Polish Annals of Medicine

Journal homepage: https://www.paom.pl

Review Paper

Food allergies to grains: Epidemiology and mechanisms of reactions to wheat, rye, oats, corn, barley, buckwheat, rice, lupine, quinoa

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Article info

Article history
Received: April 23, 2024
Accepted: November 14, 2024
Available online: May 22, 2025

Keywords
Alergens
Anaphylaxis
Urticaria
Allergic dermatitis
Cases of immediate allergic reaction

Doi
https://doi.org/10.29089/paom/196982

Abstract

Introduction: The prevalence of food allergies can reach up to 10% in children in Western countries, with cereals being a significant group of allergens. While wheat is the most commonly associated with allergic reactions, allergies to other grains such as rye, oats, and maize are less studied.

Aim: The aim of this study was to systematically review allergic reactions to wheat, rye, oats, barley, maize, buckwheat, rice, lupin, and quinoa, with the goal of enhancing understanding of their prevalence, identifying established allergens, and optimizing treatment and preventive strategies.

Material and methods: The study is based on a review of literature and case reports on allergic reactions to various grains, focusing on their prevalence, allergenicity, and clinical manifestations.

Results and discussion: Wheat has the highest prevalence of allergic reactions among cereals, with incidence in children ranging from 0.2% to 9%, depending on region and age. It contains the most allergenic proteins. Rye allergies are rare, with few cases of bronchial asthma or combined reactions to wheat and rye. Oats and maize are also weak allergens, with few reported clinical cases. Barley ranks third in causing allergic reactions among children in Japan, but reports are scarce. Buckwheat and rice allergens are well-studied, with rice being more prevalent due to its widespread consumption. Rice allergies rank 4th to 6th in some countries. Lupin and quinoa allergies are extremely rare.

Conclusions: Thus, allergies to rye, oats, maize, lupin, and quinoa are rare, allergic reactions to barley, buckwheat, rice have a medium frequency; wheat remains one of the major food allergens.

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1. INTRODUCTION

The prevalence of food allergies has been steadily increasing worldwide, with rates as high as 10% in children in Western countries. Developing countries are also seeing a rise in cases, possibly due to changes in diet, environmental factors, and urbanization. Food allergies are a major public health concern, especially among children, and certain foods account for up to 80% of all allergic reactions.[1] These include common allergens such as wheat, milk, eggs, peanuts, and tree nuts. However, allergies to cereals, although less frequently recognized, are becoming increasingly important in both clinical practice and research.

Among cereals, wheat is the most common allergen and is primarily responsible for baker's asthma. It contains a variety of allergenic proteins, which make it a major cause of food-induced allergic reactions, especially in children. However, other cereals like rye, oats, maize, barley, buckwheat, rice, lupin, and quinoa also contribute to allergic reactions, though they are often considered weaker allergens. For example, maize, despite being regarded as hypoallergenic, has been associated with some severe allergic reactions, challenging its classification as a non-allergenic food.[2] Additionally, cross-reactivity between different cereals complicates diagnosis and treatment, as patients allergic to one type of cereal may experience reactions to others. This issue is particularly evident in individuals with wheat allergies, where cross-reactivity to other cereals such as rye, oats, and barley is commonly observed. In recent years, research has focused on the molecular mechanisms underlying cereal allergies, with particular attention paid to the proteins that trigger immune responses. Despite progress, the full range of cereal allergens, especially in less common grains like quinoa and lupin, is not yet fully understood. The relatively limited number of clinical cases and the lack of comprehensive data on the prevalence of these allergies pose significant challenges for clinicians in diagnosing and treating patients effectively.

2. AIM

The aim of this study is to review and consolidate existing knowledge on allergic reactions to various cereals and legumes, focusing on their prevalence, clinical manifestations, and the molecular identification of allergens. By reviewing the current scientific literature, this paper aims to provide a clearer understanding of the frequency of these allergies, highlight the importance of accurate diagnosis, and propose strategies for better management and prevention of allergic reactions to cereals. Addressing the gaps in the current literature is crucial for improving patient care and developing more targeted treatment options.

3. MATERIALS AND METHODS

This study analyses data on immediate allergic reactions to cereals, including wheat, rye, oats, maize, barley, buckwheat, rice, lupin, and quinoa, sourced from credible databases. Research papers published between 2020 and 2024 were selected, with earlier publications reviewed when necessary. Only English-language articles with accessible abstracts and appropriate keywords were included. Keywords used for the search included 'allergy,' 'anaphylactic reaction,' 'urticaria,' 'bronchial asthma,' 'allergic rhinitis,' 'atopic dermatitis,' and 'cereal allergens.' Studies were accessed via PubMed, Scopus, Google Scholar, and ScienceDirect. Seventy-eight research articles were reviewed, with 47 meeting the selection criteria. A narrative synthesis was employed due to the variability in study designs and data reporting, which prevented a meta-analysis. This approach allowed for summarizing the findings, identifying common themes, and outlining the clinical implications of cereal allergies. Since the studies included both qualitative and quantitative data, a meta-analysis was not feasible due to differences in methodologies, sample sizes, and outcome measures used across studies. The narrative synthesis was chosen to provide a comprehensive overview and integrate diverse findings.

The study focused on cereal use, allergen proteins, and clinical cases of allergic reactions. Reactions considered included urticaria, rhinitis, dermatitis, bronchial asthma, and anaphylaxis (e.g., facial edema, dyspnea, cough, wheezing, hypotension, and tachycardia). Diagnostic tests included skin tests, total and specific IgE measurements, and oral allergen exposure tests. Wheat is the most common cereal allergen, with prevalence ranging from 0.2% to 9%, due to proteins like gliadins and glutenins that trigger immune responses.[1] Rye allergy, though rare, may occur in individuals with a history of wheat allergy, with cross-reactivity complicating diagnosis.[2,3] Bant and Kruszewski[4] found 8% of healthy men reacted to food allergens, with rye pollen being a significant inhalant allergen. Gliadins and glutenins are heat- and digestion-resistant, contributing to cross-reactivity.[5] Cereal allergies can cause symptoms from urticaria to anaphylaxis. Letrán et al.[6] reported anaphylaxis from oats, while Kubota et al.[7] highlighted barley allergies in Japan. Severe reactions to quinoa and lupin emphasize the importance of recognizing all cereal allergens. Strict avoidance is the primary management strategy, though immunotherapy and desensitization are being explored.[8] Early diagnosis and tailored treatment are essential for managing these allergies, despite challenges in diagnosing reactions to lesser-known cereals due to cross-reactivity.

4. RESULTS AND DISCUSSION

4.1. Wheat allergy: Uses, prevalence, allergens, clinical cases

Wheat (*Triticum aestivum*) is the most popular grain worldwide, which is used in cooking because it can grow in different climatic zones and is considered an unpretentious plant. However, wheat is listed as one of the most common allergens in the population, especially in children.[1] The reactions that wheat can cause can manifest as simple food allergies, exercise-related reactions, occupational bronchial asthma, allergic rhinitis or urticaria. The frequency of wheat allergy is quite high, and in some countries, it ranks third

among all food allergies. Depending on region and age, the prevalence of wheat allergy in children ranges from 0.2% to 9%, including self-reported wheat allergy, which is usually overestimated. Statistics of confirmed cases by skin tests ranged from 0.2% to 3%, and positive blood IgE determinations to wheat ranged from 0.4% to 3.6%, and patients with atopic dermatitis had higher IgE values compared to patients without atopy.[1] About 65% of children outgrow wheat allergy, which comes to resolution by age 12 years.[9] Wheat is a member of the *Poaceae* family and has many allergenic proteins, which are summarized in Table 1. All proteins have been categorized into 4 groups: albumin, globulins, gliadins and glutenins. The last two protein groups are 85% of wheat proteins, which are called gluten and prolamin because of their high proline content. Gliadins are subdivided into α/β-gliadins (fast), γ-gliadins (intermediate) and ω-gliadins (slow), and glutenins are divided into high and low-molecular-weight proteins.

Wheat allergy primarily involves sensitivity to α, β, γ, ω gliadins and glutenins, along with other allergenic proteins like β-amylase, hydrolytic enzyme inhibitors, lipid transfer proteins, and puroindolins. Heat-resistant allergens like α-amylase and trisin inhibitors are linked to occupational asthma and exercise-induced anaphylaxis. Tri a 14 triggers IgE-related allergies, and Tri a 37 is heat-resistant, making it a marker for severe wheat allergies. A study comparing spelt, einkorn, emmer, and tritordeum proteins found IgE binds to proteins in all wheat fractions, indicating similar allergenic potential.[10] A study on acid-hydrolyzed wheat protein in soap found 35 out of 61 patients experienced urticaria or anaphylaxis, with 18 testing positive for wheat protein. Nine had exercise-induced anaphylaxis, and four had food- and exercise-induced anaphylaxis.[11] Another study found 90% of children had severe reactions to wheat, while 37.5% developed tolerance over time but remained at risk for chronic symptoms.[12] Understanding wheat allergens like Tri a 37 is important, as it's heat-resistant and can cause reactions even in heat-treated wheat products. Cross-reactivity with rye, barley, and oats complicates diagnosis, requiring additional tests for accurate diagnosis and tailored recommendations.

Table 1. Wheat allergens.[1]

Allergen	Protein name	Source	View
Tri a 12	Profilin	Grasses, Plants, Poaceae, Triticum aestivum, Wheat	Pollen, Seed
Tri a 14	lipid transfer proteins		Seed
Tri a 15	α-amylase inhibitors		
Tri a 18	agglutinins		
Tri a 19	ω-5 gliadins		
Tri a 20	γ-gliadins		
Tri a 21	α–β-gliadins		
Tri a 25	thioredoxin		
Tri a 26	glutenins		
Tri a 27	thiol reductase		
Tri a 28	α-amylase inhibitor		
Tri a 29	α-amylase inhibitor		
Tri a 30	α-amylase inhibitor		
Tri a 31	triosephosphate isomerases		
Tri a 32	peroxiredoxines		
Tri a 33	trypsin inhibitors		
Tri a 34	glyceraldehyde-3-phosphate dehydrogenases		
Tri a 35	dehydrins		
Tri a 36	glutenins		
Tri a 37	thionins		

4.2. Rye allergy: Uses, allergens, clinical cases

Rye (*Secále cereále*) is an herbaceous plant belonging to the *Poaceae* family, native to Central Asia and northern Africa. Rye has a wide range of culinary uses: it is used for baking bread and making kvass. Most of the literature describes cases of allergic reaction to rye pollen, but there are few publications with reported cases of allergy to rye grain. However, cross-reactions in the form of sensitization or positive skin tests to rye have been reported in articles with wheat allergy. Studies on rye allergy describe anaphylactic reactions linked to wheat consumption. Tests on rye also showed positive reactions.[13] A case of urticaria, dyspnea, and loss of consciousness after physical activity and wheat consumption was reported.[14] Skin tests for wheat, bread, gluten, and wheat noodles were positive, as were IgE determinations for wheat, gluten, and rye. This highlights cross-reactivity between wheat and rye proteins, such as gliadins and glutenins, which trigger allergic reactions. The severity of reactions depends on the allergen dose, as even small amounts of wheat or rye can cause severe reactions in sensitized individuals. A study on beer consumption showed latent sensitization to wheat, rye, rice, oat flour, and maize, in addition to a barley allergy.[15] This highlights the importance of cross-reactivity among cereals. A study on IgE results in children showed a correlation between hypersensitization to grass and positive IgE to wheat and rye.[16] Of 944 children with allergic status, 532 had positive IgE to both wheat and rye, supporting the idea of cross-reactivity between grass pollen and cereals. Additionally, two cases of occupational bronchial asthma were reported in bakers who had rhinoconjunctivitis while working with rye flour.[17] Studies also showed early asthmatic reactions to rye flour, while wheat flour showed negative results.

4.3. Allergic reaction to oats: Uses, allergens, clinical cases

Oats (*Avena sativa* L.), a cereal from the *Poaceae* family, are widely used in cooking and as animal feed, with origins in North America, Europe, and Western Asia. Oat grains contain proteins such as globulins, albumins, avenins (prolamins), and glutenins, but the specific proteins responsible for allergic reactions remain poorly studied. However,

potential allergens identified include the seed 12S reserve globulin (23 kDa) and serpin (48 kDa). In a study by González-Afonso et al.[18], a 45-year-old man developed acute urticaria, facial edema, and dyspnea immediately after eating oatmeal pancakes. Skin tests showed positivity for oats, maize, barley, and wheat, with total IgE at 85.3 IU/mL and specific IgE to oats at 4.2 IU/mL. Tomás-Pérez et al.[19] described 2 cases: 1st involving a 14-year-old boy with atopic dermatitis who developed itching and facial redness after drinking oat milk, with specific IgE of 6.79 IU/mL, and 2nd involving a 62-year-old man with coronary heart disease who experienced anaphylaxis after consuming oat milk, with specific IgE of 40.1 IU/mL. Additionally, a 44-year-old woman with atopic dermatitis had anaphylaxis, urticaria, and facial edema after drinking oat milk-based coffee.[20] Skin tests for dried oats were negative, but she tested positive for oatmeal porridge and oat milk, with total IgE over 100 IU/mL. Her specific IgE was also positive for wheat flour, hazelnuts, maize, rice, and peanuts. Another case described an allergy triggered by oat consumption, where skin tests and IgE determination for oats were negative. It was determined that the oats were infested with Psocid insects, which caused the allergic reaction.[21]

4.4. Maize allergy: Uses, biological description, allergens, clinical cases

Maize (*Zéa máys*) is widely used in cooking in the form of breakfast cereals, maize snacks, chips, maize flour (used in sauces and soups) and in products combined with wheat.[22] Maize is a popular product in North America, South America and other temperate climates because it is an unpretentious plant. This type of legume is considered a hypoallergenic product, but some cases of anaphylactic reaction have been described in the literature, in countries where maize consumption is widespread.[2] The study of immediate type allergic conditions to maize is extremely low, as is information on prevalence, mechanisms of occurrence, allergens involved, cross-reactivity with other foods, diagnostic methods and optimization of treatment.

The main allergen proteins in maize are lipid transfer proteins. Zea m 14 is a protein that retains its molecular structure after exposure to high temperatures. In addition, maize lipid transfer proteins are known to cross-react with the same proteins of some fruits and vegetables, which include barley, rice, peach, and cherry. In this regard, it may be noted that patients allergic to maize differ significantly from those allergic to other cereals. A case report published in the literature describes a 37-year-old woman who complained of allergic skin rashes, which she attributed to taking the antihistamine drug desloratadine.[23] After a thorough work-up and interview, it was determined that the woman had a history of allergic reaction to cooked maize, seasonal allergic rhinitis and hand dermatitis related to her occupation. Skin tests and other examination methods confirmed an allergic reaction to maize through pollen inhalation and ingestion. In addition, it was confirmed that the dermatitis on the hands was allergic, which was related to the treatment of medical gloves with cornstarch used by the patient, and the antihistamine drug was also found to contain cornstarch as an excipient. The initial diagnosis was therefore changed from drug allergy to food allergy. A case of allergic rhinitis caused by eating a cornmeal-based product has also been described.[24] The patient complained of persistent rhinitis as an adult, but the classic symptoms characteristic of food allergy occurred 15 years after the onset of rhinitis. The case is considered not typical because exposure to food rarely causes signs of allergic reaction.

4.5. Barley allergy: Uses, description, allergens, clinical cases

Barley (*Hordeum vulgare*) is a plant that belongs to the family *Poaceae*, and, together with wheat, rye and oats, is a member of the subfamily *Pooideae*. Barley is widely used throughout the world as a fermentable material for the preparation of alcoholic beverages such as beer and whiskey. It is also used as an ingredient in soups, stews, and breads in Europe, the Middle East, and Asia.[25]

Barley is third on the list of causes of allergic reactions in children in Japan.[7] In addition, it was found that the percentage of patients who had a confirmed allergy to wheat and a positive cross-reaction to barley was 55%, which is significantly higher than for rye and oats. Barley allergen proteins are poorly studied, but it is known that some studies have identified proteins with molecular masses of 60–80 kDa, 40–45 kDa, 30–35 kDa.[26] Proteins have also been identified: α-amylase/trypsin, α-amylase and β-amylase, which are causes of occupational asthma, thermostable lipid transfer protein and protein Z4, is a component of beer, which can cause allergic manifestations. A study reviewed the occurrence of beer urticaria in three patients with a history of atopic dermatitis and bronchial asthma. The patients underwent skin tests for the components of beer, followed by protein identification. In the course of scientific work, it was determined that the protein that caused allergy to beer had a molecular mass of 10 kDa and was not related to the main allergen protein with a mass of 16 kDa, which was responsible for the baker's occupational bronchial asthma.[27] Furthermore, a study reviewed the occurrence of beer allergy in 27 patients. It was found that 15 of the 27 had a positive skin test reaction to one or more beer ingredients, 9 of them had a reaction to malt and other components. Skin symptoms were most common and resolved after 2 h. Single patients reacted to barley, hops or yeast.

4.6. Buckwheat allergy: Uses, biological description, allergens, clinical cases

Buckwheat (*Fagopyrum esculentum*), belonging to the *Polygonaceae* family, originates from Asia and is used in various areas of cookery in many countries. Its use is quite wide in the form of noodles, porridge, baking bread, pancakes.[28] Buckwheat tea has become popular in recent years as it has beneficial antioxidant properties. Buckwheat allergy is a latent and IgE mediated allergy that can cause severe allergic reactions that occur by eating, working or sleeping on a pil-

Table 2. Protein allergens of buckwheat.[28]

Allergen	Protein name
Fag e 1	13S globulin
Fag e 2	2S globulin
Fag e 3	7S globulin/vicilin
Fag e 4	antimicrobial peptide
Fag e 5	vicilin-like protein
Fag e 10	α-amylase inhibitor / trypsin inhibitor
Fag e T1	trypsin inhibitor
Fag t 2	2S albumin
Fag t 3	seed storage protein

low containing buckwheat husks. The allergens in common buckwheat have been studied and described quite well. As shown in Table 2, the following allergen proteins exist: Fag e 1 (13S globulin), Fag e 2 (2S globulin), Fag e 3 (7S globulin/vicilin), Fag e 4 (antimicrobial peptide), Fag e 5 (vicilin-like protein), Fag e 10 kD (α-amylase inhibitor/trypsin inhibitor) and Fag e T1 (trypsin inhibitor). Fag e 1 and Fag e 2 are the main allergens that cause an allergic reaction, in addition Fag e 2 cross-reacts with latex, and Fag e 3, Fag e 4 and Fag e 5 are relevant buckwheat allergens. Fag e T1 is a legume protein that is also detected in wild wheat.

Allergic reactions to buckwheat have been reported in Europe, Australia, and other countries. Six occupational cases were described, including 3 cooks, 1 grocery worker, and 2 bakers, with symptoms confirmed by skin tests and serum IgE measurements.[29,30] Two patients had contact urticaria, 4 had bronchial asthma, and 4 had allergic rhinitis. Three patients experienced anaphylaxis after eating buckwheat. A 48-year-old man had anaphylaxis after eating toasted buckwheat triangles, with symptoms such as bitterness in the mouth, dysphagia, and erythema in the groin, hands, and face. He had a history of rhinoconjunctivitis during pollen seasons, which resolved without medication. Skin tests for toasted and boiled buckwheat were positive, and serum IgE was also elevated.

4.7. Allergic reaction to rice: Uses, description, allergens, clinical cases

Rice (*Oryza sativa*) is a member of a cereal crop in the *Poaceae* family that is used in cooking in most of the world, providing 25%–80% of the daily calories needed. Rice is used to make side dishes, breads, snacks, and soups. Rice allergy is described mainly in countries where its consumption predominates over other foods. For instance, in Thailand, rice ranks 4th, while in Japan and Indonesia only 5 and 6, among all strong allergens, and the prevalence of allergy in European countries, USA is much lower.[31]

Among the allergens described in the literature (Table 3), it is worth highlighting: Ory s 1 (35 kDa), Ory s 12 (14 kDa), which are the main rice allergens, while Ory s 2, Ory s 7, Ory s 11, Ory s 23, Ory s 14, may be potential allergens.

Despite rice's prominence as an allergen in Asia, clinical cases are rarely reported. A study of 312 children with bronchial asthma found 29 (9.3%) with positive skin tests for rice pollen.[33] Allergen proteins identified included 16 kDa, 26 kDa, and 32 kDa. In a clinical case, a 30-year-old man with atopic dermatitis experienced itching and skin redness after rinsing rice in water, with a positive skin test result.[34] However, eating rice did not cause issues. The allergen was water-soluble, heat-resistant, and temperature-stable, as test results were weaker with more diluted rice water. Cross-reactivity between rice lipid transfer proteins (LTPs) and fruits like peach and apple has been confirmed in patients with anaphylactic reactions to rice who are hypersensitive to LTPs.[35] LTPs are small, stable proteins found in many plants, including rice, peaches, and apples. These proteins share structural similarities, allowing the immune system to recognize them as similar, triggering cross-allergic reactions. LTPs' stability at high temperatures and during digestion makes them particularly dangerous allergens. Additionally, a 5-year-old child with atopic dermatitis developed itching after eating rice bran.[36] The child lived in a house where rice was stored and milled, and contact with relatives who worked there worsened the symptoms. Positive specific IgE to rice and skin test results for rice bran and polished rice highlighted the importance of considering environmental exposure to allergens like rice, particularly in individuals with a family history of allergies. This case underscores the role of LTPs in allergic reactions, which may be present in both rice and its by-products, like rice bran.

4.8. Lupin allergy: Uses, biological description, allergens, clinical cases

Lupin (*Lupinus albus*), as well as soybean and peanut, is a member of the legume family, which are the second-largest seed plants. Lupin is cultivated worldwide, mainly as animal feed and as a soil enhancer. Lupin is increasingly used in culinary applications to enhance protein and fiber content, as well as to improve the consistency and texture of various dishes. Lupin flour has been used in bread, biscuits, pasta, snacks, meat dishes, dairy products and as a substitute for soya flour. The prevalence of lupin allergy worldwide is uncertain, as isolated cases of reactions to this product have rarely been described. However, in a study, referral of patients to tertiary level allergy centres, among all food allergy cases, in the Netherlands, was found to be 0.27%–0.81%.[37] Mostly, conditions caused by combined exposure with other legumes such as soya or peanut have been reported. Lupin has cross-reactivity with peanut and soya, but no such pat-

Table 3. Rice allergens.[32]

Allergen	Protein name
Ory s 1	β-expansin
Ory s 12	profilin A
Ory s 7	calcibiobinding protein / polocalcin
Ory s 11	glycosylhydrolase family 28 (polygalacturonase)
Ory s 23	glycosylhydrolase family 28 (polygalacturonase)
Ory s 14	lipid transfer protein

Table 4. Protein allergens of lupin.[39]

Allergen	Protein name
Lup a 1/Lup a 1	7S vicilin
Lup a 3 + isoform	Lipid transfer protein
Lup a 4	Bet v 1-like
Lup a 5 + isoform	profilin
Lup a delta conglutin	2S albumin

tern has been monitored in clinical cases. Lupin ingestion, even in the smallest amounts, can lead to severe allergic reactions.[38] Lupin allergens are poorly described and studied; however, γ-conglutin, a vicilin 7S-globulin from the cupin family, has been identified as one of the most significant lupin allergens. The remaining proteins, which are described in Table 4, are potential lupin allergens. In addition, three low molecular weight proteins were identified: Lup an alpha, Lup a gamma, Lup a delta conglutin and two proteins from the PR-10.21 family.[39]

A case of allergic reaction to lupin in a child with no allergological history was described in a study.[40] Thirty minutes after eating a waffle based on lupin flour, eggs and sugar, the patient had rhinorrhoea, lacrimation developed, followed by facial oedema and breathing difficulties. Skin test results were strongly positive for lupin flour and peanut, with total IgE of 1237 UI/mL, and specific IgE was also positive for lupin at 20.8 UI/mL and for peanut over 100 UI/mL. A 10-year-old patient, who was allergic to peanuts and nuts, experienced itching in the mouth, discomfort, and pressure sensations in the pharynx, hoarseness of voice, abdominal pain, dizziness, nasal congestion, and sneezing, after consuming lupin flour-based pancakes.[39] The skin test performed was positive for lupin beans and lupin pancakes.

4.9. Quinoa allergy: Uses, biological description, allergens, clinical cases

Quinoa (*Chenopodium quinoa*), a gluten-free pseudo-grain from the Chenopodiaceae family, is gaining popularity in Europe, the U.S., and Asia. Its seeds are rich in protein, flavonoids, dietary fiber, and amino acids beneficial for health, making it a popular substitute for wheat in those with gluten intolerance. Quinoa leaves are also used in salads. Immediate allergic reactions to quinoa are rare, with only a few cases described, and its prevalence is not well-studied. The main allergens in quinoa are 2S-albumin and 11S-globulin (8–9 kDa and 320 kDa, respectively), along with proteins like 7S-globulin and lipid transfer proteins, which can cause severe reactions. However, the study of these proteins is still insufficient.[41] One case involved a 39-year-old man with occupational asthma from long-term exposure to quinoa flour. He worked with maize, rice, and quinoa flour from age 18. By age 28, he developed rhinoconjunctivitis to grass pollen. Later, after eating quinoa pasta, he experienced urticaria, facial edema, and dyspnea. Over the next two years, mild wheezing occurred while handling quinoa flour, resolving after leaving his work environment. Skin tests for rice and maize were mildly positive, but quinoa tested positive. The patient was also allergic to amaranth, indicating cross-reactivity between quinoa and amaranth.[42] In another case, a 29-year-old man experienced facial redness, dyspnea, urticaria, and vomiting after eating a lupin dish. Skin tests revealed positivity for soy and mustard, but quinoa allergy was not confirmed.[43]

4.10. Comparative analysis of allergies to rye, barley, rice, wheat, buckwheat, maize, lupin, quinoa

Polish scientists studied patients aged 1 month to 56 years with respiratory allergies, finding positive specific IgE for birch, rye, wormwood pollen, and animal allergens. Reactions peaked between 2–3 years, declined by 4–5 years, and increased again by 6–10 years, stabilizing in adulthood. Rye sensitivity, though rare, can cause severe reactions due to cross-reactivity with other cereals.[44] A 19-year-old patient had pruritus, swelling, wheezing, and urticaria after consuming beer, wine, cider, and bananas. Skin tests showed positive reactions to cider, wine, beer, molds, and brewer's yeast, with a total IgE of 95 UI/mL and specific IgE to molds at 7.09 UI/mL.[45] Buckwheat allergy was common in 27% of 37 patients, with positive oral tests correlating with higher IgE levels. Introducing rice flakes into a child's diet before 12 months was linked to increased respiratory symptoms, infections, and allergic reactions.46 For wheat allergy, specific IgE and skin tests are essential, but a positive test may not match clinical symptoms. Occupational bronchial asthma in wheat workers often shows positive IgE results. Maize allergy, though rare, showed significant reactions in oral tests, with 77% of maize-sensitive patients also testing positive for grass pollen, indicating cross-reactivity. Forty-eight percent experienced anaphylaxis during oral tests, highlighting the need for further research on maize allergy. Lupin, even in small doses, triggers allergic reactions, with cross-reactivity complicating diagnosis. As lupin consumption rises, allergic reactions are likely to increase. Occupational exposure to fine particles, like flour, can worsen asthma. Quinoa, due to its heat stability and resistance to digestion, has been linked to allergic reactions, including asthma in some professionals.[47]

5. CONCLUSIONS

1. Wheat is the most common cereal allergen, responsible for a significant portion of allergic reactions, including baker's asthma. It contains multiple allergenic proteins, including gliadins and glutenins, which contribute to its high prevalence as an allergen.
2. Allergies to other cereals, such as rye, oats, maize, barley, buckwheat, rice, lupin, and quinoa, are less common but still clinically significant. Cross-reactivity between these cereals, particularly wheat and rye, complicates the diagnosis and management of these allergies.
3. Cross-reactivity between cereal proteins, particularly in the *Poaceae* family (wheat, rye, barley, and oats), is a critical

consideration. Sensitization to one cereal can lead to allergic reactions to others, making diagnosis more challenging.
4. The clinical manifestations of cereal allergies can range from mild symptoms (urticaria, rhinitis) to severe reactions, including anaphylaxis. Although rare, severe reactions to less common cereals like quinoa and lupin emphasize the importance of recognizing all potential allergens.
5. Accurate diagnosis is essential for effective management, requiring a combination of patient history, specific IgE tests, skin tests, and, in some cases, oral food challenges. Cross-reactivity must also be considered when diagnosing cereal allergies.
6. Management and prevention primarily involve strict avoidance of the offending cereals. However, emerging therapies, such as immunotherapy, show promise in treating patients with severe or persistent wheat allergies.
7. Further research is needed to improve the understanding of allergenic proteins in cereals, particularly in less studied grains like rye, oats, and quinoa. Investigating genetic factors and refining diagnostic methods will improve allergy management.

Conflict of interest
None declared.

Funding
None declared.

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