Molecular Nutrition and Health Research

2024 Volume1,Issue1

Research and Innovation of Production Technology for Low Allergenic Peanut Products

Chunpeng Zhang[1,a,*]

[1]Yantai Rongke Biotechnology Co., Ltd., Yantai, Shandong, China
[a]chunpengzhang02@gmail.com
[*]Corresponding author

Keywords: Low Allergenic Peanut Products, Allergen Reduction, Enzyme Treatment, Ultra high Voltage Technology, Food Safety

Abstract: Hypoallergenic peanut products are developed to address the health risks and nutritional challenges associated with peanut allergy, one of the most common food allergies worldwide. This study delves into the application of various technologies in reducing peanut allergenicity, including chemical, physical, enzymatic, and biological techniques. Specifically, chemical methods reduce IgE binding ability by modifying protein structures; physical methods such as high-temperature treatment and high-pressure treatment can significantly reduce the activity of allergenic proteins while maintaining nutrition; enzyme treatment utilizes enzymatic decomposition or cross-linking to alter the structure of allergens, significantly reducing their allergenicity. In addition, biotechnology methods such as microbial fermentation further enhance the biological activity of peanut protein while reducing the levels of major allergens such as Ara h1 and Ara h2. The research results indicate that by optimizing processing, peanut protein can become safer and more suitable for a wider consumer group, which is of great significance for improving food labeling practices. With the increase of sugar concentration, pressure, and fermentation time, the content of allergens (Ara h1 and Ara h2) in peanuts significantly decreases. Under the premise of controlling pressure, high-pressure treatment can still reduce allergen content to a certain extent while retaining most of the nutritional components.

1. Introduction

Peanuts, as an important crop widely cultivated and consumed worldwide, have extremely high nutritional value and have attracted much attention due to their high content of protein, minerals, and unsaturated fatty acids. However, peanuts are also one of the main causes of food allergies, which can lead to serious allergic reactions and even life-threatening situations for many consumers, especially children. As peanut products become more popular in the global diet, peanut allergy has become a global public health issue. How to effectively reduce the allergenicity of peanut products is a difficult problem that needs to be solved in food science and food engineering research. This study aims to reduce the allergenicity of peanuts and explores an innovative process to minimize the activity of peanut allergens by controlling processing conditions and optimizing process flow, and conducts a comprehensive analysis of the safety, nutritional content and flavor of the final product.

This paper systematically discusses the production technology of hypoallergenic peanut products. After introducing the background of the research and the demand for hypoallergenicity, this paper deeply analyzes the existing technology and its shortcomings, and proposes innovative technical solutions. The research methodology section details the experimental process of development, including the collection and analysis of key data. Furthermore, this paper presents the experimental results and their significance, and discusses the effectiveness of innovative solutions in reducing peanut sensitization. Finally, the paper discusses in depth the limitations and room for improvement of the research, and proposed future research directions.

2. Related Works

Experts have conducted specialized research on the allergenicity of peanut products for a long time. To enhance the functionality and nutritional value of peanut protein, Boukid reviewed innovative strategies in physical, chemical, and biological methods, and emphasized the research needs for reducing allergens and improving protein quality to promote its application as an effective alternative protein [1]. In order to investigate whether foods labeled as "possibly containing trace amounts of peanuts" in the Polish market contain allergens, Krejner Bienias et al. analyzed 30 samples and found that nearly one-third of the foods contained clinically relevant amounts of these two allergens [2]. Geng et al. reviewed the mechanisms, management methods, and basic structures of allergens in peanut allergies, and summarized the progress of epitope localization techniques for peanut allergens. They improved the recognition and modification of allergen epitopes by combining traditional wet chemistry research with structural simulations, promoting advances in allergy management and prevention strategies[3]. Turner et al. proposed the establishment of a "reference dose" through international consensus, below which precautionary allergen ("may contain") labels would not be required. They suggested that peanuts should be considered an example allergen for the hazard characteristics of low-level allergen exposure and recommended evidence-based rapid assessment methods [4].

Yang et al. screened lactic acid bacteria (LAB) with peanut allergy allergy relief and anti-allergy properties. The results showed that LAB reduced the pH of peanut milk and the content of the allergen Ara h1 in peanut paste through fermentation. After fermentation, the allergenic protein of Ara h1 was reduced by 74.65%[5]. To determine the optimal timing and target population for the introduction of peanut products to prevent peanut allergy, Roberts et al. analyzed data from multiple randomized controlled trials and observational studies and found that the reduction in peanut allergy was smaller in high-risk infants (particularly those with severe eczema), at only 4.6% [6]. Hariharan et al. used neutral and alkaline protease hydrolysis to improve the solubility, emulsification and foaming properties of peanut protein, making it suitable for products such as meat analogs, bread, and candy [7]. Abu Risha et al. pointed out that in addition to peanuts and soybeans, other legumes such as peas, chickpeas, lentils, lupins, etc.

were found to be potential allergens that may trigger mild to severe allergic reactions, especially peas and lupins [8]. La Vieille et al. explored the use of PAL (Precautionary allergen labeling) and discussed how to better manage and use PAL based on the latest food allergen recommendations to protect allergic consumers [9]. In a study conducted in bakeries in New York and Miami, Miller et al. found that 4 out of 154 baked goods samples (2.6%) were contaminated with peanuts, with peanut protein content ranging from 0.1 mg/100 g to 650 mg/100 g. The results showed that the risk of accidental exposure to peanut protein cannot be ignored [10]. Chang et al. found that after roasting, most of the Ara h2 in peanuts was fragmented and cross-linked, with the monomer accounting for only 13%. Roasting changed the structure of Ara h2, including disulfide bond rearrangement and decreased α-helix content. Roasting increased the potential allergenicity of Ara h2 monomers, but did not represent a change in the allergenicity of the overall peanut matrix [11]. Kim et al. evaluated the efficacy and safety of 4 mg sublingual peanut immunotherapy and explored the persistence of desensitization after drug withdrawal. The results showed that immunotherapy significantly improved the level of desensitization, with 70% of patients achieving clinically significant desensitization and 36% complete desensitization [12]. To ensure accurate labeling, Eischeid introduced a droplet digital PCR detection method based on PCR (Polymerase Chain Reaction) technology, aiming to improve the sensitivity and accuracy of peanut allergen detection [13]. Hsu et al. found that the immunoreactivity of the major allergen Ara h1 was significantly reduced after using cold argon plasma jet to treat peanut protein extract [14]. Durham & Shamji's study revealed that immunotherapy induces tolerance by reducing allergen-specific TH2 cells, inducing regulatory T and B cells, and producing IgG and IgA antibodies[15]. Existing research showed that the detection sensitivity and accuracy of peanut allergens still have room for improvement. Although new technologies such as droplet digital PCR can provide higher detection sensitivity, there are still challenges in detecting low-concentration allergens.

3. Methods

3.1 Mechanism of Peanut Allergy

Gastrointestinal sensitization is one of the common allergic reactions to peanuts. When patients with peanut allergies first ingest peanuts, their B cells will be induced to produce corresponding IgE antibodies. These IgE antibodies bind to mast cells or basophils through their Fc segments, causing the body to develop a long-term allergic reaction to peanuts. Usually this sensitization state can last for a long time, but if it avoids contact with peanuts for a long time, this sensitization state may gradually weaken. When exposed to peanuts again, peanut protein will specifically bind to IgE on the surface of sensitized mast cells or basophils. After binding, initiate the release of extracellular mediators. The released active mediators include pre stored and newly synthesized ones, among which histamine and other active mediators can trigger the contraction of gastrointestinal smooth muscles, leading to gastrointestinal symptoms such as abdominal pain, diarrhea, nausea, and vomiting. These media can also cause serious allergic reactions in areas such as the skin and respiratory system.

3.2 Methods to Reduce Allergen Sensitization

Food allergies are becoming more and more common in our lives, causing a huge burden on human health and socio-economic aspects, but there is still no effective treatment. People can only reduce the risk of allergies by avoiding eating allergic foods, but this is completely an ideal state. Therefore, reducing or eliminating the allergenicity of allergic foods is an urgent problem that needs to be solved in today's society. Food desensitization technology can be divided into chemical methods, physical methods, enzyme methods, biological methods and composite methods according to different processing methods.

3.2.1 Chemical Methods

The chemical method is to modify the chemical groups on the protein to make it undergo chemical reactions, so as to change the structure and allergenicity of the protein.

3.2.2 Glycosylation

Glycosylation modification is the early stage of the Maillard reaction, where the amino group on the protein undergoes a condensation reaction with the carbonyl group in the reducing sugar. During the processing, proteins are prone to undergo glycosylation reactions with reducing sugars, producing aromatic substances that alter the color, flavor, function, and nutritional value of proteins in food. As a safe protein modification method, glycosylation modification is widely used in the food industry and is one of the most common chemical reactions in food processing, storage and cooking. At the same time, the reaction does not require any chemical reagents as catalysts and can occur by heating at a certain water activity.

3.2.3 Enzyme Treatment

The use of enzyme treatment to reduce the allergenicity of peanut protein mainly relies on two pathways, namely enzyme cross-linking technology and enzyme decomposition technology. Polyphenol oxidase, peroxidase, and glutamine transaminase are commonly used in enzyme cross-linking technology. These enzymes catalyze the formation of cross-linking within or between protein molecules, altering their molecular structure and ultimately leading to changes in protein allergenicity. The use of peroxidase treatment can crosslink tyrosine residues in baked peanuts and exhibit significantly reduced allergenicity. Polyphenol oxidase treatment can crosslink peanut allergenic proteins Arah1 and Arah2, leading to a decrease in allergenicity. When peanut protein is cross-linked by microbial polyphenol oxidase and laccase, the allergenicity of peanuts is actually enhanced.

3.2.4 Ultra High Pressure Desensitization

Most of the current food processing methods are not sufficient to achieve satisfactory results in removing and reducing food allergens, and few of them can really be used in food processing. Therefore, it is necessary to develop other potential processing technologies. The excellent sensory quality and nutritional value of HHP processed foods are the main reasons why they have attracted much attention in recent years. This technology can be carried out without changing the original manufacturing process, pre-treating the raw materials by destroying food allergens, and then using low-allergenic raw materials to produce various foods to effectively reduce the allergen content in food. Another approach is to use HHP as the final step in food processing, where HHP is applied to packaged products while eliminating food allergens. In addition, other food processing technologies can be combined with HHP to reduce the intensity of other processing methods. For example, the temperature used for high-temperature sterilization can be reduced or the amount of additives added can be reduced, and the shelf life of food can be increased. At the same time, HHP can keep the natural flavor of food and reduce people's concerns about food safety. These advantages are not available in other food processing technologies. Therefore, HHP is a very promising food processing technology.

4. Results and Discussion

4.1 Experimental Design

This study aims to evaluate and compare the effects of different methods in reducing the allergenicity of peanut products while maintaining their nutritional and functional properties. The main research methods include chemical modification, enzyme treatment, high hydrostatic pressure (HHP) and microbial fermentation. The experimental design will focus on evaluating the changes in the content of the major allergens Ara h1 and Ara h2 in peanuts and determining their IgE binding capacity.

4.2 Materials

Peanut samples are raw peanuts purchased from a local supplier for all treatments and experiments.

Reducing sugars (e.g., glucose, fructose) of the reagents are used for chemical glycosylation modification.

Enzymes are proteases (e.g., papain, trypsin), polyphenol oxidase, peroxidase, and transglutaminase for enzymatic treatment.

Among the microbial strains, Bacillus subtilis and Bacillus natto are used for fermentation treatment.

High-pressure equipment is a high-pressure treatment equipment capable of reaching a maximum pressure of 600 MPa.

4.3 Data Analysis

In this study, the experiment used glycosylation, enzyme treatment, high pressure treatment and other methods to treat peanuts to reduce their allergenicity. These treatment methods not only effectively reduce the allergenicity of peanuts, but also retain most of the nutrients, providing a feasible process solution for the development of low-allergenic peanut products. The analysis results are as follows:

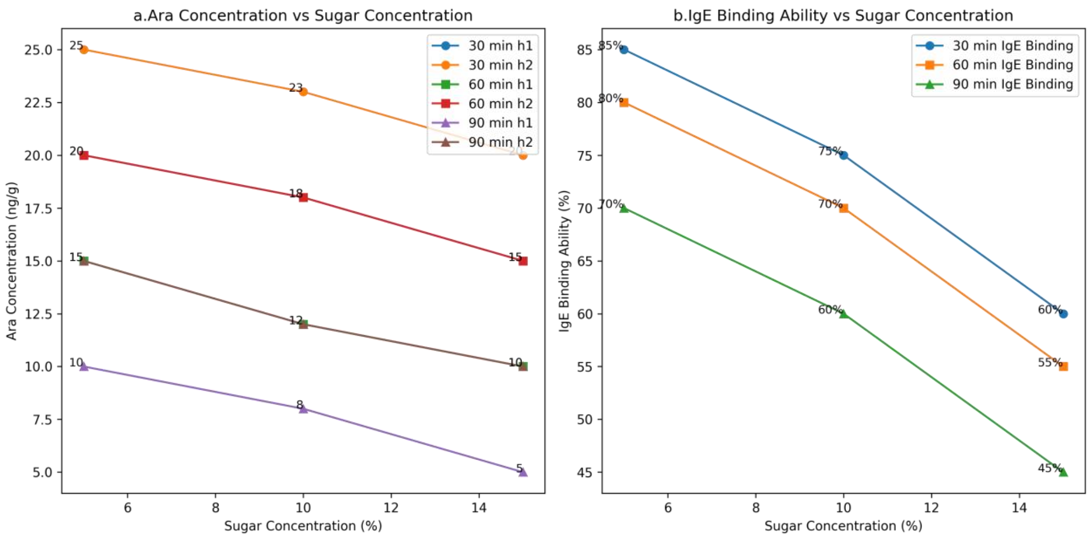

Figure 1. Glycosylation results

With the increase of sugar concentration and the extension of treatment time, the content of allergens (Ara h1 and Ara h2) in peanuts decreases significantly, and the IgE binding capacity also decreases (as shown in Figure 1a and Figure 1b). The results of IgE binding capacity further support the above trend. As the sugar concentration increases and the treatment time prolongs, the IgE binding capacity decreases significantly. At 30 minutes, the IgE binding capacity under 5% sugar concentration treatment is 85%, while under 15% sugar concentration treatment, the IgE binding capacity drops to 60%, as shown in Figure 1b. This indicates that the glycosylation treatment effectively reduces the IgE binding capacity of allergens in peanuts, possibly reducing their allergenicity.

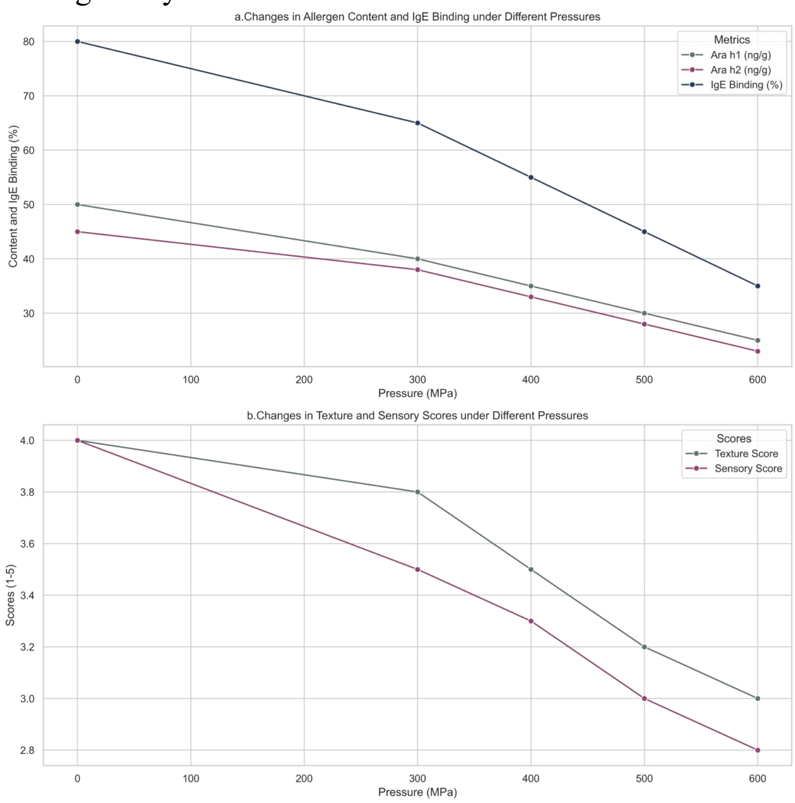

Figure 2. Texture analysis and sensory evaluation test of high pressure processing

As the pressure increases, both Ara h1 and Ara h2 contents in peanuts show a significant downward trend (50 to 25 ng/g and 45 to 23 ng/g). This phenomenon suggests that high-pressure processing helps reduce allergen content and thereby reduce the risk of allergy to peanut products. In addition, the IgE binding capacity also decreases with increasing pressure (from 80% to 35%), further verifying the effectiveness of pressure treatment in reducing product allergenicity, as shown in Figure 2(a). In terms of texture and sensory scores, pressure also affects the texture and sensory quality of peanut products. As the pressure increases, the texture score gradually decreases from 4.0 to 3.0, while the sensory score decreases from 4.0 to 2.8, indicating that high pressure treatment may have a certain impact on the texture and sensory acceptance of the product, as shown in Figure 2(b).

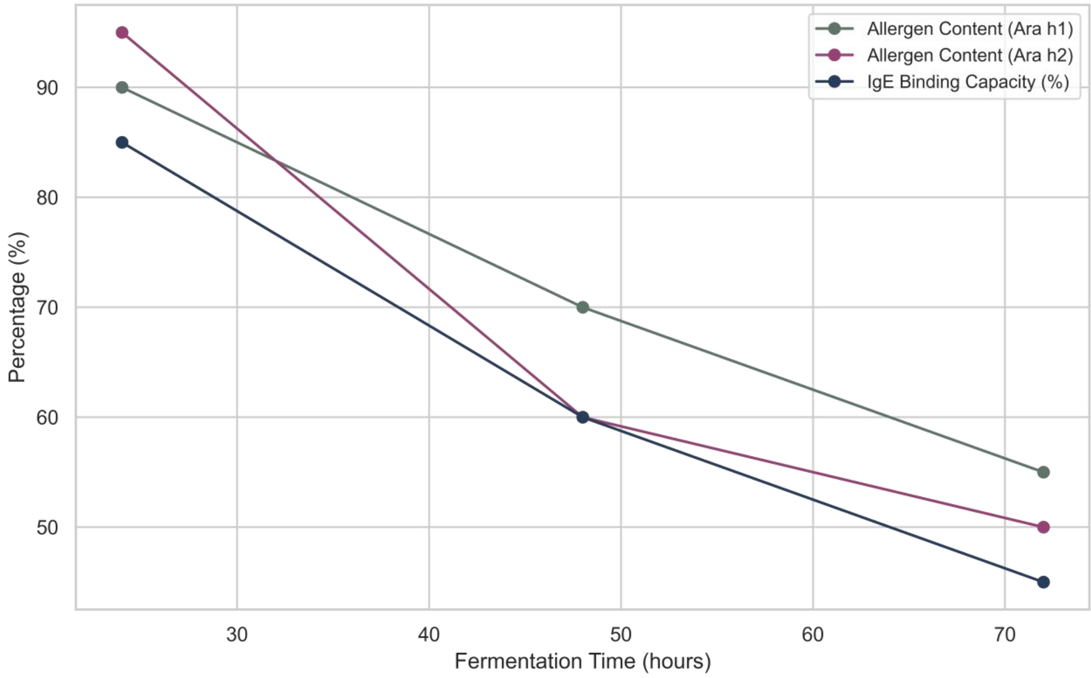

Figure 3. Changes in microbial fermentation treatment

With the prolongation of fermentation time, the contents of the main allergens Ara h1 and Ara h2 in peanuts decrease significantly. The IgE binding capacity also shows a gradual decreasing trend during the fermentation process, and drops to less than 50% of the original level after 72 hours. This trend indicates that the fermentation process effectively weakens the possibility of IgE binding to peanut allergens, further reducing the potential allergenicity of the samples, as shown in Figure 3.

Table 1. Protein content

Pressure (MPa)	Protein Content (%)	Fat Content (%)	Carbohydrate Content (%)	Vitamin Content (mg/100g)	Mineral Content (mg/100g)
0	25.4	48.2	16.3	2.1	1.9
300	24.8	47.9	16.1	2	1.8
400	24.2	47.4	15.8	1.9	1.7
500	23.7	47.1	15.5	1.8	1.6
600	23	46.7	15.3	1.7	1.5

As the pressure increases, the protein content of the peanut samples gradually decreases. In the control group at 0 MPa, the protein content is the highest, at 25.4%, while in the samples treats at 600 MPa, the protein content drops to 23.0%. The fat and carbohydrate contents also decrease slightly under high pressure treatment, but the changes are smaller. Experimental data show that increasing processing pressure will lead to the loss of some nutrients, but under the premise of controlling pressure, high-pressure processing can still reduce the allergen content to a certain extent while retaining most of the nutrients, providing a reliable process reference for the research and development of low-allergenic peanut products, as shown in Table 1.

5. Conclusion

This study focuses on the production technology of low allergenic peanut products, achieving a significant reduction in peanut allergenicity through various process innovations. Experimental data shows that this technology effectively reduces the activity of major allergens while maintaining the nutritional value of the product. This study not only enriches the existing peanut allergy research system, but also provides reliable experimental evidence for the development of hypoallergenic peanut foods. However, the production process used in this study still faces certain challenges in industrial application, such as production cost, process complexity and stability, which need to be optimized. In addition, although the experiment performed well in controlling allergens, individual differences among different populations and the complexity of actual application scenarios have brought certain limitations to the popularization and application of this technology. Future research should focus on further optimizing the production process to reduce costs and ensure stable product quality, and more human trials should be conducted to verify the wide applicability of the product. Through multidisciplinary collaborative advancement, a more solid foundation will be laid for the market promotion of low-allergenic peanut products, which is expected to solve the problem of peanut allergies worldwide and improve the safety and universality of peanut foods.

References

[1] Boukid F. Peanut protein–an underutilised by-product with great potential: a review[J]. International journal of food science & technology, 2022, 57(9): 5585-5591.

[2] Krejner-Bienias A, Grzela K, Kulus M, et al. Peanut contamination in food products: a real danger for allergic people?[J]. Advances in Dermatology and Allergology/Postępy Dermatologii i Alergologii, 2023, 40(5): 625-629.

[3] Geng Q, Zhang Y, Song M, et al. Allergenicity of peanut allergens and its dependence on the structure[J]. Comprehensive Reviews in Food Science and Food Safety, 2023, 22(2): 1058-1081.

[4] Turner P J, Patel N, Ballmer-Weber B K, et al. Peanut can be used as a reference allergen for hazard characterization in food allergen risk management: a rapid evidence assessment and meta-analysis[J]. The Journal of Allergy and Clinical Immunology: In Practice, 2022, 10(1): 59-70.

[5] Yang S, Peng Z, Hardie W J, et al. Screening of probiotic Lactobacillus to reduce peanut allergy and with potential anti - allergic activity[J]. Journal of the Science of Food and Agriculture, 2024, 104(4): 2006-2014.

[6] Roberts G, Bahnson H T, Du Toit G, et al. Defining the window of opportunity and target populations to prevent peanut allergy[J]. Journal of Allergy and Clinical Immunology, 2023, 151(5): 1329-1336.

[7] Hariharan S, Patti A, Arora A. Functional proteins from biovalorization of peanut meal: advances in process technology and applications[J]. Plant Foods for Human Nutrition, 2023, 78(1): 13-24.

[8] Abu Risha M, Rick E M, Plum M, et al. Legume allergens pea, chickpea, lentil, lupine and beyond[J]. Current Allergy and Asthma Reports, 2024, 24(9): 527-548.

[9] La Vieille S, Hourihane J O B, Baumert J L. Precautionary allergen labeling: what advice is available for health care professionals, allergists, and allergic consumers?[J]. The Journal of Allergy and Clinical Immunology: In Practice, 2023, 11(4): 977-985.

[10] Miller T A, Koppelman S J, Bird J A, et al. Peanut cross-contamination in randomly selected baked goods[J]. Annals of Allergy, Asthma & Immunology, 2022, 128(4): 439-442.
[11] Chang X, Zhou X, Tang Y, et al. Effect of processing on the structure and allergenicity of peanut allergen Ara h 2 roasted in a matrix[J]. Journal of Agricultural and Food Chemistry, 2022, 70(2): 626-633.
[12] Kim E H, Keet C A, Virkud Y V, et al. Open-label study of the efficacy, safety, and durability of peanut sublingual immunotherapy in peanut-allergic children[J]. Journal of Allergy and Clinical Immunology, 2023, 151(6): 1558-1565. e6.
[13] Eischeid A C. Optimised multiplex droplet digital PCR is more precise, but not more sensitive, than real-time PCR for the detection of allergenic peanut[J]. Food Additives & Contaminants: Part A, 2022, 39(11): 1797-1805.
[14] Hsu F C, Lin W T, Hsieh K C, et al. Mitigating the allergenicity of peanut allergen Ara h 1 by cold atmospheric pressure argon plasma jet[J]. Journal of the Science of Food and Agriculture, 2023, 103(6): 3017-3027.
[15] Durham S R, Shamji M H. Allergen immunotherapy: past, present and future[J]. Nature Reviews Immunology, 2023, 23(5): 317-328.