

Why Do Certain Foods Trigger Allergies? The Science Behind Food Allergens

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ABSTRACT

Food allergies are among the most significant food safety concerns worldwide, affecting millions of individuals and posing challenges for consumers, healthcare professionals, and the food industry. Unlike food intolerances, food allergies involve an abnormal immune response in which the body's immune system mistakenly identifies specific food proteins as harmful substances. This reaction can range from mild symptoms such as itching and skin irritation to severe and potentially life-threatening conditions such as anaphylaxis. Although thousands of foods are consumed globally, only a limited number account for the majority of allergic reactions. These include milk, eggs, peanuts, tree nuts, fish, shellfish, soy, wheat, and sesame, which are recognized as major food allergens due to their ability to trigger strong immune responses in susceptible individuals. The allergenic nature of these foods is largely attributed to specific proteins that exhibit resistance to digestion, structural stability, and a high capacity to interact with immune components such as Immunoglobulin E (IgE) antibodies. Recent advances in food science have improved our understanding of the biological mechanisms underlying food allergies, as well as the influence of genetics, environmental factors, gut microbiota, and food processing on allergenicity. In parallel, regulatory authorities have implemented mandatory allergen labelling requirements to enhance consumer safety and reduce the risk of accidental exposure.

This article explores the scientific basis of food allergens, the factors that make certain foods highly allergenic, the role of food processing in modifying allergenic potential, and the importance of allergen management and labelling in modern food systems. By understanding the science behind food allergens, both consumers and food manufacturers can contribute to safer dietary practices and improved public health outcomes.

INTRODUCTION

Food has long been recognized as a source of nourishment, health, and cultural identity. However, for some individuals, everyday foods can become a source of serious health risks. The growing awareness of food allergies has transformed the way foods are produced, labeled, and

consumed across the world. Today, allergen management is considered a critical component of food safety, influencing food manufacturing practices, regulatory policies, and consumer purchasing decisions.

The increasing demand for processed and convenience foods has further highlighted the importance of identifying and controlling allergenic ingredients throughout the food supply chain. Even unintended exposure to allergenic substances through cross-contact during processing can have serious consequences for sensitive consumers. As a result, food manufacturers face the challenge of balancing product innovation with consumer safety.

Despite extensive research, an intriguing scientific question remains: why do only a small number of foods account for most allergic reactions while thousands of other foods are consumed without adverse effects? Answering this question requires an understanding of the unique characteristics of allergenic proteins and their interactions with the human immune system. Exploring the science behind these food allergens is essential for improving food safety and developing more effective strategies to protect vulnerable populations.

WHY DO CERTAIN FOODS TRIGGER ALLERGIES?

In the case of food allergies, the body mistakes food proteins for dangerous substances that must be protected from. Normally, the immune system can distinguish pathogens from food components that do not pose any harm to the body. However, when someone is predisposed to having food allergies, the immune system recognizes certain food proteins incorrectly and considers them dangerous intruders.

When developing a food allergy, a person experiences the process of sensitization first. At their first contact with the allergen, the immune system produces allergen-specific Immunoglobulin E (IgE) antibodies. The antibodies bind to immune cells known as mast cells and basophils to help the body recognize the allergen. On subsequent contacts with the same allergenic substance, protein particles bind to allergen-specific IgE molecules located on the immune cells. This causes the release of histamine and other chemicals in the

blood system. Histamines are the cause of most symptoms experienced in a food allergic reaction, such as skin rash, stomach problems, wheezing, and others. Interestingly, not all food proteins possess the ability to trigger such immune responses. Scientists have found that allergenic proteins share several unique properties that enable them to survive digestion, maintain their structural integrity, and interact strongly with the immune system. These characteristics help explain why only a limited number of foods are responsible for the majority of allergic reactions worldwide.

WHAT MAKES A PROTEIN ALLERGENIC?

Although proteins are present in nearly all foods, only a small fraction have the ability to trigger allergic reactions. Scientists have identified several characteristics that distinguish allergenic proteins from non-allergenic ones.

One of the most important factors is **protein stability**. Many allergenic proteins can withstand food processing conditions such as heating, drying, and storage without losing their structure. This stability allows them to remain recognizable to the immune system even after cooking. For example, peanut and shellfish allergens retain their allergenic properties despite extensive thermal processing. Another important characteristic is **resistance to digestion**. While most dietary proteins are broken down into smaller fragments in the gastrointestinal tract, many allergenic proteins survive digestion and reach the intestinal immune system in a relatively intact form. This increases the likelihood of immune recognition and sensitization.

The presence of specific regions known as **epitopes** also contributes to allergenicity. These regions are recognized by Immunoglobulin E (IgE) antibodies and can trigger immune responses in sensitive individuals. Proteins containing multiple stable epitopes are often associated with stronger allergic reactions. In addition, genetic predisposition, environmental exposure, and interactions with the gut microbiota influence how the immune system responds to these proteins. Together, these factors determine whether a food protein is tolerated as harmless or recognized as an allergen.

Table 1. Major Food Allergens, Their Allergenic Proteins, and Common Food Sources

Allergen	Major Allergenic Proteins	Common Food Sources
Milk	Casein, Whey proteins	Milk, cheese, yogurt
Egg	Ovalbumin, Ovomucoid	Eggs, baked products
Peanut	Ara h proteins	Peanut butter, snacks

Tree Nuts	Ana o, Pis v, Jug r, Car i	Cashews, Pistachios, Walnuts and Pecans
Fish	Parvalbumin	Cod, tuna, salmon
Shellfish	Tropomyosin	Shrimp, crab, lobster
Soy	Gly m proteins	Soy milk, tofu, processed foods
Wheat	Gluten, Gliadin	Bread, pasta, cereals
Sesame	Ses i proteins	Bakery products, spice blends

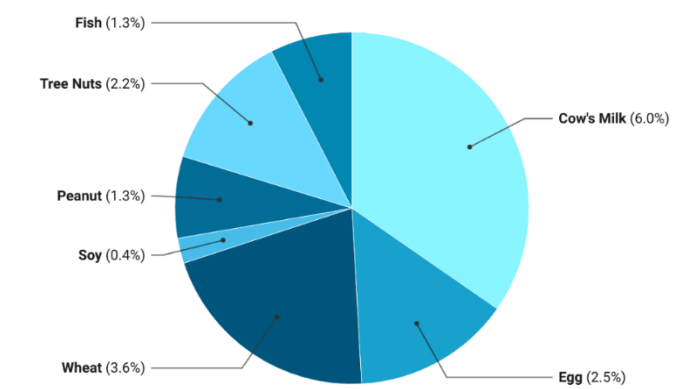


Figure 1. Lifetime Prevalence of Food Allergies by Allergen

FOOD PROCESSING AND ALLERGENICITY

Food processing can influence the allergenic potential of foods by modifying the structure of allergenic proteins. Processing methods such as fermentation, enzymatic hydrolysis, heat treatment, and high-pressure processing (HPP) have been studied for their ability to alter allergenic proteins and reduce immune recognition. For example, fermentation can partially break down allergenic proteins, while enzymatic hydrolysis cleaves proteins into smaller peptides that may be less allergenic.

Despite these advancements, allergen management remains a major challenge in food manufacturing. Shared equipment, processing lines, and storage facilities can result in unintended allergen cross-contact. To minimize such risks, manufacturers implement allergen control measures including ingredient segregation, dedicated production lines, validated cleaning and sanitation procedures, allergen testing, and routine monitoring programs. As food allergies continue to affect a growing number of individuals, understanding the impact of processing technologies on allergenicity is essential for developing safer food products and ensuring consumer protection.

ALLERGEN LABELING AND REGULATORY REQUIREMENTS

Allergen identification in food items is critical for safety reasons. In the United States, the Food and Drug Administration (FDA) has identified nine primary allergens that include milk, eggs, fish, crustacean shellfish, tree nuts, peanuts, wheat, soybeans, and sesame. These allergens should be listed on food packages either by name in the ingredients or in the "Contains" statement of foods. Many other countries have also adopted such labeling standards to assist their citizens in avoiding any allergic reactions to food products.

FUTURE RESEARCH AND INNOVATIONS

Advances in food science and biotechnology are creating new opportunities for managing food allergies. Current research focuses on the development of hypoallergenic foods through protein modification, precision fermentation, and novel processing technologies. Rapid allergen detection methods, including biosensors and molecular-based techniques, are also being developed to improve food safety and quality control. In addition, studies on the gut microbiome and immune tolerance are providing

valuable insights into the prevention and management of food allergies. These innovations have the potential to enhance consumer safety while supporting the development of safer and more inclusive food products.

CONCLUSION

Food allergies are complex immune-mediated reactions triggered by specific food proteins that possess unique structural and biological characteristics. Although only a limited number of foods account for most allergic reactions, their impact on public health and food safety is substantial. Factors such as protein stability, genetic predisposition, environmental influences, and food processing practices contribute to allergenicity and the severity of allergic responses. As the prevalence of food allergies continues to increase, effective allergen management, accurate labeling, and ongoing scientific research remain essential for consumer protection. A deeper understanding of food allergens will not only improve food safety practices but also support the development of innovative strategies for reducing allergen-related risks and enhancing the quality of life of allergic individuals.
