REVIEW

Allergic reactions to spices: a review of sensitivities to pepper, cumin, oregano, anise, mustard and other spices

Allergic reactions to spices: a review

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Summary

Spice allergies are often under-recognized and under-researched, leading to delays in diagnosis and treatment. Cross-reactivity with other plant allergens further complicates accurate diagnosis. This literature review seeks to systematize and analyze current data on hypersensitivity to spices, including pepper, cumin, oregano, anise, mustard, and other seasonings. The review covers research published from 2010 to 2023 in peer-reviewed journals, books, and conference proceedings, sourced from databases such as PubMed, Scopus, Web of Science, and Google Scholar. The main pepper allergens are PR-10 proteins, profilins and defensins. They can cause cross-allergic reactions with pollen and other plant allergens. Cumin allergens belong to the PR-10 family and can provoke allergic reactions. Cross-reactivity between cumin and other umbelliferae is common. Oregano contains Bet v 1 allergens and profilins, often leading to cross-allergies with other spices and plants. Allergies to anise are less common but can be a serious problem due to cross-reactivity with birch pollen. Mustard is one of the most allergenic spices. These proteins can cause severe reactions even in small amounts. Diagnosis is carried out using skin prick tests and blood tests for specific IgE antibodies. Cross-reactivity among spices and other allergens complicates the diagnosis and management of spice allergies. This review will be useful for the development of personalized dietary recommendations for patients, accounting for cross-reactivity and individual sensitization profiles.

KEY WORDS

Cross-reactivity; pollen-food syndrome; anaphylaxis; PR-10; Bet v 1.

IMPACT STATEMENT

Spice allergies pose serious health risks, causing symptoms from skin rashes to anaphylaxis. Improved diagnostics and treatments are essential to manage this often-overlooked allergy effectively.

Introduction

Allergic reactions to spices are an urgent problem in modern allergology. Spices such as pepper, cumin, oregano, anise, mustard and many others are widely used in cooking around the world. Their applications range from home cooking to mass food production. Despite their popularity and usefulness, spices can cause allergic reactions in sensitive people, which makes studying this problem extremely important.

Following Kanikowska *et al.* (1) from 2022, the prevalence of food allergies varies depending on the age group: in children, it is estimated at 6-10%, while in adults this figure is 2-5%. In addition, according to a study by Mazur *et al.* (2), about 20% of people suffering from food allergies, in addition to gastrointestinal symptoms, also have atopic dermatitis. This emphasises the relationship between food allergies and skin diseases such as atopic dermatitis. Krzych-Falta *et al.* (3) demonstrated significant variability in the prevalence of food allergy and the importance of individual allergens in different parts of the world. In Europe, the percentage of people reporting food allergies ranges from 1.7% to 37.3%, depending on the country. In North America, this figure ranges from 3.1% to 11%. The problem with the study is that allergic reactions to spices often remain underestimated and insufficiently studied. This can lead to delays in diagnosis and treatment, as well as underestimation of their prevalence and severity. Allergic reactions to spices can manifest themselves in the form of skin rashes, angioedema, gastrointestinal symptoms and even anaphylaxis (4). Such symptoms can significantly impair the quality of life of patients and require serious medical intervention.

Previously, both domestic and foreign scientists were engaged in research in this area. For instance, Sikorska-Szaflik and Sozańska (5) studied the risk factors for food allergy, among which he noted genetic predisposition, epigenetic changes and the impact of environmental factors that can play an important role in the onset and development of this disease. Food additives were studied and, thus, the incidence of allergic reactions to food additives was determined to be less than 1% of all food hypersensitivities in adults and to be about 2% in children (6). However, despite significant progress in this area, many unresolved issues remain. For instance, it is still unclear how spices cause allergic reactions at the molecular level and which spice components are the main allergens. In addition, more detailed data is needed on the prevalence of spice allergy in different age and ethnic groups (7). Methods of diagnosing and preventing spice allergy are also insufficiently studied, especially in the context of mass production and consumption of food.

The study is to systematise and analyse existing data on sensitivity to various spices, including pepper, cumin, oregano, anise, mustard and others. Authors plan to review the mechanisms of allergic reactions, clinical manifestations, diagnostic methods and treatment options for spice allergy. Special attention will be paid to the prevalence of this problem and possible ways of prevention.

Materials and Methods

To perform this literature review, a comprehensive assessment of existing studies on allergic reactions to spices such as pepper, cumin, oregano, anise and mustard was conducted. The review covers the period from 2010 to 2023 and includes publications from peer-reviewed scientific journals, books and conference proceedings. The main sources of data were PubMed, Scopus, Web of Science and Google Scholar databases.
The inclusion criteria were as follows: publications devoted to allergic reactions to the specified spices; studies describing clinical manifestations of allergy to spices; works on the mechanisms of allergic reactions to spices; articles containing methods of diagnosing allergy to spices; publications describing approaches to the treatment and prevention of allergy to spices; works in Russian and English; peer-reviewed studies published in scientific journals. The exclusion criteria were as follows: studies not related to the topic of spice allergy; papers that have not been peer-reviewed; publications that do not contain new data or have no scientific novelty; duplicate publications already included in the analysis; articles written in languages other than Russian and English.
The literature search was carried out using keywords and their combinations, such as “spice allergy”, “pepper allergy”, “cumin allergy”, “oregano allergy”, “anise allergy”, “mustard allergy”, “food allergy”, “diagnosis of spice allergy”, “treatment of spice allergy”. Both general and specialised terms, as well as synonyms and medical terms, were used to ensure the completeness of the search. Additionally, authors used advanced combinations, including different forms and declensions of keywords to cover the maximum number of relevant publications. For instance, variations of “pepper allergy”, “allergic reactions to cumin”, “oregano sensitivity”, “anise allergy”, “immunoreaction to mustard”, and others were used. Medical terms and synonyms were also considered, such as “*Capsicum* allergy” for pepper allergy, “*Cuminum cyminum* sensitivity” for cumin allergy, “*Origanum vulgare* allergy” for oregano allergy, and “*Pimpinella anisum* allergy” for anise allergy. The use of scientific Latin names of plants was used to find additional research that could have been missed if authors had used only commonly used terms.
The stages of the literature review included several steps. In the first stage, an initial search was conducted using keywords in databases, which resulted in more than 500 articles and publications. Then, based on the abstracts and keywords, the publications that met the inclusion criteria were selected. At this stage, about 150 articles were selected. The full texts of the selected articles were carefully studied to determine their relevance to the topic of the review. After this stage, 80 articles remained for detailed analysis. Further, the data was systematised into the following categories: clinical manifestations of allergy, mechanisms of allergic reactions, diagnostic methods, approaches to treatment and prevention. Each article was analysed to identify key data and then integrated into the review. To assess the quality and reliability of the data, authors used the criteria for evaluating peer-reviewed publications, including methodological aspects, sample size, control groups, statistical significance of the results and sample representativeness. At the last stage, 60 of the most relevant and high-quality publications were finally selected from the remaining 80 articles to be included in the review. All relevant data was synthesised into a single analytical overview presented in a structured manner. Key topics and areas for future research were identified. All ethical norms and rules were upheld. All cited works were properly cited with authors and sources of information. Figure 1 provides a visual summary of the stages involved in this process.

Results and Discussion

Pepper allergy and the role of capsaicin

Pepper allergy is a common phenomenon that can cause a wide range of symptoms in sensitive people. The main allergenic components of pepper are proteins such as PR-10, profilins and defensins. In a study from 2023, Bochorishvili *et al.* (8) showed that out of 435 allergic patients examined, 38% (164 patients) demonstrated reactivity to pan allergens of the PR-10 family, profilins and lipid transport proteins. Among them, PR-10 was the most common allergen with a sensitisation rate of 56%, followed by profilins with 43% and lipid transport proteins with 32%. Sensitisation to PR-10 allergens has been associated with allergic rhinitis and asthma. Continuing with the topic of allergenic proteins, a 2023 review by Barre *et al.* (9) characterised PR-10, profilins and lipid transport proteins as the main allergenic proteins in fruit. The review determined that most fruit allergens belong to these families, confirming their importance in cross-allergic reactions. These proteins can cause cross-allergies with pollen and other plant allergens, such as spices, plant pollen and others.
Black pepper, red pepper, and cayenne pepper can cause allergic reactions in sensitive individuals (9, 10). These proteins can trigger a strong immune response in people with a predisposition to allergies. In a 2021 study by Kattupalli *et al.* (11), a genomic analysis of PR-1 proteins from black pepper was conducted. They identified 11 PR-1 genes that play a critical role in protecting plants from biotic and abiotic stresses. PR-1 genes are involved in the plant’s defence mechanisms against *Phytophthora capsici*, a pathogen that causes root rot. This study showed a significant level of PR-1 gene expression. Perić *et al.* (12) determined that an allergic reaction to black pepper usually occurs after prolonged exposure to this allergen, which was demonstrated by the example of allergic rhinitis in an employee of a black pepper production plant. In addition, a study from 2022 by Takei *et al.* (13) identified Capsicum annuum allergens, including Cap a 7, which

shows cross-reactivity with Japanese cedar and peach pollen allergens. In a patient sensitive to these allergens, IgE reactivity to Cap a 7 and other proteins was found, which emphasises the importance of these allergens in allergic reactions to red pepper.

Furthermore, in a study from 2021, Ivens *et al.* (14) investigated the cross-reactivity of chilli peppers with Brazil nuts and hazelnuts using the xMAP food allergen test. They determined a high degree of cross-reactivity between chilli and nut allergens, which emphasises the complexity of allergen analysis in spices and the need to consider cross-reactivity in the diagnosis of allergies. Lastly, in a study conducted by Wróblewska *et al.* (15), the immunoreactivity of proteins in Capsicum (pepper) spices was investigated. Using mass spectrometry and in silico analysis, the researchers identified several highly immunoreactive allergenic proteins, including Cap a 1, Cap a 2 and Cap a 7, which can cause severe allergic reactions. The study found hidden allergens and contaminants that could pose a health risk to sensitive people.

Symptoms of allergic reactions to pepper can range from mild skin rashes and itching to serious respiratory problems and anaphylactic shock. The most common manifestations are hives, swelling of the lips and throat, difficulty breathing, nausea and vomiting (**table I**).

In some cases, gastrointestinal disorders, such as abdominal pain and diarrhoea, are observed. These symptoms can occur either immediately after consuming pepper or after a period, making it difficult to diagnose an allergy.

Caraway allergy and the role of Bet v1

Cumin is a popular spice widely used in various cuisines around the world. However, it can cause allergic reactions in some people. Cumin allergens belong to the PR-10 family and can provoke allergic reactions (16). These proteins can cause allergic reactions in sensitive people, leading to various allergic symptoms. In a 2021 review, Singh *et al.* (17) studied the phytochemistry and pharmacology of cumin. They noted that the main bioactive component of cumin is cuminaldehyde, which can cause allergic reactions, and its interaction with other spices requires further study. Clinical manifestations of a caraway seed allergy can include skin symptoms such as hives, itching and swelling, as well as respiratory problems such as nasal congestion, sneezing and difficulty breathing (18, 19). Some people also experience gastrointestinal disorders such as nausea, vomiting and abdominal pain. These symptoms can occur both immediately after consuming cumin and after a period of time, which makes it difficult to diagnose an allergy. The severity of the symptoms can range from mild manifestations to severe systemic reactions, including anaphylactic shock (20).

Cross-reactivity of cumin with other spices and allergens is common. This is due to the presence of similar protein structures in different plants. People with cumin allergy can also react to dill, parsley, carrots and other members of the umbelliferae family. Studies have shown that the similarity in protein structures between cumin and other plants can lead to cross-allergy, which is confirmed by the work of El-Rady *et al.* (21). It is worth noting that cross-reactivity can make it difficult to diagnose and manage allergies, as patients may experience symptoms when eating different foods. In the course of Słowianek *et al.* (22) research, new allergens were found in caraway seeds, including Bet v 1 analogue, profilin and elongation factor α. Furthermore, Asero *et al.* (23) observed that systemic reactions and gastrointestinal symptoms were the most frequent clinical manifestations of allergy to spices from the *Piperaceae* family. Importantly, systemic reactions to PR-10 proteins, such as Bet v 1, are generally associated with the use of proton pump inhibitors, which may influence allergenic responses by altering gastric digestion and immune sensitization.

Treatment of cumin allergy is designed around avoidance of triggers and symptomatic treatment. Patients are advised to exclude cumin and potentially cross-reactive foods from their diet. In the event of severe allergic reactions such as anaphylactic shock, patients should have epinephrine auto-injectors available for immediate use. In addition, Li *et al.* (24) determined the reason for the cross-reaction of cumin allergy with other allergens, the main allergen of birch pollen is Bet v 1, one of the seven recognised allergens. Component-specific diagnostics help to distinguish true birch allergy from false positives caused by pan-allergens. Patients with symptoms of birch pollen allergy have elevated levels of IgE to Bet v 1, which also indicates the risk of developing oral allergy syndrome when eating fruits of the Rosaceae family, nuts and vegetables of the *Apiaceae* family. Allergies to birch (*Betula*) and cereal (*Poaceae*) pollen can contribute to the development of an allergic reaction to oregano due to the similarity of allergenic proteins. From 2010 to 2015 in Davos and Munich, Maya-Manzano *et al.* (25) measured airborne pollen and its allergens Bet v 1 and Phl p 5. Most of the allergens were found in the PM>10 fraction. The Pollen Allergen Potency (PAP) for cereals was significantly higher in Munich than in Davos, but there was no difference for birch. PAP varied by day, year and location, increasing with the season for *Poaceae*, but remaining constant for *Betula*. Bet v 1 is also present in cumin, which causes a cross-reaction. Yasudo *et al.* (26) also notes that sensitisation to Bet v 1 in pollen allergy is a risk factor for spice allergy.

In conclusion, cumin allergy is a significant problem that requires careful diagnosis and an individual approach to treatment. Research in the field of molecular allergology and cross-reactivity helps to better understand the mechanisms of allergic reactions and develop effective methods of diagnosis and treatment. Raising awareness among healthcare professionals and patients about the potential for allergic reactions to spices, including cumin, and developing new therapeutic approaches can significantly improve allergy management and quality of life.

Oregano allergy and the role of profilins in its development

Oregano, a popular spice in Mediterranean and Mexican cuisine, can also cause allergic reactions in some people. The main allergenic proteins of oregano are Bet v 1 and profilin, which belong to the PR-10 and profilin families. These proteins are the main triggers of the immune response in sensitive individuals, leading to a variety of allergic symptoms. Clinical manifestations of an oregano allergy can include skin symptoms such as hives, itching and swelling, as well as

respiratory problems including nasal congestion, sneezing and difficulty breathing. Some people may also experience gastrointestinal symptoms such as nausea, vomiting and abdominal pain (27). In rare cases, anaphylactic shock may occur, requiring immediate medical attention. In a study conducted to comprehensively assess the sensitisation profile to food allergens in Polish children, the lowest sIgE sensitisation rates to food allergen extracts were found for oregano (0.3%). This emphasises the rarity of allergic reactions to oregano among the children in the study (28).
The link between oregano allergy and other food allergies is well understood. People with oregano allergy often also react to other spices such as basil, rosemary and sage, as well as to certain fruits and vegetables such as banana, kiwi, tomato and pepper. This cross-reactivity is due to the similarity of protein structures between the different plants (**table II**).

Studies show that people with oregano allergies may experience symptoms when eating other foods containing similar allergens. A study by Wagner *et al.* (29) in 2022 found that 29% of patients with allergies to birch, wormwood or grass pollen had positive skin tests for herbs, including oregano. This emphasises the importance of considering sensitisation to herbs in the diagnosis of food allergy. In a 2023 review, Fernandes *et al.* (30) investigated the antimicrobial properties of plants in the *Lamiaceae* family. They found that plants such as rosemary have strong antimicrobial properties but can also cause allergic reactions in sensitive people. A study by Högerle *et al.* (31) showed that patients with birch allergy, who also have specific IgE to the components of the allergen Bet v 1 and profilin, are more likely to suffer from oral allergic syndrome and intestinal reactions. They also have more frequent and severe symptoms of rhinitis and asthma. In conclusion, Poncet *et al.* (32) report that 30 to 60% of patients with food allergies also suffer from cross-reactions with plant pollen, which is explained by the fact that food allergens in spices and pollen have a similar structure and belong to the same family of proteins PR10, as well as profilins.
Diagnosis of oregano allergy is usually carried out using skin prick tests or blood tests for specific IgE antibodies. Skin prick tests can detect immediate allergic reactions to oregano and other potentially cross-reactive foods. Blood tests for specific IgE antibodies help confirm the diagnosis and determine the level of sensitisation to oregano. In some cases, additional tests, such as provocation tests, may be necessary to clarify the diagnosis. Treatment of oregano allergy consists of eliminating oregano and cross-reactive foods from the diet. Patients are advised to read food labels carefully and avoid eating foods containing oregano and other potentially hazardous ingredients. In case of allergic reactions, antihistamines are used to relieve symptoms such as itching, hives and nasal congestion. In more severe cases, corticosteroids or epinephrine may be required to control anaphylactic reactions. In conclusion, oregano allergy is a significant problem for some people, especially those living in regions where this spice is widely used. Careful diagnosis and effective management of oregano allergy can significantly improve the quality of life of patients, allowing them to avoid adverse reactions and minimise the risk of serious complications.

Hypersensitivity to anise and its related species
Allergic reactions to anise are less common than to other spices but can still be a serious problem for some people. Bet v 1 proteins and profilins belong to the PR-10 and profilin families, respectively. These proteins trigger an immune response in sensitive individuals, leading to various allergic symptoms. In most cases, no allergic reaction is observed directly to anise, but it is most often reacted to by people with birch pollen allergy as part of a cross-reaction (33). Polak *et al.* (34) reported that in areas where birch predominates, allergy to pollen of Fagales trees is often initiated by the allergen Bet v 1, which is the cause of cross-allergy with anise and other spices.
The prevalence of anise allergy varies by region and population. In the Mediterranean countries, where anise is widely used in cooking and medicine, allergic reactions are more common than in other regions. A study by Wang *et al.* (35) in Northern China showed that the main allergen of birch pollen, Bet v 1, is the leading component causing sensitisation, with a level of 82.8%. pollen food allergy syndrome (PFAS) was identified in 75.9% of participants, of whom 72.7% were allergic to apples. Significantly higher levels of sIgE to birch pollen and Bet v 1 were observed in patients with PFAS and apple allergy. Bet v 1 proved to be a valuable biomarker for the diagnosis of PFAS and apple allergy, while Bet v 2 should also be considered in immunotherapy.
Clinical manifestations of anise allergy can include skin symptoms such as hives, itching and swelling, as well as respiratory problems including nasal congestion, sneezing and difficulty breathing (36). Some people may also experience gastrointestinal symptoms such as nausea, vomiting and abdominal pain. In rare cases, anaphylactic shock may occur, requiring immediate medical attention (37). In addition to the main reactions, Younis *et al.* (38) provides evidence that plasma cell gingivitis (PCG) can occur as one of the possible reactions to anise. PCG is an inflammatory condition affecting the mucous membrane of the oral gums, characterised by dense polyclonal infiltration of plasma cells in the connective tissue (39, 40). The aetiology of PCG is related to hypersensitivity to certain antigens, such as toothpaste, mouthwashes, chewing gums and spices, including anise. Complications and risks of anise allergy include the development of anaphylactic shock, which can be life-threatening. Therefore, it is important to recognise allergy symptoms promptly and take appropriate precautions. Early diagnosis and proper management of aniseed allergy can significantly reduce the risk of severe reactions and improve the quality of life of patients.
According to the findings of the study by Beutner *et al.* (41), skin prick tests or blood tests for specific IgE antibodies are commonly used to diagnose anise allergy. Skin prick tests can detect immediate allergic reactions to anise and other potentially cross-reactive products. Blood tests for specific IgE antibodies help to confirm the diagnosis and determine the level of sensitisation to anise. In some cases, additional tests, such as provocation tests, may be necessary to clarify the diagnosis. As an example, Cacheiro-Llaguno *et al.* (42) used prick tests, which revealed that the most common molecular allergen was Bet v 1 (84%).

In conclusion, anise allergy is a significant problem for some people, especially those living in regions where this spice is widely used. Careful diagnosis and effective management of anise allergy can significantly improve the quality of life of patients, avoiding adverse reactions and minimising the risk of serious complications.

Allergic reactions to mustard

Mustard is one of the most allergenic spices due to the presence of strong allergens such as Sin a 1, Sin a 2, Sin a 3 and Sin a 4. These proteins belong to the 2S albumin family and can cause serious allergic reactions even in small amounts (43). Assou *et al.* (44) described the allergen Bra j, the removal of which with the help of Clustered Regularly Interspaced Short Palindromic Repeats (CRISPS) allowed for a significant reduce the allergenicity of mustard. Mustard allergy can manifest itself in various symptoms, including skin, respiratory and food reactions.

Sin a 2, Sin a 3, and Sin a 4 are potent allergens derived from mustard, exhibiting distinctive characteristics that augment their allergenic potential. Sin a 2, which belongs to the 11S globulin family, is highly stable and resistant to digestion. This allows it to trigger robust immune responses and even to survive food processing. This protein frequently exhibits cross-reactivity with other 11S globulins present in nuts and legumes, thereby increasing the likelihood of allergic reactions in individuals with prior exposure to mustard allergens. Sin a 3, a non-specific lipid transfer protein (nsLTP), is also highly allergenic and has the potential to elicit severe reactions, including anaphylaxis, even at trace amounts. Furthermore, it exhibits notable cross-reactivity with nsLTPs in fruits such as peaches, apples, and grapes, frequently resulting in oral allergy syndrome (OAS). Although less extensively researched, Sin a 4 belongs to the profilin family and exhibits comparable cross-reactivity with cruciferous vegetables such as broccoli and cabbage, thus representing a crucial aspect of mustard's allergenic profile (43).

Such allergens can result in a range of symptoms, including hives, respiratory difficulties and anaphylaxis, particularly when cross-reactive proteins are present in other foods. The use of component-specific IgE testing is an effective method for identifying sensitisation to Sin a 2, Sin a 3, and Sin a 4, which in turn facilitates an accurate diagnosis and dietary management plan. In cases where individuals are at high risk of severe reactions, it is essential to strictly avoid mustard and cross-reactive foods, while also carrying an epinephrine auto-injector (44).

Symptoms of a mustard allergy can include skin symptoms such as hives, swelling and itching, as well as respiratory problems such as difficulty breathing and asthma attacks (45, 46). Some people also experience food allergic reactions such as nausea, vomiting and abdominal pain. These symptoms can range in severity from mild to life-threatening. Bueno-Díaz *et al.* (47), in a study of albumin 2 S allergens, found that the main symptoms of hypersensitivity to this group of antigens are systemic reactions such as anaphylaxis and gastrointestinal syndrome. In addition, these antigens are available in many other products. Dreskin *et al.* (48) found these allergens in sesame, peanuts, and nuts. This is one of the reasons for the cross-reaction between these products. In addition, Achour *et al.* (49) reports that 2S albumin is present in sunflower oil, which significantly limits the diet of patients with this allergy. Lastly, according to Savvatianos *et al.* (50) this allergen was found in cashews and pistachios.

Mustard allergy is diagnosed by skin prick tests and blood tests for specific IgE antibodies. Skin prick tests can detect immediate allergic reactions to mustard, and a blood test helps to confirm the diagnosis and determine the degree of sensitisation. In some cases, provocative tests may be required to clarify the diagnosis and assess the severity of the reaction (51). Treatment for a mustard allergy includes eliminating the spice from the diet and using medication to manage symptoms. Antihistamines can help manage skin and respiratory symptoms, and epinephrine may be needed for severe reactions such as anaphylactic shock (52, 53). It is also important to educate patients to recognise allergy symptoms and take precautions when eating outdoors.

Prevention of allergic reactions to mustard includes reading food labels carefully and avoiding foods containing this spice. People with severe allergies should always carry emergency equipment, such as epinephrine auto-injectors, and inform others of their allergies. This is especially important in public places and when visiting restaurants. In conclusion, mustard allergy is a significant problem that requires a careful approach to diagnosis and management. Careful diagnosis and effective treatment can significantly improve the quality of life of patients, helping to avoid adverse reactions and minimise the risk of serious complications.

Other seasonings and their impact on allergic reactions

In addition to the above-mentioned spices, other popular spices such as coriander, basil, rosemary, sage and thyme can also cause allergic reactions. Although allergies to these seasonings are less common, they still pose a risk to sensitive people. One of the problems with spice allergies is the potential for cross-reactivity. This means that a person allergic to one spice may also react to other spices containing similar allergenic proteins. For example, people who are allergic to basil often also react to oregano and rosemary.

Coriander, also known as cilantro, can cause allergic reactions, especially in people with allergies to carrots and celery due to cross-reactivity. The main symptoms include itching, hives and, in some cases, anaphylactic shock (54). Coriander allergens include the proteins profilins and furanocoumarins, which can trigger an immune response in sensitive people (55).

Basil, used in Mediterranean cuisine, contains allergens similar to those of birch pollen, which can cause symptoms ranging from mild itching to serious respiratory problems. Cross-reactivity with oregano and rosemary means that people sensitive to basil should be careful with these spices (56).

Rosemary, popular in cooking for its aroma, may provoke skin rashes, itching, and even respiratory symptoms in sensitive individuals. People with rosemary allergy often react to sage and basil, which requires a cautious approach to their use (57).
Sage, often used for medicinal purposes and in cooking, contains allergenic proteins that can cause allergic reactions (58). Symptoms include skin manifestations, respiratory problems and, in rare cases, anaphylactic shock. Cross-reactivity with rosemary and basil is also common. Sage is a member of the *Lamiaceae* family, which means that people with sage allergy may also have cross-reactions to other herbs in the family, such as mint, oregano, basil and thyme (59). Thyme, popular in European cuisine, can cause allergic reactions in some people. Allergens can lead to skin rashes, itching and respiratory symptoms. People allergic to thyme should be careful when using other spices such as rosemary and sage (60).
Thus, spice allergy is a significant problem that requires attention from both healthcare professionals and food manufacturers. An integrated approach to the diagnosis, treatment and prevention of spice allergies can significantly improve the quality of life of sensitive people and prevent the development of serious complications.
The findings of this review underscore the significant clinical impact of spice allergies, which are frequently under-recognised despite their potential severity. The clinical presentation of spice allergies can range from mild cutaneous symptoms to severe anaphylactic reactions. This variability in symptoms highlights the necessity for heightened clinical awareness among healthcare professionals. The implementation of enhanced diagnostic techniques, such as more precise IgE tests, is of paramount importance for the accurate identification of patients at risk. A significant implication for public health is the cross-reactivity between spices and other plant-based allergens, which presents a challenge to allergy management and may result in accidental exposure in individuals with a sensitivity to these substances.
A notable deficiency in the extant research is the absence of epidemiological data concerning the prevalence of spice allergies across diverse populations and geographical regions. The majority of studies have concentrated on specific allergens, frequently within the context of isolated clinical scenarios, which has resulted in a fragmented understanding. Moreover, there is a paucity of research investigating the molecular mechanisms underlying spice allergies. Elucidation of these mechanisms could facilitate the development of targeted therapies and enhance diagnostic accuracy.
It is recommended that future research should aim to standardise diagnostic protocols, especially in cases of suspected cross-reactivity. It is imperative that large-scale epidemiological studies be conducted in order to accurately ascertain the prevalence of spice allergies and to gain insight into the regional variations that exist. Furthermore, molecular studies exploring the structural components of spice allergens could facilitate the development of allergen-specific immunotherapy, which may offer a potential pathway for long-term management. Such research would not only address existing knowledge gaps but also facilitate the development of dietary guidelines and public health interventions designed to mitigate the risks associated with spice allergies.

Conclusions

Allergies to spices are a significant problem for many people and can cause a wide range of symptoms, from mild skin rashes to serious respiratory problems and anaphylactic shock. Pepper, cumin, oregano and anise are examples of such spices, each of which contains specific allergens that can trigger an immune response in sensitive people. The main pepper allergens are PR-10 proteins, profilins and defensins, which can cause cross-allergic reactions with pollen and other plant allergens. Cumin may provoke strong allergic reactions in certain cases. Oregano contains Bet v 1 and profilins, which often lead to cross-allergies with other spices and plants. Anise allergy is less common but can also be a serious problem, especially in people with birch pollen allergy, due to cross-reactivity.
Clinical manifestations of spice allergy include hives, swelling of the lips and throat, difficulty breathing, nausea and vomiting. These symptoms can occur immediately after consuming the spice or after a while, making diagnosis difficult. The cross-reactivity between different spices and allergens also makes it difficult to diagnose and manage allergies. Skin prick tests and blood tests for specific IgE antibodies are used to confirm the diagnosis. Treatment of spice allergy is aimed at avoiding triggers and symptomatic treatment, including the use of antihistamines and, if necessary, epinephrine to stop anaphylactic reactions.
Thus, spice allergy requires a careful approach to diagnosis and treatment to avoid adverse reactions and improve the quality of life of patients. Improved awareness among healthcare professionals and patients, as well as the development of new therapeutic approaches, can significantly improve allergy management and minimise the risk of serious complications.

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Figure 1 *- Flowchart of article selection process for spice allergy review.*

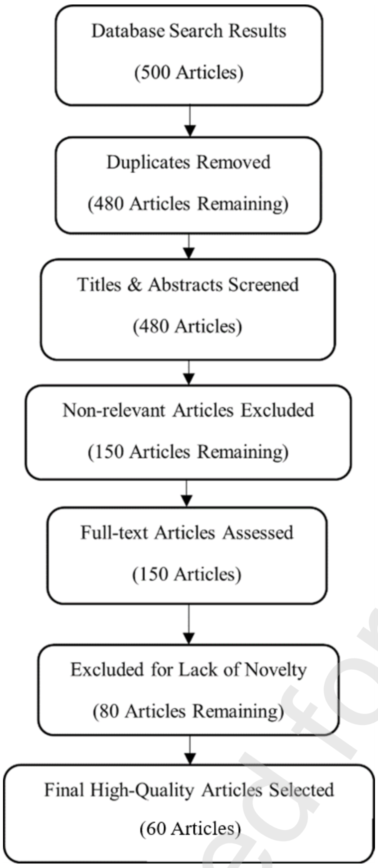

Table I *- Brief description of allergens.*

Spice	Prevalence of allergies	Clinical manifestations
Pepper	38%	Hives, swelling of the lips and throat, respiratory problems, anaphylaxis
Cumin	20%	Skin rash, itching, nasal congestion, anaphylaxis
Oregano	Unknown	Cross-allergy, skin rashes, gastrointestinal symptoms
Anise	Rarely	Cross-allergy with birch pollen, skin rashes
Mustard	High	Severe allergic reactions, urticaria, anaphylaxis

Table II - *Cross-activity of spices.*

Spice	Diagnostic methods	Approaches to treatment	Cross-reactivity
Pepper	Skin prick tests, blood tests for IgE	Exclusion from the diet, adrenaline auto-injectors for severe cases	With pollen and other plant allergens
Cumin	Skin prick tests, blood tests for specific IgE antibodies	Exclusion from the diet, symptomatic treatment	With dill, parsley, carrots
Oregano	Blood tests for specific IgE antibodies	Dietary elimination, antihistamines	With other spices and herbs
Anise	Blood tests for specific IgE antibodies	Dietary elimination, antihistamines	With birch pollen