

Allergic Diseases in Humans Caused by House Dust Mites

Phuwit Kanjanarujee¹ Ratnapree Mornchan² Sarunrak Wiwatwongsakul³

Chawanakorn Klumwilai⁴ and Nitis Smanthong^{5*}

¹ Suankularb Wittayalai School, Thailand

² Triamudom Suksa School, Thailand

³ Sarasas Ektra School, Thailand

⁴ Potisarnpittayakorn School, Thailand

⁵ Faculty of Medicine, Praboromarajchanok Institute, Thailand

*E-mail: nitis.sman@gmail.com Tel. (+66)821557008

(Received 09/02/2026, Revised 04/05/2026, Accepted 03/06/2026)

Abstract

House dust mites (HDMs) are microscopic arthropods recognized as a major source of indoor allergens worldwide, contributing substantially to allergic diseases such as asthma, allergic rhinitis, allergic conjunctivitis, and atopic dermatitis. Their remarkable environmental adaptability facilitates persistence in domestic settings and continuous production of allergens, including cysteine protease (Der p1), chymotrypsin (Der p6), and tropomyosin (Der p10), as well as microbial components such as lipopolysaccharides and beta-glucans, which enhance allergenicity and modulate immune responses. These allergens activate epithelial and immune cells, promoting type II inflammation that underlies the pathogenesis of allergic disorders. This review consolidates current knowledge of HDMs biology, geographic distribution, allergen profiles, immune mechanisms, and clinical manifestations, while highlighting recent advances in diagnostic and therapeutic approaches. Literature was systematically reviewed from databases including Google Scholar, PubMed, and Scopus using the keywords “house dust mite,” “allergens,” “inflammation,” and “treatment”. A comprehensive understanding of HDMs and their allergenic properties is critical for the development of more effective therapeutic strategies and the improvement of patients’ quality of life.

Keywords: House dust mites, Allergic diseases, Allergens

1. Introduction

House dust mites (HDMs) are microscopic arthropods belonging to the subclass Acari and constitute one of the most important sources of indoor allergens worldwide. The predominant HDMs species implicated in human allergy include *Dermatophagoides pteronyssinus*, *D. farinae*, *Euroglyphus maynei*, and *Blomia tropicalis*, with the latter being particularly prevalent in tropical and subtropical regions. HDMs thrive in warm, humid environments and feed primarily on organic debris such as human skin scales, fungi, and bacteria. Although invisible to the naked eye, HDMs and their allergenic by-products, including faecal pellets, shed exoskeletons, and eggs, are major contributors to allergic diseases such as asthma, allergic rhinitis, allergic conjunctivitis, and atopic dermatitis (Alanazi & Li, 2020; Jurkiewicz et al., 2025). HDMs allergens comprise a diverse array of protein antigens, including proteases, tropomyosins, and chitinases, as well as non-protein immunomodulatory components such as lipopolysaccharides and fungal beta-glucans, which collectively

enhance their allergenic potency (Alanazi & Li, 2020). Their rapid life cycle, high reproductive capacity, and remarkable environmental adaptability facilitate persistent colonization of household environments, resulting in continuous allergen exposure. HDMs allergy represents one of the most prevalent forms of allergic sensitization, affecting an estimated 65-130 million individuals worldwide. A substantial proportion of affected patients develop allergic asthma, with HDMs sensitization accounting for up to 90% of asthma-associated hypersensitivity responses in certain populations (Jurkiewicz et al., 2025). The global burden of HDMs-induced allergic disease is particularly pronounced among children and genetically predisposed individuals. In this context, allergen immunotherapy (AIT) has emerged as an effective disease-modifying therapeutic strategy (Kim, 2023). Nevertheless, the widespread application of AIT remains constrained by multiple factors, including safety concerns, variable efficacy, and challenges related to allergen standardization. Recent advances in recombinant allergen technology, hypoallergenic vaccine design, and artificial intelligence-driven epitope mapping highlight the need for innovative, precision-based approaches to enhance treatment safety, efficacy, and long-term disease control.

This review provides a comprehensive overview of current knowledge and recent advances in house dust mite (HDMs) biology, allergen characterization, therapeutic strategies, and emerging technological innovations relevant to HDMs research and management.

2. Methodology

A systematic literature search was conducted across multiple databases, including Google Scholar, PubMed, and Scopus, to identify relevant publications published between 2010 and 2025. The search strategy employed keywords such as “house dust mite,” “allergens,” “inflammation,” “treatment,” and “innovation.” Inclusion criteria were restricted to peer-reviewed scientific articles published in English, while non-English publications and non-scientific sources were excluded to ensure methodological rigor. Eligible studies were thematically synthesized, and the quality of evidence was assessed using standardized evaluation frameworks to ensure the validity, reliability, and relevance of the review’s conclusions.

3. Results and Discussion

3.1 Characteristics of House Dust Mites (HDMs)

Mites are extremely small arthropods that are potent allergens, causing asthma, rhinitis, and dermatitis in humans. Mites are classified as: Phylum: Arthropoda, Class: Arachnida, Subclass: Acari (Mites and Ticks), Order: Astigmata, Superfamily: Pyroglyphoidea, Family: Pyroglyphidae, Echimyopodidae, Genus: *Dermatophagoides* and *Euroglyphus*. The most important HDMs are *Dermatophagoides pteronyssinus* (Der p), *Dermatophagoides farinae* (Der f), and *Euroglyphus maynei* (Eur m). Another key allergenic species, *Blomia tropicalis*, belongs to the family Echimyopodidae but thrives in tropical and subtropical homes, where it is a dominant source of allergens (Bergmann, 2022; Miller, 2019). It measures 0.1–0.6 mm in length (Bergmann, 2022). The body and appendages are covered with fine setae (hair-like structures), whose functions are not fully understood but may include mechanical and sensory roles. In the larval stage, it consists of three pairs of legs, while nymphs and adults carry four pairs. Each leg is segmented and ends with specialized pads and claws that enable mites to grip fibers, surfaces, and particles in their habitat (Miller, 2019; Saha, 2019). Similar to other

arthropods, mites must periodically molt their exoskeleton to grow; these shed cuticles, containing chitin and allergenic proteins, represent an additional source of allergens in the indoor environment (Bergmann, 2022; Miller, 2019).

3.1.1 Reproduction and Life Cycle

HDMs lifespan is broadly divided into two halves: the developmental phase (from egg to adult) and the reproductive phase, with each immature stage occupying a roughly equal duration. HDMs undergo sexual reproduction, with a well-defined series of developmental stages and mature through four stages: egg, larva, protonymph, and tritonymph, finally reaching adulthood (Bergmann, 2022; Linn et al., 2024). Progression to the next developmental stage involves a 2–3 days quiescent phase, followed by molting. Temperature significantly influences the lifespan of mites (Bergmann, 2022).

Reproduction of HDMs begins with mating. The female possesses a ventral ovipore near the posterior legs, connected dorsally to a sperm receptacle that links with the ovaries, while the male is equipped with a sclerotized aedeagus and a pair of copulatory suckers adjacent to the anus. Supported by suction pads on the hind legs, males cling tightly to females during copulation, which may last several hours up to 48 hours, with the female carrying the male on her dorsum throughout this period. Fertilization: Each female deposits approximately 50–80 eggs over her lifetime at room temperature. After about eight days, a six-legged larva emerges and sequentially develops through the protonymph and tritonymph stages before becoming an adult (Bergmann, 2022; Miller, 2019). In conclusion, the reproduction and life cycle of HDMs combine a multi-stage development, prolonged mating strategies, modest but sustained egg production, and pheromone-based communication. These features not only guarantee their persistence in human environments but also contribute significantly to allergen exposure through eggs, molted skins, and adult waste products (Bergmann, 2022).

3.1.2 Respiration, Water Balance, and Temperature

The global distribution of HDMs is primarily determined by humidity and temperature. Due to their minute size, gas exchange is mainly through the outer cuticle tracheal system—reduced or absent in many species (not all)—instead, they rely on passive gas exchange through a thin, water-permeable cuticle. Their bodies contain over 70% water, and a relative humidity of approximately 60–80% (depending on the species) is optimal for growth and reproduction, while populations decline when humidity falls below 50% (Bergmann, 2022). A specialized supracoxal gland regulates water balance by concentrating on sodium and potassium ions to osmotically absorb water vapor from the environment (Miller, 2019). Humidity is therefore critical to HDMs survival, influencing both population density and allergen production. At high humidity, mites are able to maintain water balance; however, such conditions also promote the growth of competing molds, while at low humidity, remaining below the critical threshold of 50%, dust mites exhibit a progressive decline in feeding activity, reproduction, and allergen production (Miller, 2019). Climate change and rising global temperatures are predicted to increase indoor humidity and allergen exposure, while urbanization and air conditioning may also alter mite habitats by promoting localized moisture accumulation despite overall humidity reduction (Seow et al., 2024). Optimal temperatures for survival and reproduction occur between 20 and 28 °C. Mites can tolerate extreme temperatures for limited periods, surviving exposure to -25 °C for several hours, +50 °C for over 4 hours, and +60 °C for up to 1 hour. Below the optimal range, particularly at 15 °C,

developmental rates are markedly reduced. The cold mortality threshold for *D. farinae* is -18 °C after 48 hours of exposure, while exposure to -28 °C for more than 6 hours is lethal to *D. pteronyssinus*, *D. farinae*, and *E. maynei*. In contrast, the heat mortality threshold for *D. pteronyssinus* is 45.5 °C following 24 hours of exposure (Bergmann, 2022).

3.1.3 Food, Digestion, and Excretion

HDMs feed on organic debris such as human skin scales, fungi, yeasts, and bacteria. Allergenic exposure is not limited to live mites but also arises from their faecal pellets, shed exoskeletons, and other remains, which are major contributors to indoor allergen load (Bumbacea et al., 2020). The HDMs gastrointestinal (GI) tract includes a mouth with movable chelicerae for grasping food, salivary glands, an esophagus, small and large intestines, and an anal opening. Throughout their lifespan, a single mite produces approximately 1,000 faecal particles (the allergen-containing particles), each measuring about 25 µm, and each surrounded by a peritrophic membrane (Allergen substance) containing proteolytic digestive enzymes, facilitate digestion and enable coprophagy—the re-ingestion of faecal material—to maximize nutrient extraction and survival in nutrient-poor environments. However, the significant role and problem of peritrophic membrane in atopic allergen are still poorly understood (Miller, 2019).

3.2 Geographic Distribution of HDMs and their Allergens

The geographical distribution of HDMs is primarily determined by humidity and temperature. Among HDMs, Der p and Der f represent the most important allergen sources for allergic patients globally, whereas *B. tropicalis* requires a very humid (80%) and hot climate (30 °C) and is thus restricted to tropical and subtropical areas (Huang et al., 2023). In the Southeast Asian countries, the detection rates of Der f1 and Der p1 varied in Indonesia, Malaysia, Thailand, and Vietnam, compared to South Korea. Der f1 was the highest in Thailand, while that of Der p1 was the highest in Indonesia, compared to South Korea (Kim et al., 2024).

HDMs allergens are composed of both protein antigens and non-protein immunomodulatory elements. There are over 30 protein allergens such as a cysteine protease (Der p1), chymotrypsin (Der p6), tropomyosin (Der p10), chitinases (Der p15), trypsin (Der p3), alpha-amylase (Der p4), and fatty-acid binding protein (Der f13). In addition to protein allergens, HDMs also contain various microbial components, such as lipopolysaccharide (LPS), which acts as a ligand for TLR-4 receptors on pulmonary epithelial cells, resulting in the release of epithelial-derived Th-2 promoting cytokines in airway inflammation and bronchial hyper-reactivity, beta-glucan (a component of fungal spores), and various bacterial cell wall components (Alanazi & Li, 2020).

3.3 Sensitization reaction to HDMs Allergens

House dust contains numerous species of mites; nevertheless, only three of them are very common in homes worldwide: Der p, Der f, and *Euroglyphus maynei* (Eur m). They can be found in temperate climate, but it is also important to mention *Blomia tropicalis* (Blo t), which is prevalent in tropical and subtropical climate (Bumbacea et al., 2020). A community-based study of 1,239 adolescents aged 13–14 years found that HDMs sensitization and asthma were associated with Der p allergen concentrations as low as 0.29 µg/g dust. Notably, 96.3% of asthmatic subjects were exposed to Der p1 levels below the commonly accepted

sensitization threshold of 2 µg/g dust, suggesting that sensitization may occur at lower allergen concentrations than previously proposed, particularly in tropical environments (Sundaru, 2006).

Type II inflammation triggered by HDMs allergens involves the activation of pattern recognition receptors (PRRs) on epithelial cells. Upon allergen exposure, epithelial cells become activated and initiate immune responses. For instance, Der p1, a cysteine protease, along with several serine proteases such as Der p3, Der p6, and Der p9, can degrade epithelial tight junctions through the activation of protease-activated receptor 2 (PAR2) (Jacquet, 2021), thereby compromising the epithelial barrier (Hendriks, 2020).

Additionally, Der p2 engages Toll-like receptors 2 and 4 (TLR2/4), stimulating epithelial cells to produce innate cytokines. A novel pathway described by Smole et al. (2020) involves the fatty acid-binding protein (FABP) allergen Der p13, which induces dissociation of hexameric forms of the soluble pattern recognition receptors (PRRs) serum amyloid A (SAA). This dissociation promotes the release of interleukin-33 (IL-33) from epithelial cells through formyl peptide receptor 2 (FPR2) signaling.

The resulting proinflammatory cytokines from epithelial cells activate group 2 innate lymphoid cells (ILC2s) and dendritic cells. The latter migrate to draining lymph nodes, where they present allergens to naïve T cells, leading to their differentiation into T helper 2 (TH2) cells, which subsequently home to the lungs.

During allergic airway inflammation, hallmark features of asthma are driven by cytokines secreted by both ILC2s and TH2 cells. IL-4 facilitates class switching in allergen-specific B cells to produce immunoglobulin E (IgE); IL-5 recruits eosinophils; and IL-13 contributes to goblet cell hyperplasia, excessive mucus production, smooth muscle hyperresponsiveness, and further disruption of epithelial integrity. Additional cytokines, such as granulocyte-macrophage colony-stimulating factor (GM-CSF)—which promotes the proliferation and differentiation of granulocytes and macrophages to enhance their functions in host defense (Mu et al., 2021), and thymic stromal lymphopoietin (TSLP)—a pleiotropic cytokine that acts on multiple cell surfaces, affecting their maturation, survival and recruitment, and it referred to as alarmins (Gauvreau et al., 2020), also play important roles in amplifying the inflammatory response (Hendriks, 2020) (Figure 1).

The immunological characteristics of HDMs-induced allergic diseases were examined, with particular emphasis on allergen component-specific sensitization profiles, their distinguishing features, and their correlations with clinical manifestations, as assessed through specific IgE (sIgE) quantification. Sensitization to HDMs allergens was highly prevalent, with 96.67% of the study population demonstrating positive reactivity. The highest sensitization rates were observed for Der p1 and Der f1 (each 95.83%), followed by Der p2 (86.67%), Der f2 (85.83%), and Der p23 (62.50%). Correlation analyses of sIgE concentrations across HDMs allergen components revealed predominantly strong positive associations, most notably between Der p2 and Der f2 ($r = 0.96$, $p < 0.01$), suggesting a shared immunological basis for sensitization to these group 2 allergens. Collectively, these findings identify Der p1, Der f1, Der p2, Der f2, and Der f23 as the principal major allergens in HDMs-driven sensitization. Notably, Der p5, Der p7, and Der p23 exhibited age-dependent sensitization patterns, highlighting the influence of host maturation on allergen-specific immune responses. From a clinical perspective, Der p2 and Der f2 were found to be closely associated with respiratory allergic manifestations, while Der p23 demonstrated a particularly strong association with asthma development, underscoring its potential relevance as a biomarker in disease stratification and severity assessment (Xu et al., 2025).

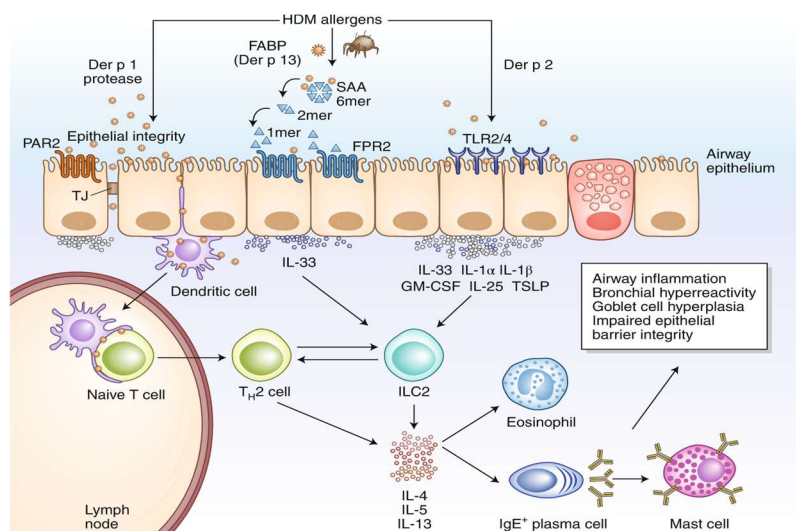


Figure 1 Schematic representation of type II inflammation induced by HDM allergens.
Adapted from Hendriks (2020).

3.4 House Dust Mites Associated Diseases

HDMs allergy belongs to the most important allergies and affects approximately 65–130 million people worldwide (Huang et al., 2023), with most of the patients suspected of allergic asthma by showing Type I hypersensitivity reactions. An untreated patient may lead to the development of severe disease manifestations, such as asthma, perennial allergic rhinitis, and atopic dermatitis (Huang et al., 2023; Jurkiewicz et al., 2025).

Asthma: HDMs are one of the major triggers of asthma, especially in individuals with a genetic predisposition. They cause type 2 bronchial inflammation, which is a hallmark of allergic asthma (Caraballo, 2024). It can trigger airway inflammation and structural changes through classical IgE-mediated pathways, although non-IgE mechanisms may also contribute. IgE, the antibody typically associated with allergic reactions, can promote the production of leukotriene C4. This molecule promotes airway smooth muscle growth, a key feature of severe asthma. Interestingly, this effect occurred without the need for specific IgE antibodies, suggesting that HDMs can activate non-IgE pathways that contribute to asthma (Abu Khweek et al., 2020).

Rhinitis: Allergic rhinitis is one of the most common long-term conditions and is caused by an IgE-mediated allergic reaction. People with a family history of allergies, asthma, or atopic dermatitis have a higher risk of developing it. The condition happens when the body reacts to inhaled allergens, such as pollen or dust mites. IgE antibodies on immune cells (mast cells and basophils) recognize these allergens. This leads to the release of histamine and leukotrienes, which cause nasal congestion and sneezing (Eguiluz-Gracia et al., 2020; Weaver-Agostoni et al., 2023). Allergic rhinitis is one of the most common allergy triggers among children in Eastern Thailand (Dardaranonda et al., 2022).

Allergic conjunctivitis: It is the most common ocular condition in allergic children and is classified into perennial allergic conjunctivitis (PAC) with 61.60%, followed by seasonal allergic conjunctivitis (SAC) with 21.30%, vernal keratoconjunctivitis (VKC) with 12.20%, and atopic keratoconjunctivitis (AKC) 4.90%. This condition frequently co-occurs with rhinitis (97.6%) (Jongvanitpak et al., 2022).

Atopic dermatitis: It is a common, long-lasting skin condition that often occurs alongside other allergic diseases like asthma and food allergies. These connections are complex and not yet fully understood. Both IgE-mediated (allergic) and non-IgE-mediated immune responses seem to play a role in AD. The symptoms are a weakened skin barrier, which is partly due to reduced or defective skin proteins like filaggrin and claudins, as well as changes in skin lipids, especially ceramides. This damaged barrier makes it easier for allergens, microbes, and irritants from the environment to enter the skin and come into contact with immune cells. As a result, AD patients are more likely to develop both type I (immediate) and type IV (delayed) hypersensitivity (Bumbacea et al., 2020).

3.5 Approaches in Immunotherapy for HDMs Allergy

Allergic diseases are characterized by dysregulated immune responses. Allergen immunotherapy (AIT) is a well-established and highly promising treatment for allergic rhinitis and asthma and has gained increasing attention for the management of HDMs sensitization through the use of modified HDMs allergens. Despite its therapeutic potential, AIT continues to face significant limitations, underscoring the need for more precise and modernized approaches to optimize efficacy and safety. Current AIT delivery strategies include subcutaneous immunotherapy (SCIT), sublingual immunotherapy (SLIT), intralymphatic immunotherapy (ILIT), and epicutaneous immunotherapy (EPIT) (Kim, 2023).

3.5.1 Types of HDMs Allergens in AIT Development

Peptides and modified recombinant allergens - Designed to be recognized by antigen-presenting cells via the major histocompatibility complex (MHC), leading to T-cell activation.

Allergoids - Modified allergens that lack conformational IgE epitopes but retain linear T-cell epitopes, reducing allergic responses while preserving immunogenicity. Allergoids are well suited for sublingual administration, with safety, tolerability, and efficacy. They may offer greater cost-effectiveness compared to other AIT options.

Nucleic acid - based approaches - Although high doses or repeated injections may cause serious adverse events such as anaphylaxis or even mortality, messenger RNA (mRNA) remains of interest for vaccine development.

Conjugation and adjuvants - Combining allergoids or modified recombinant allergens with adjuvants such as aluminum hydroxide (well-known), calcium phosphate, and microcrystalline tyrosine to promote a Th1-dominant response and interferon- γ secretion, thereby counteracting the Th2-mediated allergic reaction.

3.5.2 Challenges and Necessary Developments in AIT

The challenges and necessary developments fall into three main categories.

3.5.2.1 Safety and efficacy of treatment delivery

Injection routes and AIT products require further optimization to improve safety and effectiveness. Allergen modifications, a combination of HDMs allergen components, and rigorous quality control are essential for immune tolerance. Long treatment duration, painful injections, and adverse effects reduce patient and clinician acceptance.

3.5.2.2 Incomplete understanding of AIT mechanisms of action.

Deeper mechanistic insights are critical for the rational design and improvement of AIT. It may, in certain contexts, suppress not only allergen-specific immune responses but also broader, nonspecific immune activity.

3.5.2.3 Need for reliable tools to assess and predict treatment outcomes.

Biomarker development is needed to monitor and predict AIT efficacy, such as immunoglobulin E (IgE), IgG-subclasses, serum inhibitory activity for IgE (Qin et al., 2024). Component-resolved diagnosis supports precision diagnosis and personalized medicine.

3.5.3 Clinical Applications in Thailand

In Thailand, the first reported case of SLIT tablet therapy for HDMs allergy in a patient with severe atopic dermatitis (AD) demonstrated promising clinical improvement (Kiatiwat et al., 2024). For SCIT, a study in moderate-to-severe allergic rhinitis (AR) patients already on intranasal corticosteroids found that one-year HDMs SCIT significantly reduced symptoms and medication use. However, longer-term studies are needed to confirm potential disease-modifying effects (Suratannon et al., 2024; Yuenyongviwat et al., 2025).

3.6 Technological Advances and Innovations in HDMs Control and Therapy

Numerous studies have investigated strategies for controlling HDMs populations in indoor environments, including the physical method such as removal of bedding and fabric materials, regular vacuuming, heating, freezing, and washing; the use of plant-derived extracts as mint essential oils, linalool as active compounds, in adult HDMs (Cai et al., 2025), and the application of chemical agents such as acaricides. Ultraviolet-C irradiation is lethal to a wide range of *D. pteronyssinus* and *D. farinae* by damaging their nucleic acids (DNA and RNA) with immediate mortality of 100% in direct irradiation at 10 cm distance for 60 mins. UV-C radiation also reduced the egg hatchability greater than 50% (Lah et al., 2012). More recently, ozone-based fumigation has gained attention as an effective HDMs control method. Ozone fumigation at a concentration of 30 mg L⁻¹ for 3 hours resulted in complete eradication of adult HDMs. Furthermore, increasing the ozone concentration to ≥40 mg L⁻¹ for the same exposure duration reduced HDMs allergen levels by more than 50%, representing a significantly greater reduction compared with treatment at 30 mg L⁻¹ (45.8%) (Pumnuan et al., 2020). However, ozone is a toxic inhalant for humans. Avoiding direct inhalation is essential due to its well-documented pulmonary toxicity. Therefore, ozone should be used for air and surface disinfection only in unoccupied spaces. In parallel with environmental control strategies, advances in modern technologies, particularly artificial intelligence (AI), are transforming prophylactic vaccine development for HDMs allergy. For instance, a sublingual immunotherapy (SLIT) tablet targeting HDMs allergy—marketed globally as Acarizax and developed in Denmark—is available for adults with confirmed HDMs-induced allergic rhinitis or allergic asthma (Sidenius et al., 2021). AI-driven approaches have been employed to map B-cell and T-cell epitope interactions of the HDMs allergen Sui p2, enabling rational antigen redesign. Using this approach, 29 amino acid residues were substituted with alanine to generate a hypoallergenic variant with reduced IgE-binding capacity, enhanced IgG-binding potential, and a threefold increase in MHC class II-restricted T-cell epitopes relative to the native antigen. These findings underscore the utility of AI-guided alanine mutagenesis as a promising strategy for the development of safer and more effective HDMs vaccines (Arevalo & Ramos, 2025).

4. Conclusions

HDMs are small arthropods that include *D. pteronyssinus* (Der p), *D. farinae* (Der f), *E. maynei* (Eur m), and *B. tropicalis* (Blo t). Their survival and reproduction are highly dependent on temperature and humidity. The HDMs life cycle consists of four stages: egg, prelarva, larva, protonymph, deutonymph, tritonymph, and adult. HDMs allergens comprise protein antigens and non-protein immunomodulatory components, with over 30 protein allergens, including cysteine protease (Der p1), chymotrypsin (Der p6), tropomyosin (Der p10), and chitinases (Der p15). In addition to proteins, HDMs carry microbial elements such as lipopolysaccharides (LPS), beta-glucan (from fungal spores), and bacterial cell wall components, all of which enhance allergenicity. These allergens are major triggers of asthma, allergic rhinitis, conjunctivitis, and atopic dermatitis, particularly in children. AIT is an effective treatment strategy, with sublingual (SLIT) and subcutaneous (SCIT) immunotherapy showing success in managing HDMs-induced allergic rhinitis and atopic dermatitis in Thailand. Continued development of AIT strategies is needed to improve safety, efficacy, and long-term disease modification.

Despite considerable advances in understanding the role of HDMs in allergic diseases, significant knowledge gaps remain. Current evidence is predominantly derived from temperate regions, leaving HDMs diversity, regional allergen profiles, and environmental determinants of exposure in tropical settings largely underexplored. The impact of climate change on HDMs ecology and allergen burden also remains incompletely characterized. Additionally, emerging evidence suggests that HDMs-indoor microbiome interactions may contribute to allergic sensitization, though the underlying mechanisms are poorly understood. Future research should prioritize longitudinal cohort studies, multi-omics approaches, and precision medicine frameworks to advance the prevention, diagnosis, and treatment of HDMs-related allergic diseases.

5. References

- Abu Khweek, A., Kim, E., Joldrichsen, M. R., Amer, A. O., & Boyaka, P. N. (2020). Insights into mucosal innate immune responses in house dust mite-mediated allergic asthma. *Frontiers in immunology*, 11, 534501. <https://doi.org/10.3389/fimmu.2020.534501>
- Alanazi, H. H., & Li, X. D. (2020). Modulation of type 2 inflammation by sensing immunomodulatory RNA in house dust mite and viruses. *Journal of Allergy and Infectious Diseases*, 2(1), 17-23. <https://doi.org/10.46439/allergy.2.017>
- Arevalo, C. F., & Ramos, J. D. (2025). Artificial intelligence-assisted hypoallergenic sui p 2 design as a potential prophylactic vaccine for house dust mites allergies. *Acta Manilana*, 73, 17-26. <https://doi.org/10.53603/actamanil.73.2025.ncbh2047>
- Bergmann, K. C. (2022). Biology of house dust mites and storage mites. *Allergo Journal International*, 31, 272-278. <https://doi.org/10.1007/s40629-022-00231-8>
- Bumbacea, R. S., Corcea, S. L., Ali, S., Dinica, L. C., Fanfare, I. S., & Boda, D. (2020). Mite allergy and atopic dermatitis: is there a clear link? (review). *Experimental and therapeutic medicine*, 20(4), 3554-3560. <https://doi.org/10.3892/etm.2020.9120>
- Cai, H., Zhang, X., Lin, Z., Li, S., Lin, H., & Lin, Y. (2025). Mint essential oil: a natural and effective agent for controlling house dust mites. *PloS one*, 20(2), e0318639. <https://doi.org/10.1371/journal.pone.0318639>

- Caraballo, L. (2024). Exploring the relationship between house dust mites and asthma. *Expert Review of Clinical Immunology*, 20(9), 1019-1022. <https://doi.org/10.1080/1744666X.2024.2346585>
- Dardaranonda, B., Tansavatdi, T., & Tattiyakul, P. (2022). Patterns of aeroallergen sensitization among children with allergic rhinitis in eastern Thailand. *Burapha Journal of Medicine*, 9(1), 28-41. <https://he01.tci-thaijo.org/index.php/BJmed/article/view/251718>
- Eguiluz-Gracia, I., Mathioudakis, A. G., Bartel, S., Vijverberg, S. J. H., Fuertes, E., Comberiati, P., Cai, Y. S., Tomazic, P. V., Diamant, Z., Vestbo, J., Galan, C., & Hoffmann, B. (2020). The need for clean air: The way air pollution and climate change affect allergic rhinitis and asthma. *Allergy*, 75(9), 2170-2184. <https://doi.org/10.1111/all.14177>
- Gauvreau, G. M., Sehmi, R., Ambrose, C. S., & Griffiths, J. M. (2020). Thymic stromal lymphopoietin: its role and potential as a therapeutic target in asthma. *Expert Opinion on Therapeutic Targets*, 24(8), 777-792. <https://doi.org/10.1080/14728222.2020.1783242>
- Hendriks, R. W. (2020). A soluble allergen sensor sounds the alarm. *Nature immunology*, 21(7), 724-726. <https://doi.org/10.1038/s41590-020-0709-2>
- Huang, H. J., Sarzsinszky, E., & Vrtala, S. (2023). House dust mite allergy: The importance of house dust mite allergens for diagnosis and immunotherapy. *Molecular immunology*, 158, 54-67. <https://doi.org/10.1016/j.molimm.2023.04.008>
- Jacquet, A. (2021). Characterization of innate immune responses to house dust mite allergens: pitfalls and limitations. *Frontiers in Allergy*, 2:662378. <https://doi.org/10.3389/falgy.2021.662378>
- Jongvanitpak, R., Vichyanond, P., Jirapongsananuruk, O., Visitsunthorn, N., & Pacharn, P. (2022). Clinical characteristics and outcomes of ocular allergy in Thai children. *Asian Pacific journal of allergy and immunology*, 40(4), 407-413. <https://doi.org/10.12932/AP-160519-0564>
- Jurkiewicz, K., Jutel, M., & Smolinska, S. (2025). Update on HDM allergy: principal changes over the years. *International journal of molecular sciences*, 26(12), 5660. <https://doi.org/10.3390/ijms26125660>
- Kiatiwat, P., Mitthamsiri, W., Boonpiyathad, T., Pradubpongsa, P., & Sangasapaviliya, A. (2024). Successful treatment of atopic dermatitis with house dust mite sublingual immunotherapy tablets. *Asian Pacific journal of allergy and immunology*, 42(3), 253-257. <https://doi.org/10.12932/AP-231120-1004>
- Kim, D., Jeon, H., Park, J. Y., Othman, H., Hien, T. T., Lestari, P., Tantrakarnapa, K., & Lee, K. (2024). Characteristics of house dust mite allergens in Southeast and East Asia with the effect of hygienic practices. *Indoor Environments*, 1(2), 100010. <https://doi.org/10.1016/j.indenv.2024.100010>
- Kim, I. S. (2023). New approaches to immunotherapy in house dust mite allergy. *Clinical and experimental pediatrics*, 66(4), 161-168. <https://doi.org/10.3345/cep.2022.00479>
- Lah, E. F., Musa, R. N., & Ming, H. T. (2012). Effect of germicidal UV-C light (254 nm) on eggs and adult of house dustmites, *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae* (Astigmata: Pyroglyphidae). *Asian Pacific journal of tropical biomedicine*, 2(9), 679-683. [https://doi.org/10.1016/S2221-1691\(12\)60209-3](https://doi.org/10.1016/S2221-1691(12)60209-3)

- Linn, C., O'Malley, A., Khatri, K., Wright, E. M., Sebagh, D., Grbić, M., Kowal, K., & Chruszcz, M. (2024). Microscopic menaces: the impact of mites on human health. *International journal of molecular sciences*, 25(7), 3675. <https://doi.org/10.3390/ijms25073675>
- Miller, J. D. (2019). The role of dust mites in allergy. *Clinical reviews in allergy & immunology*, 57(3), 312-329. <https://doi.org/10.1007/s12016-018-8693-0>
- Mu, X., Liu, K., Li, H., Wang, F. S., & Xu, R. (2021). Granulocyte-macrophage colony-stimulating factor: an immunotarget for sepsis and COVID-19. *Cellular & molecular immunology*, 18(8), 2057-2058. <https://doi.org/10.1038/s41423-021-00719-3>
- Pumnuan, J., Insung, A., & Wangapai, T. (2020). The use of ozone for controlling european house dust mite, *Dermatophagoides pteronyssinus* (Trouessart). *Current Applied Science and Technology*, 20(3), 420-428. <https://li01.tci-thaijo.org/index.php/cast/article/view/243747>
- Qin, R., Fu, W., Huang, R., Xian, M., Guo, Y., He, L., Shi, X., & Li, J. (2024). Predicting allergen immunotherapy efficacy based on early maintenance phase response in routine clinical practice. *The World Allergy Organization journal*, 17(12), 100986. <https://doi.org/10.1016/j.waojou.2024.100986>
- Saha, G. K. (2019). House dust mite allergy in Kolkata metropolis in response to change in lifestyle. *International Journal of Zoology and Animal Biology*, 2(6), 1-8. <https://doi.org/10.23880/IJAB-16000189>
- Seow, I., Siew, Z. Y., Wong, S. T., Wong, S. F., Fang, C. M., Kan, M. S., & Voon, K. (2024). House dust mites eradication treatments: Current updates emphasizing on tropical countries. *Tropical Biomedicine*. 41(4), 450-460. <https://doi.org/10.47665/tb.41.4.005>
- Sidenius, K., Arvidsson, P., Indbryn, R., & Emanuelsson, C. A. (2021). A real-life one-year non-interventional study assessing safety, tolerability, and treatment outcome of the SQ HDM SLIT-tablet (Acarizax®) in house dust mite allergic rhinitis with or without asthma. *Pulmonary Therapy*, 7(1), 221-236. <https://doi.org/10.1007/s41030-021-00150-z>
- Smole, U., Gour, N., Phelan, J., Hofer, G., Köhler, C., Kratzer, B., Tauber, P. A., Xiao, X., Yao, N., Dvorak, J., Caraballo, L., Puerta, L., Roskopf, S., Chakir, J., Malle, E., Lane, A. P., Pickl, W. F., Lajoie, S., & Wills-Karp, M. (2020). Serum amyloid A is a soluble pattern recognition receptor that drives type 2 immunity. *Nature immunology*, 21(7), 756-765. <https://doi.org/10.1038/s41590-020-0698-1>
- Suratannon, N., Limsuwan, T., Tantilipikorn, P., Chatchatee, P., Saengapaswiriya, A., Boonpiyathad, T., Thongngarm, T., Roongpuvapaht, B., Chantaphakul, H., Kulalert, P., Thanaviratananich, S., Sangsupawanich, P., Fooanant, S., Manuyakorn, W., Chusakul, S., Piboonpochanun, O., Apornpong, T., Wongpiyabovorn, J., Ruxrungham, K., & MITAR Study Group (2024). A large scale multicentre randomized, placebo-controlled subcutaneous house dust mite allergen immunotherapy (HDM SCIT) in allergic rhinitis: MITAR Study. *Asian Pacific journal of allergy and immunology*, 42(3), 233-245. <https://doi.org/10.12932/AP-221123-1735>
- Sundaru, H. (2006). House dust mite allergen level and allergen sensitization as risk factors for asthma among student in Central Jakarta. *Medical Journal of Indonesia*, 15(1), 55-59. <https://doi.org/10.13181/mji.v15i1.213>

Weaver-Agostoni, J., Kosak, Z., & Bartlett, S. (2023). Allergic rhinitis: rapid evidence review. *American family physician*, 107(5), 466-473.

Xu, Q., Shang, Y., Li, X., Ran, S., Lu, M., & Cheng, L. (2025). Exploring the role of allergenic components in children with house dust mite-induced allergic diseases. *Journal of Asthma and Allergy*, 18, 183-193. <https://doi.org/10.2147/JAA.S505471>

Yuenyongviwat, A., Jintanapanya, N., Sangsupawanich, P., & Koosakulchai, V. (2025). Safety of house dust mite subcutaneous immunotherapy with a rush and cluster combination protocol in the build-up phase. *Asian Pacific journal of allergy and immunology*, 43(3), 613-619. <https://doi.org/10.12932/AP-260922-1465>