

ALLSA RESEARCH AWARDS REPORT

ALLERGIES IN THE WORKPLACE

WORK-RELATED ALLERGY AND ASTHMA TO INHALED SPICES – A REVIEW

Anita van der Walt, MB ChB, DOH, Dipl Midw

Mohamed F Jeebhay, MB ChB, DOH, MPhil (Epi), MPH (Occ Med), PhD

Centre for Occupational and Environmental Health Research, School of Public Health and Family Medicine, University of Cape Town, South Africa

ABSTRACT

Spices have always been the most sought-after ingredients to enhance the flavour of food. In fact, the word *spice* comes from the same root as *species*, meaning a class of things having some common characteristics. Spices are derived from taxonomically different plant species and harbour allergenic potency which can induce a wide spectrum of symptoms, ranging from mild local to severe systemic reactions. Aerosolisation of spice dust has been associated with inhalant allergies via IgE cross-reactivity, but direct irritative mechanisms also play a role in the development of respiratory symptomatology. This review takes a closer look at the biologically active constituents of spices, exposures, immunological and cross-reactivity patterns, as well as risk factors and potential health effects caused by inhalable spice dust exposure.

INTRODUCTION

This review focuses on work-related allergy and respiratory disease associated with milling, processing and packing of spice products. To identify relevant manuscripts, PUBMED, MEDLINE and EBSCO literature searches were undertaken for studies on occupational spice allergy and respiratory disease since 1940. The keywords used included epidemiology, asthma, allergy, respiratory, immunology, spice, garlic, chilli, endotoxin, work-related, workplace, occupational. Only selected publications were used after evaluation, as this review focuses on occupational allergy and respiratory health effects associated with inhalable spice dust among spice workers and not ingestion-related food allergy.

THE FOOD PROCESSING INDUSTRY AND ALLERGIC DISEASE

The food industry employs a large proportion of workers exposed to potential allergens capable of causing occupational allergies and asthma.¹ Among consumers reporting food allergies, that affect 2% of the adult population in the industrialised world, spice allergy represents 2% of such cases.² The total number of employees exposed to spice dust in South Africa remains unclear, but the food manufacturing and processing industry in South Africa employs over 180 000 workers who are involved in a broad spectrum of occupations.¹

Workers are employed in various sectors involved in processing of meat, fish, fruit, vegetables, oils and fats, dairy products, grain mill products, starches and prepared animal feeds, and beverages. Materials processed include both raw products (plant/vegetable, ani-

mal or microbial origin) and chemicals for food preservation, flavouring, packaging and labelling. These biological and chemical materials are known to contain sensitising agents capable of causing occupational allergies among high-risk working populations. Food processing activities such as thermal denaturation, acidification and fermentation may destroy allergens, cause conformational changes or result in the formation of new sensitising epitopes which may increase the allergenicity of the protein.

In the occupational setting, allergic constituents of food products enter the body either through inhalation or dermal contact, resulting in adverse reactions on an irritant or allergic basis. Gill *et al.*³ outline the allergic diseases commonly encountered in the food industry, which include occupational asthma, rhinitis, conjunctivitis, dermatitis, and hypersensitivity pneumonitis. Occupational asthma represents between 3% and 20% of all asthma cases in the food industry and is the most common form of occupational lung disease. Occupational skin diseases may represent between 10% and 15% of all occupational diseases and have significant economic impact. Data from a voluntary Surveillance of Work-related and Occupational Respiratory Disease in South Africa (SORDSA) programme described 44 cases of occupational asthma (14.4%) reported in food handlers (October 1996 to June 2002).⁴ The majority of cases were from the flour and grain (80%), baking (27%) and milling (18%) industries. The true burden of occupational diseases among workers involved in the milling, blending and packaging production of spices (Fig. 1) in South Africa is still unknown.



Fig. 1. Spices are commonly ground into a fine powder and blended according to various recipes before being packaged.

Correspondence: Dr A van der Walt, e-mail anitavdw@mweb.co.za



Fig. 2. A spice mill factory where spices are milled, blended and packed generates high levels of inhalable dust, which poses a health risk to exposed workers.

SPICE-INDUSTRY WORKING POPULATIONS AT RISK AND ENVIRONMENTAL EXPOSURES

Occupational exposure to spice allergens occurs mainly in spice milling (Fig. 2), the food industry and herb processing plants. During spice milling, blending/sifting, weighing, scooping and packing activities high dust exposures result in potential inhalation by exposed workers. Limited studies are available on exposure assessment in the spice milling industry and there is great variability of exposure within and among various jobs during the handling and milling processes of spices.

In a study of spice grinders in Singapore, spice dust levels ranged from 0.03 to 0.82 mg/m³, with a mean value of 0.15 mg/m³.⁵ Slightly higher levels of airborne dust (1–2 mg/m³) have been reported in packaging of buckwheat in a company that imported, prepared and distributed plant products used in spices and 'health foods'.⁶ Studies of inhalable dust concentrations in the work areas of Croatian spice factory workers ranged between

0.5 and 10.1 mg/m³ (mean 2.9 mg/m³).⁷ Polish studies of workers processing herbs (nettle, caraway, birch, celandine, marjoram, mint, peppermint, sage, St. John's wort, calamus, yarrow) have reported very high levels of dust and endotoxin associated with bacterial and fungal contamination.⁸ The concentrations of airborne dust ranged between 3.2 and 946.0 mg/m³ (median 18.1 mg/m³), exceeding the Polish occupational exposure limit (OEL) value of 4 mg/m³. The airborne endotoxin concentrations in this study ranged between 0.2 and 2681.0 × 10⁴ EU/m³ (median 16.0 × 10⁴ EU/m³). During peppermint and chamomile herb processing, high median concentrations of airborne microorganisms, inhalable dust (peppermint 552.3 mg/m³, chamomile 12.3 mg/m³) and endotoxin levels (peppermint 57.3 × 10⁴ EU/m³, chamomile 0.96 × 10⁴ EU/m³) have also been reported.⁹

A number of factors influence the manifestation of allergic disease in relation to the environmental exposures. These include dose, duration and route of exposure, biochemical properties (e.g. stimulation of histamine release), physical properties (e.g. alteration of the protein structure as a result of processing), immunological properties (e.g. allergenic potency and cross-reactivity of different spice antigens) and industrial hygiene and engineering practices.¹⁰ However, the level of exposure is probably the most important determinant of IgE-mediated sensitisation to occupational agents and the development of work-related allergic disease outcomes among exposed workers.¹¹ On the other hand, very low levels are needed to elicit allergic symptoms ranging from skin reactions due to skin contact, food-associated symptoms after ingestion and/or asthma after inhaling spice dust.¹²

CONSTITUENTS OF DUST PRODUCED IN SPICE MILLS

Organic dust derived from a spice mill contains pure spice or blends from various different botanical families (Fig. 3). Since spices are derived from plants, they have allergenic potential because of the bioactive ingredients present in processed vegetable dusts.¹² The majority of allergens in the food industry are of high molecular weight (HMW), e.g. flour, soybean dust, vegetable gums, animal proteins,³ typically in the 5–70 kDa range that can provoke a specific IgE-mediated response in exposed workers.¹³ Spice dust allergens are potentially HMW sensitisers.¹² However, irritant reactions in addition to allergic responses in workers handling spices have also been reported.¹⁴ Cereal flour added to spice blends contains wheat proteins which are well-known HMW sensitisers.¹³ Aside from cereal flours (wheat, rye, barley, rice flour, cereal malt flour), non-cereal flours (soybean, buckwheat, lecithin from soybean) are also potential allergens as these ingredients have been reported to be potential occupational allergens causing allergy and asthma in bakers.¹⁵ These well-known HMW sensitisers may well be added to spice mixtures and have the potential to cause allergic respiratory disease.

Additives such as preservatives are known for their potential allergenicity. Sulphur dioxide is used extensively in the food industry for the preservation of food.¹⁶ Preservatives (sodium benzoate, potassium metabisulphite), and added ingredients to spice recipes, could potentially become 'inhalant' allergens when aerosolised during spice-blending processes.¹⁷ Natural red dyes are also used as colorants in spice production and hypersensitivity reactions have been reported to carmine proteins, known HMW proteins from cochineal extract.¹⁸

Dust generated during herb processing (peppermint, sage, marjoram, mint, caraway) has been shown to be contaminated with microorganisms (fungi, bacteria) as

Table 1. Blends composed of a variety of spices according to a local manufacturer's recipe

Spice blends	Composition
Cajun seasoning	Black pepper, chilli powder, garlic powder, nutmeg, onion powder, parsley flakes, cayenne (red pepper), salt
Season-all	Black pepper, celery seed, chilli pepper, coriander, garlic powder, nutmeg, onion, paprika, salt
Lemon and pepper	Black pepper, celery seed, citric acid, cornstarch, garlic powder, lemon oil, onion, salt, sugar
BBQ marinade	Parsley, garlic powder, garlic liquid, onion powder, mustard, thyme, cayenne pepper, black pepper, paprika oleo, paprika rosen, tomato powder, cumin, sugar (brown), dextrose, salt, guar gum, sodium benzoate
Fleischwurst seasoning	Soya flour, maize starch, paprika rosen, cloves, coriander, ginger, nutmeg, white pepper, celery flavour, black pepper, dextrose, sugar (white), salt, ascorbic acid, lecithin, sodium nitrate, erythrosine, sodium carbonate

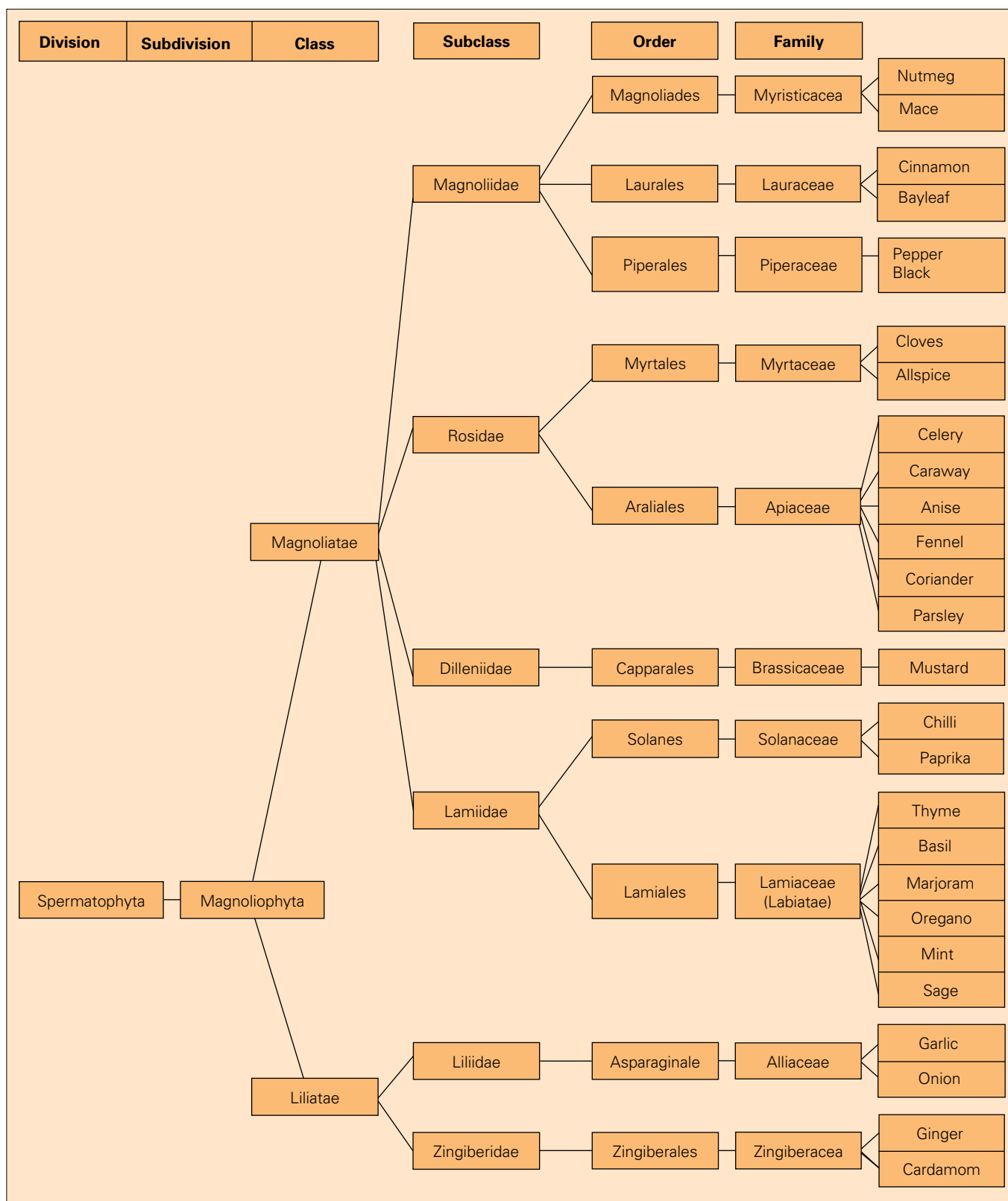


Fig. 3. Taxonomical relationships in the family of spices.¹²

well as endotoxins.⁸ Mycotoxins such as ochratoxin can also contaminate spices, coffee, cocoa beans and foods, and may pose a health risk for workers in the spice industry.¹⁹

Aside from milling individual spices, spice plants package various spice blends that consist of many different mixtures of spices. Table I outlines the composition of some common blends used in spice mills. It is evident that garlic powder, wheat/maize and various types of dried hot peppers (chilli pepper, paprika rosen, cayenne

pepper) appear as essential ingredients of these different recipes.

BIOCHEMICAL/IMMUNOLOGICAL PROPERTIES OF SPICE ALLERGENS

Spice dust, being an organic dust, which is not biologically inert, exerts its effects through various pathophysiological mechanisms, the immunogenic activity being most well described (Fig. 4).²⁰ It is well known that aside from ingestion-related food allergy, various spices

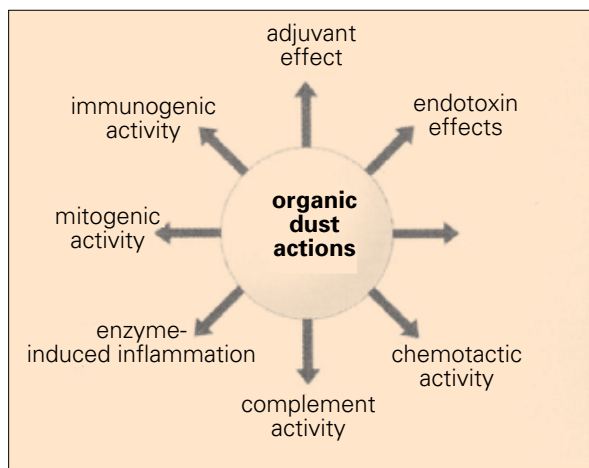


Fig. 4. Biological effects attributable to organic dust (Salvaggio and Hendrick²⁰).

can also cause inhalant allergies through their immunogenic activity, which is commonly IgE-mediated.¹²

Garlic (*Allium sativum*) belongs to the Alliaceae family (formerly Liliaceae), together with other members such as, onion, leek, shallot and asparagus (Fig. 2). Patients with asthma induced by garlic dust have been shown to display immunological evidence of cross-allergenicity with other related members of the Liliaceae family.^{21,22} Several garlic protein allergens have been identified using IgE immunoblotting techniques. In individuals with occupational asthma due to garlic, two major protein bands have been demonstrated at approximately 12 kDa and 54 kDa in garlic-sensitised workers.²² The latter proved to be the major IgE-binding protein and shared similar allergenic epitopes with onion. Several Liliaceae share allergenic components with garlic, demonstrated by SDS-PAGE immunoblotting, when IgE-binding proteins of 12 kDa were found in young garlic, garlic, onion and leek extracts.²³ Alliin lyase, a 56 kDa IgE-binding protein, has recently been identified as a major garlic allergen in a group of Taiwanese patients aged 7-48 years with garlic allergy.²⁴ This protein is widely distributed in other *Allium* species, namely leek, shallot, onion, and has been described as a potentially new cross-reactive allergen.

Homology exists among allergens due to protein sequence identity conservation, structural/conformational similarities and the frequent occurrence of certain biochemical functions among allergens.²⁵ Evidence of cross-reactivity between onion and garlic has also been shown in previous case reports of occupational asthma. Two main IgE-binding proteins with molecular weights of 55 kDa and 35 kDa were revealed in extracts of fresh garlic and onion, and only the 35 kDa protein showed strong IgE binding with sera from a worker diagnosed with occupational asthma due to onion.²⁶ In another case report, IgE immunoblotting showed very strong bands at 14 kDa and 40 kDa with garlic extract in a worker diagnosed with occupational rhinoconjunctivitis due to garlic and onion dust exposure.²⁷ Characterisation of ground green and black pepper (Piperaceae) and paprika (Solanaceae) allergens by N-terminal amino sequence analysis proved that a 28 kDa allergen identified for pepper showed 70% similarity to and 58% identity with the N-terminus of wheat germin protein.^{28,29} These studies also identified a 23 kDa paprika allergen that showed 100% identity with the N-terminus of tomato protein called pathogenesis-related protein PR23. Moreover, cross-reacting allergenic molecules in the range of 60 kDa were also found to be responsible for type 1 allergy to anise, fennel, coriander or cumin, members of the Apiaceae family.³⁰

Evidence for adjuvant effects of spice dust has also been proposed. Schöll *et al.* have suggested that the hotter spices are, as is the case with chilli, the more likely they could act as adjuvants for sensitisation by promoting the transport of other molecules below a molecular mass of 70 kDa.^{12,31} This molecular size corresponds to the size of molecules that are relevant for sensitisation and IgE binding in spice allergy. This adjuvant effect might also contribute to multiple sensitisations to airborne spice allergens as has been demonstrated.¹⁷ It has also been shown that flour dust from bakeries and flour dust extract are strong pro-inflammatory mediators that can cause non-allergic airway inflammation as well as enhance allergen-mediated airway inflammation.³²

Aside from innate biological properties, spices, when processed, may also change their ability to cause adverse health effects. Hot spices, paprika and chilli pepper (*Solanaceae*), are routinely processed by drying and grinding.¹² This procedure destroys Bet v 1 homologues as well as profilins mainly for paprika²⁸ derived from dried bell-pepper fruits.³³ The higher-molecular-weight molecules of spices of the *Solanaceae* as well as the *Apiaceae* families expressing cross-reactive carbohydrate determinants^{34,35} seem to be more resistant to food processing including grinding, roasting and cooking, and retain their potential to induce clinical symptoms.^{28,36} Depending on the extent and type of processing of the raw spice, enhancement of the IgE-binding capability of the allergen is also possible, as has been demonstrated for garlic and onion powder processed in the dry form in spice-mill workers with work-related asthma.¹⁷

Evidence for irritative mechanisms associated with spices has also been reported. Work-related respiratory symptoms of an irritant nature have been reported in epidemiological studies of chilli grinders.^{37,38} Lundberg *et al.*³⁹ found that substance P and capsaicin (an active ingredient in chilli and paprika) induced a dose-dependent contraction of human segmental bronchi *in vitro*.³⁹ In animal studies, different spices (chilli pepper, paprika, caraway, coriander leaves, coriander seeds, cinnamon, ginger, onion, curry and parsley) have demonstrated a dose-related contractile response of isolated guinea pig tracheal smooth muscle. This finding suggests that the dusty conditions in spice factories result in a highly efficient direct bronchoconstrictor challenge of the respiratory tract.¹⁴

POLLINOSIS AND THE FOOD-POLLEN SYNDROME IN SPICE ALLERGY

Individuals with pollinosis often display sensitisation to various plant-derived foods (class 2 food allergies). These reactions are the result of IgE cross-reactivity to profilins and lipid transfer proteins, but may also be due to HMW glycoproteins.⁴⁰ Spice allergy has also been commonly described in association with sensitisation to common pollen inhalants.¹² The closer the plant producing the pollen is related to the spice, the more likely cross-reactions may occur. IgE cross-reactivity is due to the presence of conserved homologues in different plants.³³ Sensitisation to mugwort and birch pollen represents a high risk factor for progression to spice allergy.³⁰

Profilin and a homologue of the major birch pollen allergen Bet v 1 seem to be responsible for much of the cross-reactivity^{33,34} and have been detected in certain strains of bell peppers (*Capsicum annuum*) as well as among the *Apiaceae* family of spices.^{29,33} Dried *Apiaceae* spices like anise, fennel, coriander or cumin contain genetically intact Bet v 1 and profilin homologues and may, besides other HMW allergenic agents, be responsible for the type 1 allergic responses.³⁰ This may be an

important cause of cross-reactions within the Apiaceae family, as well as to pollen.⁴¹

Clinical pollen-food syndromes such as the mugwort-mustard-allergy, celery-mugwort-spice-allergy and the celery-birch-mugwort-spice syndrome have been previously described.^{34,42} Patients with food allergies specifically to Liliaceae (garlic, onion, leek) have also been found to have celery-mugwort-spice syndrome.⁴³ Birch tree (*Betula verrucosa*) profilin Bet v 2 and mugwort (*Artemisia vulgaris*) profilin Art v 4 have been identified as significant contributors to allergic reactions to pollen and plant-derived food within the celery-birch-mugwort association due to cross-reaction with celery profilin Api g 4.^{44,45}

Leitner *et al.*²⁸ investigated allergens originating from pepper (Piperaceae) and paprika (Solanaceae) and showed that IgE cross-reactivity in the celery-birch-mugwort-spice syndrome to spices other than Apiaceae (carrot, caraway seeds, parsley, fennel seeds, coriander seeds, aniseed) is not exclusively caused by Bet v 1 homologues and/or profilins.²⁸ The celery-mugwort or celery-birch-mugwort association comprises additional botanical families such as Solanaceae (paprika), Piperaceae (pepper) and Liliaceae (garlic, onion).⁴³

The number of allergen sources involved, the nature of the allergens and the influencing factors render the celery-birch-mugwort-spice syndrome a clinical feature of high complexity. Interestingly, cross-reactivity of grass pollens (*Phleum pratense*) with garlic allergens was confirmed in previous immunoblotting inhibition studies.²² Sensitisation to grass pollens (*Phleum pratense*) might therefore also be a potential risk factor for the development of garlic allergy. Furthermore, immunoblotting confirmed cross-reactivity of mugwort, paprika, short ragweed and black pepper with unique allergens (67-75 kDa) in fennel seed in a fennel-sensitised atopic spice worker.⁴⁶ A significant degree of cross-reactivity was also demonstrated between saffron and *Lolium*, *Salsola*, or *Olea* pollens by radio-allergosorbent test (RAST) inhibition studies.⁴⁷ It appears that allergy to spices rarely represents an autonomous sensitisation, but is rather a consequence of pollen allergy on the basis of immunological cross-reactivity.³³

HEALTH EFFECTS OF SPICES

The bioactive ingredients in spices have the potential of inducing symptoms ranging from mild local to severe systemic allergic reactions.¹² Workers in the spice-related industry are exposed to a variety of different respiratory sensitisers that may cause sensitisation through inhalation or skin contact. Inhalation of spice dust has the potential to cause respiratory allergies such as rhinoconjunctivitis, asthma, and allergic alveolitis, contact dermatitis and occasionally anaphylaxis.¹² Studies have also shown that symptoms of occupational rhinitis are more often reported to precede occupational asthma in the case of HMW compared to low-molecular-weight agents.⁴⁸

The food industry accounts for the largest number of cases of occupational rhinitis,⁴⁹ and the prevalence of occupational allergic rhinitis has been reported to be between 3% and 60%³ depending on the exposure environment and the level of exposure.¹¹ The prevalence of rhinoconjunctivitis in subjects with occupational asthma was found to be 76-92%.⁴⁸ Occupational rhinoconjunctivitis has been previously described for a spice worker handling garlic and onion powder dusts, identified by nasal challenge test,²⁷ and usually precedes the development of occupational asthma.⁵⁰ Fennel seed and saffron (pollen and stamen proteins) have also been associated with IgE-mediated sensitisation in spice workers and the subsequent development of occupational

allergic rhinoconjunctivitis and asthma.^{46,47} In a study of workers preparing and distributing plant products, buckwheat used in spices and 'health foods', a high prevalence of work-related symptoms of rhinitis (39%), asthma (21%) and conjunctivitis (18%) were recorded and a strong correlation was observed between those with positive allergy tests (28%) and work-related symptoms.⁶ A similar high prevalence of asthma (22.5%) has been reported in Sri Lankan workers processing cinnamon.⁵¹

Various studies have also reported symptoms of upper and lower airway irritation in relation to spice dust. A high prevalence (49.2%) of upper respiratory tract symptoms of irritation (sneezing and runny nose) has been reported for spice grinders in Singapore.⁵ Respiratory symptoms of an irritant nature have also been documented in Sri Lanka for workers exposed to spice dust containing cinnamon (88%), cloves (76%) and pepper (44%),⁵² as well as for chilli grinders (95%).³⁷ Inhalation of capsaicin, however, does cause dose-dependent coughing in subjects with and without asthma.⁵³ Among capsicum-exposed workers the reported prevalence of cough (59%) was more than double the prevalence in the non-exposed controls (21%).⁵⁴

Studies of lower respiratory tract symptoms and lung function associated with organic dust exposures in the food processing industry have consistently demonstrated a higher prevalence of both acute and chronic respiratory symptoms.⁵⁵ Among spice-exposed workers a high prevalence of chronic cough (40%) and acute dry cough (58.7%) has been reported. Pulmonary function impairment manifesting as across-shift FEV₁ (-9.9%) and FVC (-3.7%) changes and particularly marked small airways changes FEF₂₅ (-26.7%) and FEF₅₀ (-21.6%) alluding to asthma have also been reported. However, studies of chilli grinders show that no statistically significant across-shift change in lung function or any significant difference in pre-shift measures was recorded for chilli grinders in Sri Lanka when compared to the controls.⁵⁶

Occupational asthma has been reported involving a range of spices including cinnamon, paprika, mace, coriander, aniseed, garlic and onion.^{26,51,57,58} Garlic (*Allium sativum*) belongs to the Alliaceae family (formerly Liliaceae), with the first report of garlic-induced asthma dating back to 1940, when Henson described an atopic foreman with ragweed pollinosis whose asthmatic symptoms disappeared after the garlic 'powder' was replaced with 'kernels'.⁵⁹ Inhalation-related garlic allergy has since been reported in different occupational settings including food preparation and catering, sausage making, harvesting and storing of garlic bulbs, spice manufacturing, as well as packing and selling of spices.^{21,22,50,60}

Occupational exposure to paprika dust has been associated with the development of hypersensitivity pneumonitis 'paprika splitter's lung'.⁶¹ Processing of chilli does not involve splitting the fruits, and furthermore, chilli workers are not exposed to *Mucor stolonifer* as in the case of paprika splitters. Although chilli and paprika both belong to the genus *Capsicum*, and contain the pungent capsaicin in the fruits, fibrosing alveolitis has not been demonstrated for chilli workers.³⁸

RISK FACTORS FOR ALLERGIC SENSITISATION AND THE DEVELOPMENT OF ASTHMA

Host factors

Host factors play an important role in disease development, since only a limited number of presumably similarly exposed workers develop occupational disease.

Host factors include atopy, prior allergic sensitisation to the specific occupational allergen, occupational rhinoconjunctivitis, airway hyperresponsiveness, genetic factors and smoking.⁶² Approximately 5% of workers exposed to sensitising agents develop occupational asthma.³ Therefore, host factors are likely to affect an individual's risk of developing occupational asthma.

Atopy is an important risk factor for IgE-mediated reactivity to HMW allergens,¹¹ but less relevant for non-IgE-mediated occupational asthma.³ Although atopic individuals are at an increased risk of asthma as a result of HMW occupational agents, atopy itself is a weak predictor of sensitisation and development of occupational asthma.⁶³ Atopy and simultaneous sensitisation to various plant profilins may pose additional risk factors for sensitisation to class 2 allergens and the development of occupational asthma in spice-mill workers.¹⁷

Occupational rhinitis is associated with an increased risk of asthma, although the proportion of subjects with occupational rhinitis who will develop occupational asthma remains unknown.¹¹ Malo *et al.*⁴⁸ suggested that in the case of HMW agents, the appearance of rhinoconjunctivitis in a sensitised individual might be a marker of the likelihood of developing occupational asthma. Ocular-nasal symptoms often precede and co-exist with occupational asthma symptoms in the case of HMW agents.¹¹ The prevention of work-related rhinitis may also provide an excellent opportunity to prevent the development of occupational asthma.

The relationships between **smoking** and occupational asthma, occupational rhinitis and occupational sensitisation are complex, controversial and contradictory. Data from an in-depth review on various studies done, from 1970 to 2005, for a wide range of occupations, from laboratory, farm, brewery and hospital workers, to bakers, printers, cleaners and others, showed surprisingly little to support the view that the risk of occupational asthma is increased in workers who are smokers.⁶⁴ A recent study though, showed that smoking might pose an additional risk factor for allergic sensitisation to wheat flour or enzymes in atopic workers.⁶⁵ Very little is known about the association between smoking and occupational sensitisation and asthma to spice dust. However, studies by Zuskin *et al.*⁵⁵ suggest that aside from dust exposures, smoking is independently related to across-shift respiratory symptoms and decline in lung function in workers exposed to spice dust.⁵⁵

Environmental factors

Furthermore, environmental factors such as **exposure concentration and duration** are important determinants of occupational allergy and asthma to spices. The interaction between exposure to occupational allergens and other co-factors in the environment, such as endotoxin, are also important risk factors in the development of sensitisation and asthma.⁶⁶ The relationship between endotoxin exposure and health effects is still controversial because of the paradoxical nature of the health effects observed.⁶⁷ Some studies have demonstrated protective response for developing asthma, while others show priming of the allergic response and an exacerbation of asthma.⁶⁸ Detailed exposure-response relationships in spice-mill workers, in relation to specific spice-allergen exposure concentrations have not been conducted and need to be explored further.

CONCLUSION

This review has illustrated that airborne spice dust is not biologically inert but is associated with various clinical disease endpoints, including occupational allergy and asthma, as a result of inhalation of spice dust in the workplace setting.

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Declaration of conflict of interest

The authors declare no conflict of interest.

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