Review Article

Food Processing and Its Effects on Allergenicity of Food Allergens

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ABSTRACT

A food allergy is a medical condition in which the body's immune system overreacts to a specific protein in an ingested allergen. When the allergen is ingested and the protein is released in the blood, the protein binds to antibody Immunoglobulin E (IgE), causing a wide array of uncomfortable and painful symptoms (1). Food allergies can be treated in a variety of ways, including the administration of antihistamines and, most recently, immunotherapy. Immunotherapy relies on exposing the patient to slightly growing increments of an allergen over time to build immunological tolerance against the allergen. Despite certain successes, neither antihistamines nor immunotherapy are foolproof treatments (2). Food processing, including thermal and chemical treatments, is now considered a safer new approach to overcome food allergies. These treatments reduce the allergenicity of some food, but did not render the food entirely non-allergic. Food treatment, combined with other approaches of treatment, opens a new avenue for safer, more convenient, and more efficient food allergy handling. In this review, we will discuss the available methods of food treatment and how this affects the nature of the allergens in the food.

Keywords: Food Allergy, IgE, Food Allergens, Food Processing, Allergenicity

INTRODUCTION

Food allergies have dramatically increased with each generation. According to the Centers for Disease Control and Prevention (CDC), the existence of food allergies in children increased by 50% between 2007 and 2021. Around 8% of children within the United States suffer from food allergies, and this statistic is expected to grow (3).

Therefore, food allergies are an increasingly growing problem, and searching for prospecting treatment types is very relevant. One such type of treatment that could possibly prove to be very useful is food processing. Food processing can see the reduction of allergenicity in several allergen types through various types of temperament, including, but not limited to, fermentation, microwaving, and hydrolysis. If deemed possible, food processing's effects on allergens could completely change the lives of those with food allergies by changing the proteins within allergens, thus causing the reactivity in the body to have less allergenic potential and become safe to ingest.

Research has already been conducted to observe how food processing could affect the allergenic potential of allergens. In this literature review, I focus on more current findings, and specifically on the research conducted over the past fifteen years.

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The objective of this review is to dive deeper into the existing research to determine how food processing affects allergenicity and whether it is possible to use it as a treatment. It has been concluded that while food processing *does* have an effect on the proteins the body deems harmful, there is no conclusive data at this point about whether food processing could be used as a form of treatment. This paper reviews multiple studies aimed at determining the overall consensus upon food processing and its effect on food allergies.

LITERATURE REVIEW

There have been many studies addressing the question of how different types of food processing technologies affect the allergenic potential of numerous allergens. This review will organize itself based on allergen type, and how each can be affected by different processing methods.

Milk Processing and Allergenicity

A milk allergy is very common (4). One form of food processing is pasteurization, which is a type of thermal processing. In pasteurization, milk is heated up to a set temperature for a measured time. It was discovered through multiple trials that the pasteurization of milk decreases allergenicity due to decreased IgE antibodies binding to allergens, which leads to less reactivity (11). The effects of other moist heat processing, such as sterilization added to this theory that heated milk decreased IgE-mediated reactivity (7). A drop in IgG-binding to β-lactoglobulin and α-lactalbumin proteins in milk was observed after undergoing sterilization. In sterilization, the heat can denature whey proteins in milk by rendering the epitopes, a part of the antigen, less or not interactive with IgE. This makes it difficult for the antibodies to recognize the proteins, causing less binding and therefore a decrease in reactivity (5).

It was also found that a hydrolysis reaction creates highly soluble and reactive amounts of amino acids, which can affect the structure of proteins within the foods, and that it also affects allergenicity. For instance, milk faces a drop in the allergenic potential of the protein β-lactoglobulin within it after undergoing hydrolysis (8). Gamma radiation, a novel processing type, proved to affect milk allergens. It is a non-thermal processing method. Additionally, while fermentation saw little to no change in IgE-binding in milk (8) in comparison to other, more effective forms of processing (pasteurization), the introduction of pulsed ultraviolet (UV) light to a particular food, a more novel type of processing, saw the decrease of allergenicity within milk proteins (specifically a-lactal-bumin and b-lactoglobulin) (9). However, a study on ultrasound treatment's effects on milk found that, while there were structural changes in milk's proteins, not much was done to decrease the allergenicity. The same was found for high hydrostatic pressure (HHP) treatment on milk allergens (10). Ultimately, it seemed that various processing types had potential to deplete the allergenicity of milk allergens. However, this does not guarantee success; there is hope for a positive outcome, but it is not certain. Most of the processing types mentioned were successful, but not enough to completely get rid of all IgE-binding.

Egg Processing and Allergenicity

Another popular allergen is egg. A study found that heating the egg allergen to extensive heat through moist heat processing resulted in lowering the allergenicity in the egg white; the large majority (50–85%) of egg allergic patients were found to be tolerant to heated egg products (12). A separate study on hard-boiled eggs detailed that Ovomucoid and Ovalbumin, two allergen proteins within egg, were observed to have decreased allergenic potential after being heated extensively (13). Meanwhile, irradiation, utilizing a focused, high-energy radiation, might have the ability to change the allergenic potential of raw eggs, but more studies must be done to confirm this (14). Additionally urea denaturation within eggs increased the IgE binding capabilities of OTf and Lyz, other allergenic egg proteins (15). Therefore, some patients with egg allergies are able to safely consume some forms of egg, though this plan is not foolproof in completely avoiding allergic reactions.

Tree Nuts and Peanut Processing and Allergenicity

Tree nuts are another popular allergen globally. It can be seen that thermal food processing on tree nuts has only affected the tree nut allergies a part of protein-10 family that are directly related to a major birch pollen allergen (Bet v 1) (16). Other types of thermal and non-thermal testing alike showed very little variation in allergenicity; these allergen proteins are far more stable towards heated processing (17). Specifically, results displayed that almond, cashew, hazelnut, and walnut remained very stable throughout heat processing (18). Pecan allergens were also stable to in vitro digestion within the body (19). Moreover, while heating certain allergens *may* see a slight reduction in IgE-binding, it is not substantial enough to be used as treatment. Additionally, when other types of processing were tested on tree nuts, it was found that microwave

heating and gamma radiation did not significantly alter the IgE-binding capacity of the allergens at all (18). More studies were done, utilizing both thermal and novel methods of processing, establishing that tree nuts are steadily thermostable and quite resistant to chemical changes at high temperatures. Overall, it was found that no one processing method significantly reduced allergenicity in tree nuts.

Additionally, another extremely common allergen is peanut. It was discovered that boiling peanuts highly reduces their allergenic potential. This happens through the denaturation of allergenic proteins during the boiling process as well as the transferring of low molecular weight (LMW) proteins out of the peanut itself and into cooking water (20). Roasting peanuts, however, has the opposite effect. Roasting the allergen tends to immunogenicity the proteins by generating more IgE antibodies, which only increases the body's reactivity towards the peanut allergen (21). However, not every type of processing greatly affects allergenicity, as in a study done on the Ara h 2 protein within peanuts, it was observed that the structure changed, but the allergenic potential did not (22).

Soy Processing and Allergenicity

Another well-studied allergen was soy. Soy is not often fully consumed in its raw state, almost always making its way into the diet through another processed outlet. The collected evidence potentially proves that soy allergenicity could be reduced by some types of food processing. There also has been no indication that food processing could *increase* the allergenicity of soy. Highly refined soybean oil and other further processed soybean products decrease allergenic potential within the allergen, as the level of soybean proteins within the products are lowered (23). Specifically, when examined for possible effects on allergens, soy products were tested and displayed a decrease in the IgE-binding capabilities; however, the product still had allergenic properties, as IgE-binding still commenced, just at a lower rate (24). Novel food processing methods, like UV pulsed light and microwave heating also decreased allergenicity of soy proteins (25). High hydrostatic pressure (HHP) treatment was also utilized. It was found that soybeans treated with HHP showed significantly reduced allergenicity compared to untreated seeds. HHP could potentially be more effective when combined with other thermal processing methods, but more research is needed (26). Therefore, it is seen that *just* food processing is unlikely to be able to fully destroy the allergenicity of the soy allergen.

Wheat Processing and Allergenicity

Wheat allergy is another prevalent allergy. It seemed that direct heating of wheat did not change much and had the same ratio of IgE-binding as when wheat was ingested raw (27). However, it was observed that heating wheat products at high temperatures can cause the substance to become more difficult to fully digest (28). Adding on, acid hydrolyzed gluten in wheat was shown to induce reactivity within those who did not have a previous history of wheat sensitivity, thus causing more people to face further allergic response (29). Another slew of studies observed goes on to investigate how heating wheat during bread baking has the possibility to eliminate some, though not all, allergenic proteins. It was found that baking can make certain proteins in wheat more resistant to pepsin digestion, potentially leading to further digestive issues (30). Overall, processing had little impact on wheat allergens and did not yield significantly positive results.

In all, it was seen that food processing, while able to reduce allergenicity by some forms of processing in most foods, ultimately did not make much of a positive impact. Processing was able to reduce

IgE-binding and lower overall allergenicity in foods such as soy, milk, and eggs, but a fully hypoallergenic food had never been created; no study found allergens to be completely rid of their allergenicity. Multiple studies also concluded that more research was needed on the foods that were the most promising before any further work could be started. Overall, it is seen that food processing has the possibility of being successful in diminishing IgE-binding within various allergens, but currently does not seem to be completely effective on these listed allergens.

Less common food allergens

On the topic of less common food allergies, apples were also brought up in discussions of the connection between allergenicity of proteins and food processing. A certain investigation found that HHP processing had little effect on apple protein Mal d 1 and did not explore other methods (31). Another study noted that only extreme heat processing reduced the allergen Mal d 3's IgE-binding, but the effort required for such processing may not be justified (32). Overall, while processed apples can result in a potentially decreased allergenicity, current processing methods do not significantly reduce IgE-binding.

Peach allergens are another example of a less common food allergy. When researched, scientists noted that although peach is rather stable in heat, other methods like ultrafiltration processing have the potential to produce a fully hypoallergenic peach nectar. The chemical removal

of skin also proved to be possibly useful (33). However, the process also removed many of the desirable nutrients and elements from the peaches. Thus, while the peach achieved hypoallergenic status, the final product had fewer components than desired (33).

Lupine allergies are also a topic of research. It was noted that microwave heating had limited effects on lupine flour allergenicity (34). Meanwhile, another group of scientists found that autoclaving lupine seeds significantly reduced the 23 and 29 kDa allergens, lowering IgE-binding significantly, though not completely (34). Thus, while thermal processing can reduce lupine allergenicity, it does not fully eliminate it.

Studies investigating wet and dry food processing displayed that the stability of the allergens varied heavily. However, without focusing to varying degrees, the consensus tended to resolve the fact that dry and moist heat food processing is not completely effective on most allergens; some proteins even did not seem to change in response to processing. While some of the foods processed had decreased amounts of symptoms, reactivity still persisted. Therefore, while many allergens decreased in allergenic potential, but none completely.

The same can be said for nonthermal food processing, including processing methods such as proteolysis, a hydrolysis reaction, ultrafiltration, and fermentation. What was seen was that proteolysis can have a positive effect on decreasing the allergenicity of particular allergens, but the overall effect is far and few. Ultrafiltration could be promising in extracting allergenic proteins from others, but more work must be done to fully ensure this. While fermentation has some positive impacts on the allergenicity of some proteins, it is either not enough or other processing types have shown to be more promising. Therefore, similar to moist and dry heat processing, these methods succeeded in lowering allergenicity, but not getting rid of it permanently.

Overall, it is seen that some foods reduced IgE-binding under specific processing methods, none became completely hypoallergenic without any negatives. Most retained some allergenic potential, with some foods showing no positive effects due to their heat-resistant protein structures. Peach was the only food that achieved a fully hypoallergenic product after processing, but even then, it has its own drawbacks.

DISCUSSION

Ultimately, the immediate consensus is that various processing methods can reduce IgE-binding in allergenic foods, such as HHP for soybeans, UV exposure for milk proteins, and ultrafiltration for peaches. However, no single processing method or food has achieved complete elimination of allergenicity. The closest result was the hypoallergenic peach nectar, though it had drawbacks in that it lacked many of the original peach's nutrients.

Current research indicates that no processing method can completely eliminate allergenicity in foods. While some methods can reduce IgE-binding, they do not provide a complete solution for allergy treatment. However, for individuals with minor allergies, reasonable processing techniques, such as choosing boiled over roasted peanuts or microwaving soybean products, may offer some benefit in allergy management.

More research is needed to understand the connection between food processing and allergies. This is an emerging field, and whether processing can be used as an allergy treatment remains debated and evolving. As new technologies and information emerge, ongoing research will continue to explore and expand our understanding of this complex issue. The significant impact of food allergies on many lives will drive further investigation and innovation in this area.

This paper highlights the importance of ongoing research in understanding food allergies. Unlike many resolved medical issues, effective treatment for food allergies remains elusive. Continued investigation and questioning are crucial as we work toward solutions. The challenge of food allergies and their impact on lives drives the need for persistent research and discovery in this field.

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