased exposures to 1,3-β-glucan were also observed for bedding work, cleaning and feed/grain storage work.

DIAGNOSIS AND MANAGEMENT

The diagnostic approach for suspected occupational allergy in food handling workers is no different to other occupational exposure contexts [1▪]. Raulf reviewed allergen component analysis and concluded that despite various efforts to characterize occupationally relevant wheat allergens, no major allergen in wheat is identifiable [48]. A whole-wheat extract remains the best option to determine IgE sensitization due to its higher diagnostic sensitivity for baker's asthma. However, single wheat allergens may assist in differentiating between different classes of food allergy viz. wheat-induced food allergy (class 1), grass pollen allergy (class 2) and baker's asthma (class 3).

Taghiakbari *et al.* using clinical scores developed a model to predict OA due to HMW agents (53% exposed to flour and associated agents). Significant variables included those ≤40 years of age, rhino-conjunctivitis, inhaled corticosteroid use, agent type, nonspecific BHR and occupational-specific sensitization. This is a useful approach for clinics without access to specific inhalation challenge tests [49].

A systematic review of 26 nonrandomized controlled studies of workplace interventions for the management of OA by Henneberger *et al.* concluded that both removal and reduction of exposure had better clinical outcomes than continued exposure [50]. However, only removal from exposure was associated with improved lung function. The potential benefits of this approach need to be considered within the context of potential job loss.

PREVENTION

Various strategies are aimed at either reducing exposures, the risk of sensitization or the development of OR and OA to food agents.

Table 4. Summary of recent epidemiological studies of work-related symptoms, rhinitis and asthma in animal food handling workplaces

Author/ Country	Study design	Subjects (n)	Participation rate (%)	Age (yrs.) mean (range)	Workplace	Diagnostic methods for defining rhinitis	Diagnostic methods for defining asthma	Atopy assessment	Risk factors (host and occupational)	Predictors of WRS/rhinitis symptoms/ asthma symptoms/ OA: OR (95% CI) (unless otherwise stated)
Thomassen 2021, Norway [31■]	Cross-sectional	184	Not stated	37.25 (35.6–38.9)	Crab workers	Q	Q	Phadiatop	Atopy, self-reported allergy	*Positive SPT to crab* - atopy ($P=0.001$) *IgE to crab* - atopy ($P<0.001$) *Respiratory sx* - atopy ($P<0.001$) - self-reported allergy ($P<0.001$)
Dahlman-Höglund, 2020, Sweden [32]	Cross-sectional survey	4717 (1836 fishers, 916 processors, 1965 controls)	~51	Fishermen/Filleting/ Processing 46 ± 11 Controls 45 ± 13	Fishermen, fish processing	Q	Q	Q	Duration in filleting work, atopy, female gender	*Adult-onset asthma during work in fishing industry* - filleting work HR: 3.6 (1.6–8.1) - atopy 3.4 (1.8–6.7) - female 2.6 (1.2–5.6)
Ngajilo, 2018, South Africa [35]	Cross-sectional	230	78	37 ± 9	Poultry farm	Q	Q, BHR, sIgE	Phadiatop	Atopy, casual work, department, exposure to high gas/dust/fumes	*Sensitisation to poultry allergens:* - atopy 20.9 (4.7–93.2) - casual worker 6.0 (1.1–35.9) *WR chest sx:* - rearing department 3.2 (1.2–8.4) - exposure to high gas/dust/fumes 4.8 (2.4–9.5) *BHR:* - casual worker 10.9 (2.0–60.3)

BHR, bronchial hyperresponsiveness; FeNO, fractional exhaled nitric oxide; HR, hazard ratio; IQR, interquartile range; ND, not done; NR, not reported; OA, occupational asthma; PEF, peak expiratory flow; Q, questionnaire; sIgE, serum-specific Immunoglobulin E; SPT, skin prick tests; sx, symptoms; WR, work-related.

Policy, regulatory frameworks and exposure standards

There are a few occupational exposure limits for food allergens, and these vary between countries as is evident for flour dust with the 8-h-TWA varying between 0.5 and 10 mg/m^3 [1■,38■]. Other food agents with exposure standards include grain dust, tea dust, poultry dust, *Penicillium* and proteolytic enzymes. Evidence-based exposure benchmarks to prevent allergic respiratory disease have been used to revise the Dutch exposure standards for flour dust (0.2 mg/m^3) and fungal α-amylase (0.9 ng/m^3) in workers irrespective of atopic status. This represents a major advance for prevention in food handling occupations [51].

Workplace control measures to reduce exposures

Strategies for reducing exposure are generally specific to the occupation in the food industry and may include modification of food processing, mechanization or automation, use of modified materials, better organization of work, improvement of workplace conditions, improving ventilation and use of respiratory protective devices [52].

In this review period, three studies reported on the effectiveness of control measures to reduce flour dust exposures in bakeries. Martinelli *et al.* evaluated control measures viz. installation of a sleeve to the end of a pipeline, lid on a mixer tub and local exhaust ventilation system, resulting in 16–70% lower dust levels [53■]. Karjalainen *et al.* focused on changing the working methods used in Finnish bakeries. This included lowering the height when adding ingredients to mixers; careful handling of empty bags to avoid dustiness; emptying bags near the bottom of the mixer; and sprinkling flour from as low a height as possible onto the baking table. Using these methods, mean reductions between 39 and 45% were demonstrated within one year [54].

The effectiveness of a multifaceted intervention (dough mixer lid, training) in South African supermarket bakeries in reducing the incidence of allergic sensitization, OR and OA was also reported given the 50% or more reduction in dust and allergen levels previously reported [55,56]. A greater decline in the incidence of wheat sensitization (21% vs 6%) and mean FeNO (16.9 ppb vs 7.7 ppb) among bakers with baseline FeNO $\geq$ 25 ppb was observed in the intervention group, one year after the intervention. The intervention group also showed a decline ($\geq$ 10%) in FeNO at follow-up, particularly in bakers with work-related ocular-nasal symptoms at baseline (OR = 3.73, CI: 1.22–11.42).

Finally, an educational intervention designed to improve the knowledge of preventive measures for allergy and asthma was evaluated in Bavarian farm apprentices [57]. The effect of a short educational video was evaluated 6 months later and reported to improve the knowledge about preventive measures in 20% of apprentices.

Immunotherapy

In certain settings, workers with OA may choose to continue working in jobs with reduced allergen exposures where it cannot be totally eliminated. A review that included three studies involving foods (all used wheat flour) concluded that there was increasing but modest evidence of beneficial short- and long-term effects of immunotherapy and safety in worker populations [58]. Dubini *et al.* also reported on the success of sublingual specific immunotherapy (SLIT) for baker's asthma and rhinitis [59]. Despite baker's asthma being a common entity, the use of immunotherapy has been limited due to the lack of identifiable major allergenic wheat flour proteins. Given these findings further confirmation is required in larger randomised controlled trials.

CONCLUSION

In conclusion, this review has highlighted that occupational inhalant allergy in food handling occupations is a common and recognisable clinical entity (class 3 food allergy) in high-risk food occupations such as bakeries and seafood processing. This risk may be enhanced across the food value chain as a result of food being subjected to various food processing techniques. Increasing advances in food technology have also resulted in the introduction of new and unusual allergens as food additives in the food matrix. Future studies need to focus on exposure-response studies to establish improved exposure limits especially for flour dust, the relevance of cooked vs raw food in influencing risk, identifying and characterising major food allergens and evaluating the effectiveness of interventions including immunotherapy for common high-risk food sensitizers causing OR and OA.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

■ of special interest
■■ of outstanding interest

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