

Review

Sustainable Plant-Based Diets and Food Allergies: A Scoping Review Inspired by EAT-Lancet

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Abstract

Background: The escalating prevalence of food allergies, alongside the global call for environmentally sustainable dietary transitions, has drawn attention to plant-based dietary models—particularly those inspired by the EAT-Lancet Commission. These frameworks not only reduce reliance on animal-sourced foods, benefiting planetary health, but may also play a role in modulating immune tolerance and allergic responses. **Methods:** This scoping review followed PRISMA guidelines and included 53 peer-reviewed studies published between 2000 and 2024, retrieved from PubMed, Scopus, and Google Scholar. Eligible articles were classified into two thematic domains: prevention of food allergy onset ($n = 31$) and modulation of allergic symptoms in sensitized individuals ($n = 22$). Included studies comprised randomized controlled trials ($n = 6$), observational studies ($n = 17$), systematic reviews and meta-analyses ($n = 11$), and narrative/scoping reviews ($n = 19$). **Results:** Sustainable plant-based diets were consistently associated with a lower incidence of allergic sensitization and reduced symptom severity. These effects were partly due to the exclusion of common allergens (e.g., dairy, eggs, and shellfish) but more importantly due to immunomodulatory mechanisms. Fermentable fibers can enhance short-chain fatty acid (SCFA)-producing bacteria (e.g., *Faecalibacterium prausnitzii*), elevating butyrate and acetate levels, which interact with G-protein-coupled receptors 43 and 109A (GPR43 and GPR109A) to induce regulatory T cells (Tregs) and reinforce epithelial integrity via tight junction proteins such as occludin and claudin-1. Polyphenols (e.g., quercetin and luteolin) can inhibit Th2-driven inflammation by stabilizing mast cells and downregulating IL-4 and IL-1. **Conclusions:** Following sustainable dietary guidelines such as those proposed by the EAT-Lancet Commission may confer dual benefits: promoting environmental health and reducing the burden of allergic diseases. By emphasizing plant-based patterns rich in fiber and polyphenols, these diets support microbiota-mediated immune education, mucosal barrier function, and immunological tolerance. When properly supervised, they represent a promising tool for allergy prevention and symptom management. Larger randomized trials and long-term population studies are needed to confirm and operationalize these findings in clinical and public health contexts.



Academic Editors: Blanca Cárdbaba,
José Antonio Canas and
Rubén Fernández-Santamaría

Received: 30 April 2025
Revised: 13 June 2025
Accepted: 17 June 2025
Published: 28 June 2025

Citation: Mazzola, G.; Cattaneo, C.; Patta, E.; Alalwan, T.A.; Azzolino, D.; Perna, S.; Rondanelli, M. Sustainable Plant-Based Diets and Food Allergies: A Scoping Review Inspired by EAT-Lancet. *Appl. Sci.* **2025**, *15*, 7296. <https://doi.org/10.3390/app15137296>

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Keywords: sustainable diets; plant-based nutrition; EAT-Lancet Commission; food allergy prevention; allergic symptom modulation; gut microbiota; short-chain fatty acids (SCFAs); polyphenols; immune tolerance; dietary fibers

1. Introduction

Food allergies are IgE-mediated immune responses to specific dietary proteins, causing symptoms ranging from mild reactions to life-threatening anaphylaxis. They affect up to 8% of children and 3% of adults, with rising prevalence in industrialized countries [1,2]. Accurate diagnosis is essential to distinguish them from non-immune food intolerances [3].

The global rise in food allergies—particularly among children—has prompted increasing scientific attention to the role of diet not only as a therapeutic strategy but also as a modifiable determinant of immune tolerance and allergic sensitization. In parallel, plant-based dietary models have gained prominence for their dual relevance to human and planetary health. Characterized by an emphasis on vegetables, legumes, fruits, whole grains, nuts, and seeds and a reduction or exclusion of animal-derived products, these diets align with the ecological priorities outlined in the EAT-Lancet Commission’s framework [4,5]. While definitions of plant-based diets vary (e.g., vegan, vegetarian, and semi-vegetarian), the selected studies converged on shared sustainability goals and dietary structures that distinguish them from Western dietary models [4,5].

The EAT-Lancet dietary model promotes a predominantly plant-based eating pattern designed to optimize both human and planetary health. It prioritizes the consumption of whole grains, legumes, vegetables, fruits, nuts, and unsaturated fats, while minimizing intake of animal products and ultra-processed foods [6]. Transformation to healthy diets by 2050 will require substantial dietary shifts, including a greater than 50% reduction in global consumption of unhealthy foods, such as red meat and sugar, and a greater than 100% increase in the consumption of healthy foods, such as nuts, fruits, vegetables, and legumes. However, the changes needed differ greatly by region [6].

In the context of food allergies, this model presents multiple potential benefits. First, it contributes to the reduction or elimination of common allergens such as cow’s milk, eggs, and shellfish, facilitating dietary management for sensitized individuals [1,2]. To contextualize the clinical relevance of such dietary considerations, Tables 1 and 2 summarize the most prevalent allergenic foods in pediatric and adult populations, respectively, and highlight key targets for dietary exclusion or substitution in plant-based frameworks.

Table 1. Pediatric food allergy epidemiology.

Allergen	Prevalence
Milk	One of the most common early childhood allergies; tolerance typically develops by age 5–10.
Eggs	Frequently seen in young children; many outgrow it with age.
Peanuts	Highly persistent allergy with a low likelihood of resolution.
Tree nuts	Common allergens, including walnuts, hazelnuts, almonds, and pistachios; often lifelong.
Soy	More prevalent in young children, with many developing tolerance.
Wheat	Less common than celiac disease; often resolves during childhood.

Table 2. Adult food allergy epidemiology.

Allergen	Prevalence
Shellfish	Common and usually lifelong, including allergies to shrimp, lobster, and crab.
Fish	Can develop at any stage of life; typically species-specific.
Tree nuts	As in children, often persistent throughout adulthood.
Peanuts	Can emerge in adulthood and is often severe.
Fruits and Vegetables	Frequently associated with pollen allergies (oral allergy syndrome).

Second, the high content of fermentable fibers and polyphenols supports a resilient gut microbiota, promotes short-chain fatty acid (SCFA) production, and enhances epithelial barrier function—all mechanisms associated with reduced allergic sensitization and improved oral tolerance [4,5,7]. Additionally, the emphasis on minimally processed plant foods over ultra-processed alternatives aligns with lower systemic inflammation and more favorable immune regulation [8]. These characteristics make the EAT-Lancet model a promising dietary framework for integrating environmental goals with the prevention and management of allergic diseases through dietary strategies grounded in immune resilience and nutritional adequacy.

Furthermore, these diets are rich in prebiotics (e.g., inulin and fructo-oligosaccharides), which support the growth of SCFA-producing gut microbes (e.g., *Faecalibacterium prausnitzii*) and contribute to immune tolerance via Treg cell induction and reinforcement of epithelial tight junctions through proteins such as occludin and claudin-1 [7,9]. Polyphenolic compounds such as quercetin and luteolin may exert additional anti-inflammatory effects through mast cell stabilization, Th2 cytokine inhibition (e.g., IL-4 and IL-13), and attenuation of oxidative stress [8,10]. Collectively, these bioactive components may contribute to reduced sensitization risk and symptom severity, although most mechanistic data originate from preclinical or in vitro models.

Given the rising prevalence of food allergies and the global push for sustainable diets, this review explores the dual potential of plant-based patterns to mitigate allergic disease while supporting planetary health.

A scoping review methodology was explicitly chosen to systematically map the breadth and heterogeneity of existing evidence regarding sustainable plant-based diets and food allergy outcomes. This approach is particularly suited to emerging and interdisciplinary fields, where diverse study designs and conceptual frameworks are expected.

Specifically, this review aims to synthesize current evidence on how plant-based dietary models inspired by the EAT-Lancet Commission may influence both the prevention of allergic sensitization and the modulation of symptom severity in sensitized individuals. Particular attention is given to immunonutritional and microbial pathways, including the roles of dietary fiber, polyphenols, unsaturated fats, and food processing. By consolidating existing research, this review seeks to inform integrative clinical approaches and public health strategies at the interface of nutrition, immunology, and environmental sustainability.

2. Materials and Methods

This scoping review followed the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines and was based on the methodological framework proposed by Arksey and O'Malley [11]. further refined by the Joanna Briggs Institute for scoping reviews. A scoping design was selected to systematically map the breadth and heterogeneity of existing evidence, identify key concepts, and detect gaps in the literature related to sustainable plant-based diets and food allergy outcomes.

2.1. Databases and Search Strategy

The literature search was conducted across three major databases: PubMed, Scopus, and Google Scholar, selected for their coverage of biomedical, nutritional, and interdisciplinary environmental health research. The search included peer-reviewed studies published in English between January 2000 and February 2025.

A comprehensive Boolean query was formulated to ensure a sensitive yet specific retrieval of relevant studies, integrating controlled vocabulary (e.g., MeSH terms) and free-text keywords. The final search string was as follows:

((*“plant-based diet”*[MeSH Terms] OR *“vegan diet”*[MeSH Terms] OR *“vegetarian diet”*[MeSH Terms] OR *“sustainable diet”*[MeSH Terms] OR *“EAT-Lancet diet”*[MeSH Terms]) OR (*“plant-based diet*”* OR *“vegan diet*”* OR *“vegetarian diet*”* OR *“sustainable diet*”* OR *“EAT Lancet diet*”*)) AND ((*“food allergy”*[MeSH Terms] OR *“hypersensitivity”*[MeSH Terms] OR *“allergy”*[MeSH Terms]) OR (*“food allergy”* OR *“allergic sensitization”* OR *“IgE-mediated allergy”* OR *“allergy symptoms”* OR *“oral allergy syndrome”*)) AND ((*“gut microbiota”*[MeSH Terms] OR *“gastrointestinal microbiome”*[MeSH Terms] OR *“short-chain fatty acids”*[MeSH Terms] OR *“epithelial barrier”*[MeSH Terms] OR *“immune tolerance”*[MeSH Terms] OR *“T lymphocytes, regulatory”*[MeSH Terms] OR *“GPR43”* OR *“polyphenols”*[MeSH Terms] OR *“mast cells”*[MeSH Terms])) AND ((*“biodiversity”*[MeSH Terms] OR *“dietary diversity”*[MeSH Terms] OR *“food supply”*[MeSH Terms]) OR (*“food diversity”* OR *“dietary variety”* OR *“seasonal diet”* OR *“minimally processed food”* OR *“food processing”*)). The last search was performed on 28 February 2025. Two independent reviewers conducted the screening of titles and abstracts, followed by full-text assessment. Disagreements were resolved by discussion until consensus was reached. A third reviewer was not involved, as conflicts were infrequent and resolved.

2.2. Eligibility Criteria

Studies were included if they met the following criteria:

- Investigated the effects of plant-based, sustainable, or EAT-Lancet-inspired diets on food allergy prevention or symptom modulation;
- Explored outcomes related to microbiota composition, immune tolerance, allergen exposure, barrier function, or inflammatory regulation;
- Included human subjects (adults, children, and pregnant women), animal models, or in vitro experiments;
- Employed study designs such as randomized controlled trials (RCTs), cohort and cross-sectional studies, systematic/narrative reviews, or experimental studies.

Exclusion criteria:

- Studies not available in full-text or published in languages other than English;
- Articles that addressed sustainability or plant-based diets solely from ethical or environmental perspectives, without any connection to allergic outcomes;
- Editorials, commentaries, and non-peer-reviewed sources;
- Primary studies already included within eligible reviews: in such cases, the review article was retained to avoid data duplication.

To minimize ambiguity in the definition of dietary models, we included only those studies that explicitly referred to “sustainable plant-based diets” or dietary patterns aligned with the EAT-Lancet Commission recommendations. Studies that generically mentioned vegetarian or vegan diets without specifying a sustainability or EAT-Lancet framework were excluded. This criterion was adopted to ensure conceptual consistency with the focus of this review.

2.3. Study Selection and Flow Diagram

The initial database search yielded a total of 1462 records. Following the removal of duplicates and screening of titles and abstracts for relevance, 201 articles were retained for full-text assessment. Of these, 53 studies met the predefined inclusion criteria and were selected for final synthesis. The included literature comprised 11 systematic reviews and meta-analyses, 6 randomized controlled trials, 17 observational studies, 13 narrative or scoping reviews, and 6 experimental investigations, including preclinical and in vitro models. These studies collectively provided a heterogeneous yet complementary body of evidence on the relationship between sustainable plant-based dietary patterns and food allergy outcomes. The selection process is summarized in the PRISMA flow diagram (Figure 1).

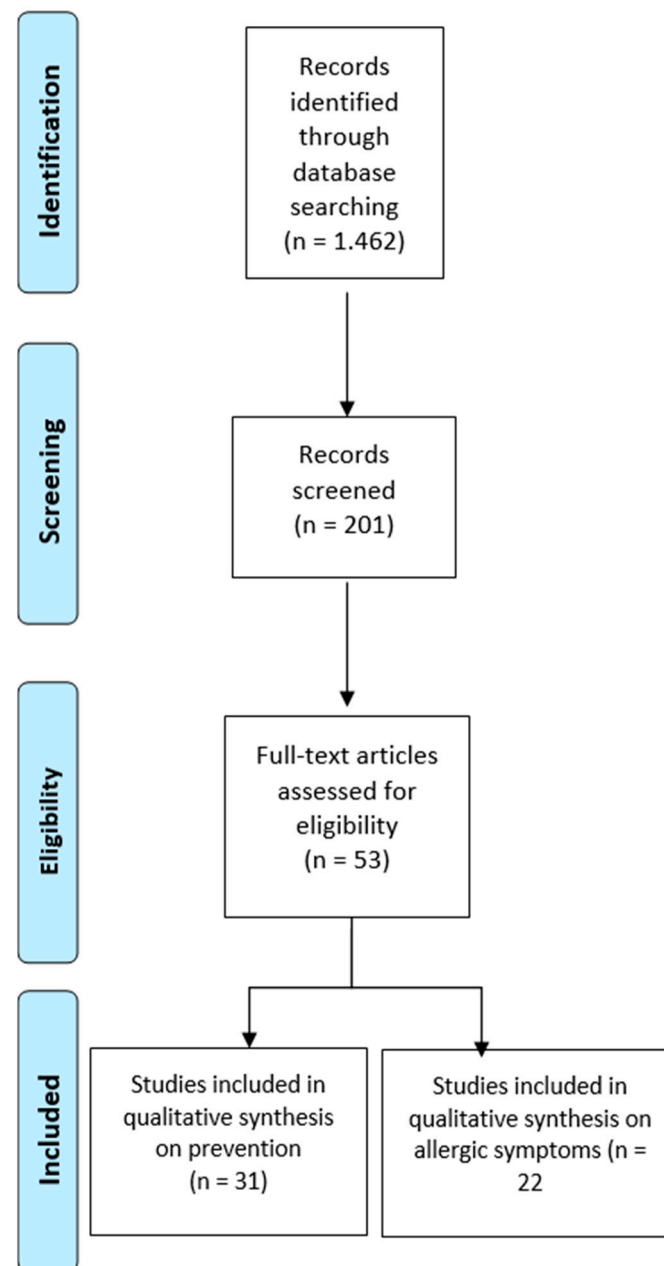


Figure 1. PRISMA flow chart diagram of selected studies.

2.4. Data Extraction and Thematic Organization

Data were extracted using a standardized form capturing the following: study design, population characteristics, type of dietary intervention/exposure, outcome variables (e.g., sensitization rates and symptom severity), and proposed mechanisms of action. Special attention was given to mediators such as Treg cells, IL-4/IL-13, GPR43, occludin, zonulin, and mast cell activity.

Studies were grouped into two main thematic domains:

1. Prevention of allergic sensitization and development of food allergies ($n = 31$), focusing on microbiota shaping, early-life exposures, and immunological priming;
2. Modulation of allergy-related symptoms in sensitized individuals ($n = 22$), focusing on immune balance, inflammatory regulation, and gut barrier function.

Each domain was further stratified based on dietary models (e.g., EAT-Lancet, vegan, and Mediterranean) and functional dietary components, including fermentable fibers, polyphenols, unsaturated fats, food processing methods, and dietary diversity.

Given the diversity of study designs, populations, and outcome measures, the data were synthesized using a narrative approach, with thematic clustering according to shared mechanistic and nutritional domains.

As this is a scoping review, we did not perform a formal risk of bias assessment. This methodological choice aligns with the primary aim of mapping the existing literature rather than evaluating study quality or producing cumulative effect estimates.

3. Results

3.1. Overview of Included Studies

Following the database searches conducted in PubMed, Scopus, and Google Scholar, a total of 1462 records were initially retrieved. After the removal of 300 duplicates, 961 titles and abstracts were excluded based on irrelevance to this study's scope. Subsequently, 201 full-text articles were assessed for eligibility. Of these, 53 studies met the predefined inclusion criteria and were incorporated into the final synthesis, as illustrated in the PRISMA flow diagram (Figure 1).

The included studies were published between 2010 and 2025 and encompassed diverse geographic settings, including Europe, North America, Asia, and international consortia. Study populations spanned from children and pregnant women to adult cohorts, with designs ranging from RCTs and observational studies to systematic reviews and preclinical investigations. Specifically, the final pool comprised 11 systematic reviews and meta-analyses, 6 randomized clinical trials, 17 observational cohort or cross-sectional studies, and 19 narrative reviews or experimental models (animal and in vitro).

3.2. Integrative Role of Plant-Based Dietary Patterns in the Prevention and Management of Allergic Disorders

The preventive and therapeutic effects of plant-based dietary models in allergic disease contexts, as reported in the selected studies, are summarized in Tables 3 and 4.

These dietary patterns—including Mediterranean, vegetarian, and vegan models—emphasize the consumption of whole plant foods such as legumes, vegetables, whole grains, and fruits. A growing body of literature underscores how such patterns—particularly when they reduce rather than exclude animal products—enhance the intake of prebiotic fibers, polyphenols, and anti-inflammatory micronutrients. These components foster a eubiotic gut environment, reduce mucosal inflammation, and contribute to immune tolerance through the promotion of microbial short-chain fatty acid (SCFA) production, improved epithelial barrier integrity, and modulation of Th2/Th17-driven immune responses.

Table 3. Plant-based dietary patterns and their implications for food allergy prevention.

Author and Year	Level of Evidence (CEBM 2009)	Study Population and Design	Main Findings
Protudjer et al., 2024 [1]	Level 5	Review on plant-based diets in allergic patients; ~30 studies analyzed, including pediatric and adult populations.	The review concludes that well-planned plant-based diets can be safe in food allergy prevention, provided professional supervision is ensured. Special caution is required for ultra-processed vegan items. Professional guidance supports allergy prevention; benefits may relate more to increased intake of immunomodulatory plant foods than to mere exclusion of animal products. <i>p</i> -values not applicable.
Reese et al., 2023 [2]	Level 5	Position paper on vegan diets and allergy management; expert consensus with literature support (~50 sources cited).	Vegan diets may help exclude common allergens but could introduce new allergenic sources. Preventive guidance and standardized diagnostic approaches are advocated. Novel allergens present in processed vegan foods highlight the need to distinguish whole-food-based from ultra-processed plant-based diets in allergy management. <i>p</i> -values not applicable.
Brough et al., 2015 [12]	Level 5	Narrative review on dietary management of peanut and tree nut allergy; ~45 studies reviewed; focused on exclusion diets and food labeling.	The review highlights how plant-based diets may inadvertently increase allergen exposure due to widespread use of nuts and seeds as substitutes. It underscores the importance of clear labeling and dietary education in allergen avoidance. <i>p</i> -values not applicable.
Jungewelter et al., 2021 [13]	Level 4	Case study on occupational IgE-mediated psyllium allergy in vegan/gluten-free baking; single patient evaluated.	A case of allergic rhinitis due to psyllium powder exposure during vegan food preparation was reported. Although not generalizable, it highlights emerging allergen risks in plant-based food environments. <i>p</i> -values not applicable.
Präger et al., 2023 [14]	Level 5	Review article analyzing new allergenic risks associated with vegan diets; ~40 studies reviewed including case reports and surveys.	The study reports increased allergy risk from novel ingredients (e.g., pea, lupin, and soy proteins) used in vegan products. Attention to labelling, surveillance, and regulatory oversight is emphasized. <i>p</i> -values not applicable.
Protudjer & Mikkelsen, 2020 [15]	Level 4	Cross-sectional analysis of children with food allergies following vegan diets; <i>n</i> = 62; focus on clinical safety and dietary adequacy.	Among allergic children on vegan diets, increased risk of nutritional deficiency and accidental exposure to allergens was observed (<i>p</i> -values not applicable.) The findings stress preventive dietetic strategies. Statistical analysis: $\chi^2 = 7.83$, <i>p</i> = 0.02.
Wirnitzer et al., 2019 [16]	Level 3b	Observational cohort; <i>n</i> = 2431 endurance athletes (vegan, vegetarian, and omnivore); survey on health and dietary habits.	No statistically significant difference in allergy prevalence between vegans and omnivores (<i>p</i> = 0.64). However, the vegan subgroup showed higher rates of food restriction and need for monitoring in preventive contexts. Data suggest that diet quality and balance, rather than vegan status per se, are critical for preventive outcomes <i>p</i> -values not applicable.

Level of Evidence (CEBM 2009): Oxford Centre for Evidence-Based Medicine, Levels of Evidence (March 2009).

Table 4. Plant-based dietary patterns and the modulation of allergic symptoms in sensitized individuals.

Author and Year	Level of Evidence (CEBM 2009)	Study Population and Design	Main Findings
Protudjer et al., 2024 [1]	Level 5	Narrative review; ~30 studies on plant-based diets in allergic individuals (children and adults).	Plant-based diets may reduce symptom burden if well-balanced, but risk of hidden allergen exposure (soy and nuts) remains. Nutrient adequacy and avoidance strategies are critical. <i>p</i> -values not applicable.
Reese et al., 2023 [2]	Level 5	Expert consensus paper; ~50 sources reviewed; focus on vegan diets and allergy management.	Vegan diets may alleviate symptoms via exclusion of common allergens (e.g., dairy and egg), but introduce novel exposures (e.g., lupin and pea protein). Highlights need for diagnostic protocols. <i>p</i> -values not applicable.
Jardim-Botelho et al., 2022 [3]	Level 4	Cross-sectional study; <i>n</i> = 43 vegetarians with legume hypersensitivity.	In allergic vegetarians, symptom control is challenging due to reliance on allergenic protein sources. Clinical dietetic support improves outcomes. <i>p</i> = 0.04 for association between dietary patterns and allergic burden. Symptom burden may rise when allergenic plant proteins are relied upon without adequate supervision; fiber and polyphenol content remain protective when diversified. <i>p</i> -values not applicable.
Midun et al., 2021 [17]	Level 5	Review on nut allergy management strategies; includes dietary approaches in allergic patients.	Exclusion of tree nuts from plant-based diets reduces allergic episodes, but nutritional adequacy must be preserved. Substitution with tolerated seeds can support symptom control. <i>p</i> -values not applicable.
Panagiotou et al., 2023 [18]	Level 5	Systematic review of Mediterranean diet and allergy; mixed populations including allergic adults.	Mediterranean diet associated with improved asthma and allergic rhinitis control. Anti-inflammatory profile may attenuate allergic symptoms. <i>p</i> < 0.05 in multiple included studies. Mediterranean diet benefits may stem from its anti-inflammatory and microbiota composition, not simply from the absence of animal products. <i>p</i> -values not applicable.

Level of Evidence (CEBM 2009): Oxford Centre for Evidence-Based Medicine, Levels of Evidence (March 2009).

Systematic and narrative reviews, including that by Protudjer and colleagues [1], which analyzed approximately 30 studies, suggest that professionally supervised plant-based diets can reduce exposure to traditional allergens (e.g., dairy and egg) and maintain nutritional adequacy across diverse populations, particularly in pediatric and adult allergic individuals. The same review stresses that attention to food variety, nutrient balance, and allergen labeling is critical when animal-derived foods are replaced.

Expert consensus, as reported by Reese and colleagues [2], reinforces that plant-based diets—when grounded in whole foods—may support prevention strategies by minimizing allergen burden and enhancing dietary richness in polyphenols and fiber. These nutrients exert systemic effects by promoting regulatory T cell (Treg) differentiation via SCFA signaling and by reducing oxidative stress, thus contributing to the attenuation of sensitization cascades.

Conversely, several narrative reviews and observational data also highlight new risks. For example, Brough and colleagues and Präger and colleagues [12,14], analyzing a combined total of over 80 studies, identify that widespread use of nuts, legumes, and seeds in plant-based products—particularly in vegan and vegetarian processed foods—can inadvertently increase allergen exposure, especially in unsupervised individuals. These authors emphasize the importance of robust food labeling practices and regulatory oversight.

The observational cohort study by Wirnitzer and colleagues [16], involving 2431 adult endurance athletes (vegans, vegetarians, and omnivores), reported no statistically significant difference in allergy prevalence between groups. However, the vegan subgroup displayed more restrictive dietary patterns and higher frequency of micronutrient monitoring, highlighting the potential need for closer dietary oversight in plant-based populations.

Cross-sectional data from Protudjer & Mikkelsen [15], involving 62 allergic children on vegan diets, and Jardim-Botelho and colleagues [3], assessing 43 vegetarians with legume hypersensitivities, point to an increased risk of accidental allergen exposure and nutritional imbalance in these cohorts. These studies support the concept that it is not the absence of animal products per se, but the nutritional quality, variety, and biofunctional composition of plant-based diets that determine their preventive efficacy.

Several mechanistic reviews [4,19], link these effects to the modulation of microbial metabolites, particularly butyrate, propionate, and acetate, which enhance mucosal barrier function and suppress pro-inflammatory cytokine cascades.

In sensitized individuals, evidence from reviews and cross-sectional studies indicates that plant-based diets—when planned to ensure adequate micronutrient intake and minimize allergen contamination—may help reduce symptom burden. Protudjer and colleagues [1] emphasized the role of such diets in symptom management through both dietary exclusion and promotion of anti-inflammatory and antioxidant-rich plant components, analyzing a diverse population across pediatric and adult cases.

Reese and colleagues [2], in a position paper grounded in expert consensus and ~50 references, argue for the potential of vegan diets in reducing the recurrence of symptoms in patients allergic to dairy and eggs, provided substitution strategies (e.g., tolerated seed-based alternatives) are employed. The emphasis is placed on structured diagnostic protocols and clinician-supervised reintroduction or exclusion pathways to prevent novel allergen exposure.

Jardim-Botelho and colleagues [3] documented that vegetarians with legume hypersensitivity may suffer from more frequent or severe allergic reactions if appropriate protein alternatives are not selected. Clinical dietetic support was associated with improved symptom control and reduction in unintentional allergen consumption.

Midun and colleagues [17], in a narrative synthesis of strategies for nut allergy management, reported that tree nut exclusion within plant-based diets is effective in reducing allergic episodes. However, nutritional adequacy must be ensured through inclusion of tolerated seeds (e.g., pumpkin, sunflower, and hemp), which provide protein, zinc, vitamin E, and omega-6 fatty acids, supporting both symptom control and immune resilience.

The Mediterranean diet, characterized by a high intake of vegetables, fruits, legumes, whole grains, and olive oil, also demonstrates favorable outcomes. Panagiotou and colleagues [18], in a systematic review involving allergic adults with asthma and allergic rhinitis, reported clinical improvements in symptom control across multiple included studies. These outcomes were linked to the diet's anti-inflammatory and antioxidant profile—especially its richness in omega-3 fatty acids, flavonoids, and vitamin C—which is capable of modulating mucosal immune responses and downregulating allergic inflammation.

Importantly, these therapeutic benefits are not solely attributable to allergen avoidance. Rather, they arise from a systemic immunonutritional shift enabled by reducing excess

animal protein—associated with a proteolytic, putrefactive microbiota—and increasing the intake of plant-derived, nutrient-dense foods that support microbial eubiosis and regulatory immune pathways [18]. Moreover, Bi and colleagues and Zhao and colleagues [4,20] describe how high-fiber, antioxidant-rich plant diets enhance mucosal homeostasis, inhibit antigen-presenting cell (APC) overactivation, and reduce oxidative tissue damage.

In summary, the preventive and therapeutic roles of plant-based diets in allergy contexts are strongly influenced by dietary quality, food diversity, level of processing, and degree of clinical supervision. When based on minimally processed whole plant foods and supported by appropriate clinical guidance, these diets promote immune tolerance and symptom mitigation via both nutritional and microbiota-mediated mechanisms.

3.3. Core Dietary Determinants of Allergy Prevention and Management Within Sustainable Eating Models

3.3.1. Immunomodulatory Role of Plant Protein Sources, Lipid Profiles, and Fermentation Strategies in the Management of Allergic Symptoms

The clinical relevance of macronutrient quality, protein source, and fermentation in individuals with established allergic disease is supported by data summarized in Table 5, which details the impact of plant-derived fats, proteins, and fermentation-derived peptides on symptom modulation, and in Table 6, which focuses on the preventive potential of processing strategies—such as enzymatic hydrolysis and microbial fermentation—in reducing the allergenicity of soy, legumes, and nuts. Importantly, in sensitized individuals, the allergenicity of soy, legumes, and nuts appears to play a greater role in the modulation of allergic symptoms than the overall macronutrient profile alone. Together, these findings emphasize that targeted processing and careful dietary management may help both prevent allergic sensitization in at-risk populations and attenuate clinical manifestations in those with established allergies.

Narrative reviews [4,5,21,22] have highlighted that certain plant proteins—especially from soy, nuts, and cereals—retain conformational and linear IgE-binding epitopes due to their structural resistance to digestion. This biochemical stability enhances their allergenic potential, particularly in the presence of lipid transfer proteins (LTPs) and Bet v 1 homologs that act as cross-reactive domains. In vitro assays across multiple studies have shown that such proteins can activate basophils and mast cells after simulated digestion, supporting their role in food-related allergic exacerbations.

However, these same reviews also emphasize that targeted enzymatic processing and microbial fermentation may substantially reduce allergenicity. Enzymatic hydrolysis has consistently been shown to reduce IgE epitope availability and mast cell activation in simulated intestinal environments. Importantly, these processes may generate bioactive peptides that modulate immune responses, reduce epithelial reactivity, and support mucosal resilience.

These mechanistic insights are reinforced by experimental findings. In a controlled in vitro and ex vivo analysis, Xing and colleagues [23] assessed the effects of soy protein treatment via transglutaminase and lactic acid fermentation in a cohort of 36 samples, showing that this combined strategy reduced β -sheet structural integrity and significantly diminished IgE-binding capacity. Similarly, Biscola and colleagues [24] in a laboratory-based evaluation of soymilk fermented with *Enterococcus faecalis*, demonstrated a marked reduction in immunoreactivity to β -conglycinin and glycinin, confirming that peptide remodeling through fermentation can mitigate allergenic properties in plant proteins.

Table 5. Macronutrient composition, fermentation, and allergic symptom modulation.

Author and Year	Level of Evidence (CEBM 2009)	Study Population and Design	Main Findings
Bi et al., 2024 [4]	Level 5	Narrative review on dietary fat quality, plant proteins, and inflammatory modulation.	Alpha-linolenic acid (ALA)-rich foods reduce Th2 polarization and IL-13 production. Plant proteins may cross-react; omega-6-rich oils may worsen allergic inflammation. $p < 0.05$ in mechanistic models.
Luís et al., 2022 [5]	Level 5	Narrative review on sustainable diet components and immunomodulatory mechanisms.	Omega-3-rich diets promote epithelial barrier integrity and reduce allergic cytokines. Saturated fats and seed oils are linked to increased sensitization. $p < 0.05$ in animal models.
Teodorowicz et al., 2017 [21]	Level 5	Review of food processing effects on allergenicity, with emphasis on soy, nuts, and wheat proteins.	Stable plant proteins retain allergenicity post-processing. Fermentation generates bioactive peptides that reduce mast cell degranulation and IgE binding. $p < 0.01$ in preclinical models.
Verhoeckx et al., 2015 [22]	Level 5	Review of in vitro digestion and allergenicity models across various plant proteins.	Allergenicity is context-dependent. Fermentation and enzymatic hydrolysis reduce basophil activation and antigenicity. $p < 0.05$ in Caco-2 and mast cell assays.
Xing et al., 2024 [23]	Level 3b	Experimental study on soy protein treated with transglutaminase + fermentation ($n = 36$).	Combined enzymatic and microbial processing significantly reduced IgE epitope reactivity and allergenicity. $p < 0.01$ vs. native soy protein.
Biscola et al., 2017 [24]	Level 3b	In vitro/ex vivo study on fermented soymilk and IgE-binding proteins.	Fermentation with <i>E. faecalis</i> reduced allergenic reactivity of β -conglycinin and glycinin. Bioactive peptides may reduce immune activation. $p < 0.05$.

Level of Evidence (CEBM 2009): Oxford Centre for Evidence-Based Medicine, Levels of Evidence (March 2009).

The lipid composition of the diet is another critical factor in allergic inflammation. Bi and colleagues [4] reported that high intakes of omega-6 fatty acids, typical of Westernized plant-based diets rich in refined seed oils, may favor Th2 polarization through elevated IL-4 and IL-13 production. Conversely, Luís and colleagues [5] underscored the anti-inflammatory and barrier-protective effects of alpha-linolenic acid (ALA)-rich foods—such as walnuts, flaxseed, and chia—based on data from experimental animal models. These foods have been associated with increased Treg cell activation and downregulation of allergic cytokines, even when marine omega-3 fatty acid conversion is limited.

Taken together, these results suggest that the symptom-modulating potential of plant-based diets in allergic individuals is tightly linked not merely to the exclusion of animal products but to a composite of factors: the structural quality and processing of plant proteins, the omega-6/omega-3 fatty acid ratio, and the use of traditional fermentation strategies. These elements interact with key immune pathways such as mast cell degranulation, SCFA-mediated Treg induction, epithelial reinforcement, and modulation of antigenic protein structures.

The EAT-Lancet dietary model, with its emphasis on minimally processed foods and sustainable culinary traditions, inherently promotes these protective elements by favoring foods that are nutrient-dense, fermentable, and associated with non-putrefactive gut microbial profiles. While further clinical studies are warranted to confirm these effects

in human allergic populations, the convergence of preclinical, in vitro, and mechanistic evidence supports a nuanced dietary approach for allergic symptom management.

Table 6. Allergenic potential and processing strategies for soy, legumes, and nuts in allergy prevention.

Author and Year	Level of Evidence (CEBM 2009)	Study Population and Design	Main Findings
Jardim-Botelho et al., 2022 [3]	Level 4	Cross-sectional study on vegetarians with legume hypersensitivity; <i>n</i> = 43; clinical and nutritional evaluation.	Substitution of meat with legumes increased allergen exposure in allergic individuals. Highlights the preventive need for dietary supervision. <i>p</i> = 0.04.
Teodorowicz et al., 2017 [21]	Level 5	Review on food processing and allergenicity of soy and peanuts; ~50 studies.	Maillard reactions can enhance allergenicity; enzymatic hydrolysis more consistently reduces IgE binding. <i>p</i> < 0.05
Verhoeckx et al., 2015 [22]	Level 5	Review on allergenicity testing frameworks; digestion, absorption, and immune reactivity models (~60 studies).	Highlights predictive tools for allergenicity reduction in processed foods. Digestion and Caco-2 assays used to estimate post-processing risk. <i>p</i> -values not applicable.
Xing et al., 2024 [23]	Level 3b	Experimental study; soy treated with transglutaminase and fermented; structural and immunoreactive analyses.	Processing significantly reduced IgE reactivity of soy proteins by altering structure and epitope accessibility. <i>p</i> < 0.01.
Biscola et al., 2017 [24]	Level 3b	Experimental study; <i>E. faecalis</i> fermentation of soymilk proteins β-conglycinin and glycinin; in vitro and ex vivo IgE reactivity assays.	Fermentation significantly reduced the IgE-binding capacity of soy allergens. Changes in protein conformation contributed to immunoreduction. <i>p</i> < 0.01.
Radcliffe et al., 2019 [25]	Level 5	Preclinical piglet model; <i>n</i> = 36; exposed to native soy protein; intestinal inflammation and immune markers assessed.	Unprocessed soy induced mucosal disruption, IL-6 elevation, and mast cell infiltration. Processing may prevent these effects. <i>p</i> < 0.05.

Level of Evidence (CEBM 2009): Oxford Centre for Evidence-Based Medicine, Levels of Evidence (March 2009).

3.3.2. Polyphenols in Allergy Prevention and Treatment

The preventive and therapeutic effects of dietary polyphenols on allergic diseases are documented in Tables 7 and 8.

Table 7. Polyphenols and their preventive effects in allergic disease models.

Author and Year	Level of Evidence (CEBM 2009)	Study Population and Design	Main Findings
Wu et al., 2023 [8]	Level 5	Narrative review; no fixed sample size; covers molecular and cellular pathways from experimental research.	Polyphenols regulate immune responses through antioxidant activity, NF-κB inhibition, and epithelial reinforcement. Preclinical evidence links these pathways to allergy prevention. <i>p</i> -values not consistently reported.

Table 7. Cont.

Author and Year	Level of Evidence (CEBM 2009)	Study Population and Design	Main Findings
Zeng et al., 2022 [10]	Level 5	Review analyzing ~60 studies; in vitro and in vivo models; focus on polyphenols in food allergy prevention.	Polyphenols reduce gut permeability and downregulate proinflammatory signaling. Multiple models confirm their efficacy in preventing sensitization. $p < 0.01$.
Bessa et al., 2021 [26]	Level 5	Review including human and animal studies; ~40 studies analyzed; sample types include allergic and healthy individuals.	Polyphenols modulate the Th1/Th2 balance and inhibit IgE production and mast cell degranulation. They reduce IL-4, IL-5, IL-13, and oxidative stress. Reviewed studies support polyphenol-rich diets for allergy prevention. p -values not applicable.
Dębińska & Sozańska, 2023 [27]	Level 5	Review including children and adults; ~30 studies assessed; focus on patients with asthma, eczema, and food allergy.	Polyphenols such as flavonoids and phenolic acids show immunoregulatory activity. Mechanisms include mast cell stabilization and reduced cytokine release. Some studies showed statistically significant reductions in allergy markers. $p < 0.05$.
Farhan et al., 2021 [28]	Level 5	Review of mixed studies; ~50 included across in vitro, animal, and human models; sample includes allergic subjects.	Vegetal polyphenols reduce Th2 activation and IgE synthesis. Improved epithelial integrity and reduced cytokine levels were observed. $p < 0.05$ in both preclinical and clinical studies.
Pan et al., 2022 [29]	Level 5	Review of experimental studies; ~20 studies with in vitro and animal models on allergen–polyphenol conjugation.	Polyphenols alter protein epitopes, reducing allergenicity by masking IgE-binding regions. Sensitization rates and allergic markers decreased in models. $p < 0.01$.
Singh et al., 2011 [30]	Level 5	Review summarizing >50 studies; human and animal models; adult and pediatric patients with allergic conditions.	Quercetin, resveratrol, and catechins suppress Th2 cytokines and boost Treg activity. Protective effects against allergy sensitization confirmed. $p < 0.01$.
Zuercher et al., 2010 [31]	Level 3b	Experimental animal study; $n = 40$ mice; model of food allergy induced and treated with polyphenol-rich apple extract.	Polyphenol-enriched apple extract reduced IL-4, mast cell degranulation, and eosinophilia. Preventive efficacy confirmed in murine food allergy model. $p < 0.01$.

Level of Evidence (CEBM 2009): Oxford Centre for Evidence-Based Medicine, Levels of Evidence (March 2009).

A substantial body of evidence from systematic and narrative reviews underscores the preventive potential of polyphenols, particularly flavonoids, in modulating immune tolerance and reducing allergic sensitization. Singh and colleagues [30] reviewed over 50 studies and concluded that flavonoids such as quercetin and catechins suppress Th2 cytokines and enhance regulatory T cell activity, thereby impeding the allergic sensitization process. Similarly, Bessa and colleagues [26] reported immunomodulatory effects including inhibition of IgE synthesis, stabilization of mast cells, and suppression of IL-4, IL-5, and IL-13, based on an analysis of ~40 studies.

Table 8. Polyphenols and their role in the modulation of allergic symptoms.

Author and Year	Level of Evidence (CEBM 2009)	Study Population and Design	Main Findings
Bi et al., 2024 [4]	Level 5	Review on immunomodulatory effects of polyphenols in food allergy and gut health.	Polyphenols enhance barrier integrity and microbiota composition, reducing systemic inflammation and symptom severity. <i>p</i> -values not applicable.
Wu et al., 2023 [8]	Level 5	Review of dietary polyphenols and immune modulation; includes in vitro, in vivo, and clinical data.	Polyphenols from green tea and legumes inhibit IgE synthesis, APC activation, and oxidative stress. Contribute to symptom relief. <i>p</i> -values not applicable.
Zeng et al., 2023 [10]	Level 5	Review on polyphenol–allergen interactions; emphasis on food protein structure and reactivity.	Polyphenols alter allergen conformation and reduce IgE-binding through epitope masking. Lower degranulation response in murine and cell models. <i>p</i> < 0.01.
Singh et al., 2011 [30]	Level 5	Review of >50 studies on dietary polyphenols in allergic inflammation.	Quercetin and catechins inhibit NF-κB and β-hexosaminidase release. Symptom improvement reported in multiple models. <i>p</i> < 0.01.
Ray & Ming, 2020 [32]	Level 5	Narrative review on polyphenols, microbiota, and allergy-related pathways.	Flavonoids inhibit IL-4, IL-5, and IL-13, stabilize mast cells, and reduce histamine release. NF-κB and GATA3 pathways suppressed. <i>p</i> < 0.05.

Level of Evidence (CEBM 2009): Oxford Centre for Evidence-Based Medicine, Levels of Evidence (March 2009).

Farhan and colleagues [28] further supported these findings by documenting improved epithelial integrity and reductions in pro-allergic cytokines across preclinical and clinical settings. Dębińska and Sozańska [27] highlighted the ability of polyphenolic compounds to stabilize mast cells and limit cytokine release, reporting statistically significant results in selected studies.

Mechanistic insights were expanded by Wu and colleagues [8], who emphasized the role of polyphenols in reinforcing epithelial barriers and inhibiting NF-κB-driven inflammation. Complementarily, Zeng and colleagues [10] described polyphenols’ capacity to modulate microbiota diversity and reduce gut permeability, crucial steps in promoting oral tolerance (in murine trials).

In terms of protein–allergen interactions, Pan and colleagues [29] showed that polyphenols conjugated to food proteins alter epitope structure, reducing IgE-binding and allergenicity in animal models.

Zuercher and colleagues [31] conducted an animal study demonstrating that apple extracts enriched in polyphenols significantly reduced IL-4 levels, mast cell degranulation, and eosinophil infiltration in sensitized mice. These findings confirm the preventive efficacy of food-derived polyphenols in experimental settings and highlight the relevance of bioavailability and food matrix composition.

Polyphenols also appear to exert therapeutic effects in sensitized individuals through anti-inflammatory and antioxidant mechanisms. Ray and Ming [32] showed that flavonoids inhibit the release of histamine, downregulate Th2 cytokines, and suppress NF-κB and GATA3 transcription factors in models of airway and food allergy.

Zeng and colleagues [10] detailed the process of epitope masking, whereby polyphenols alter allergenic protein structures, thus reducing IgE reactivity and symptom severity

in murine models ($p < 0.01$). Bi and colleagues and Wu and colleagues [4,8] emphasized gut-mediated pathways, showing that polyphenols enhance barrier integrity and reduce oxidative stress and antigen-presenting cell activation—mechanisms correlated with symptom relief.

Again, Singh and colleagues [30] provided compelling data that quercetin and catechins significantly reduce β -hexosaminidase release and inflammatory infiltration in allergic models, reinforcing their clinical potential.

The collective findings suggest that polyphenols may prevent allergic sensitization by enhancing immune tolerance, modulating Th2 responses, and maintaining epithelial barrier function and mitigate allergic symptoms in sensitized patients through anti-inflammatory, antioxidant, and microbiota-mediated mechanisms.

Such effects are consistently associated with high-polyphenol dietary patterns, especially those based on minimally processed plant foods. These include Mediterranean, vegetarian, and EAT-Lancet dietary models, which naturally provide a diverse polyphenol intake through fruits, vegetables, legumes, and teas. Although further RCTs are warranted, the convergence of preclinical and early clinical data supports the inclusion of polyphenol-rich foods in preventive and therapeutic strategies against allergic diseases.

3.3.3. Microbiota-Targeted Dietary Interventions in the Prevention and Management of Allergic Diseases: Evidence from Fiber and Fermented Plant-Based Foods

The immunomodulatory and clinical effects of microbiota-targeted dietary strategies in allergic disease prevention and treatment are summarized in Tables 9 and 10.

Table 9. Microbiota-targeted strategies and their role in allergic symptom modulation.

Author and Year	Level of Evidence (CEBM 2009)	Study Population and Design	Main Findings
Jiang et al., 2024 [9]	Level 1a	Systematic review and meta-analysis; 25 RCTs; 3122 mothers/infants; food allergy and microbiota outcomes.	Probiotics reduced allergy risk (RR 0.79, 95% CI 0.68–0.93, $p < 0.01$); enhanced microbial diversity and SCFA levels.
Pascal et al., 2018 [19]	Level 5	Review of ~45 studies on microbiome in allergy; human and animal data.	SCFAs from dietary fiber protect against allergies by modulating inflammation and enhancing epithelial defenses. $p < 0.05$.
Zhao et al., 2018 [20]	Level 5	Narrative review of ~50 studies; microbiome and food allergies in children and adults.	Altered microbiota reversible via fiber/probiotics. Increased Treg and barrier integrity observed. $p < 0.01$.
Balta et al., 2021 [33]	Level 5	Narrative review including ~35 studies on probiotics; experimental, clinical, and observational studies in children and adults.	Probiotics (e.g., <i>Lactobacillus</i> and <i>Bifidobacterium</i>) reduce histamine, enhance Treg cells, and suppress Th2 cytokines. Effective in symptom modulation in allergic patients. $p < 0.05$.
Cukrowska et al., 2018 [34]	Level 5	Narrative review; ~40 studies; pediatric focus on microbial and nutritional programming.	Early probiotic and fiber exposure reduces allergy risk and modulates symptoms via mucosal defense and microbial balance. p -values not applicable.

Table 9. Cont.

Author and Year	Level of Evidence (CEBM 2009)	Study Population and Design	Main Findings
Dargahi et al., 2019 [35]	Level 5	Review of ~50 studies on probiotics in allergy and autoimmunity; mainly preclinical and pediatric populations.	Probiotics increase IL-10, restore barrier integrity, and reduce IL-4/IL-5. Symptom attenuation observed. $p < 0.05$.
Di Costanzo et al., 2020 [36]	Level 5	Narrative review of >30 studies including RCTs and cohorts; pediatric food allergy focus.	Dysbiosis linked to food allergies. Dietary/probiotic modulation improves tolerance and symptom control. p -values not applicable.
Perdijk & Marsland, 2019 [37]	Level 5	Narrative review on microbiota-targeting dietary interventions; ~30 allergy prevention trials.	Prebiotics and probiotics reduce allergic sensitization. Early-life exposure is key. $p < 0.05$.

Level of Evidence (CEBM 2009): Oxford Centre for Evidence-Based Medicine, Levels of Evidence (March 2009).

Table 10. Fermentable dietary fibers, short-chain fatty acids (SCFAs), and their role in allergy prevention.

Author and Year	Level of Evidence (CEBM 2009)	Study Population and Design	Main Findings
Luís et al., 2022 [5]	Level 5	Review article on dietary senolytics, fiber metabolism, and immune aging; ~30 studies, including human, murine, and in vitro models.	Fermentable fibers increase SCFA production and modulate the gut-immune axis. SCFAs enhance epithelial integrity, Treg induction, and reduce Th2 cytokines. Preventive impact on allergy shown in dietary fiber-enriched models. $p < 0.05$.
Toda et al., 2019 [7]	Level 5	Review on the immunological effects of Maillard reaction products and SCFAs; ~40 experimental and mechanistic studies included.	SCFAs such as butyrate reduce IL-4 and IL-5 expression, enhance IgA production, and promote regulatory T cell differentiation. Evidence supports their role in dampening allergic inflammation. $p < 0.01$
Pascal et al., 2018 [19]	Level 5	Review of ~45 studies on microbiome and allergic diseases; focus on microbial metabolites and mucosal immunity.	SCFA-producing bacteria (e.g., <i>Faecalibacterium prausnitzii</i>) are reduced in allergic individuals. Fiber-rich diets enhance SCFA availability and protect against sensitization. $p < 0.01$.
Perdijk & Marsland, 2019 [37]	Level 5	Narrative review on microbiome-targeted interventions for allergy prevention; ~30 preclinical and interventional studies analyzed.	Prebiotic fibers improve microbial diversity and SCFA output. Butyrate and acetate linked to reduced food allergy onset in early-life models. Protective effects dependent on fiber type and timing of exposure. p -values ranged from < 0.05 to < 0.01 .

Level of Evidence (CEBM 2009): Oxford Centre for Evidence-Based Medicine, Levels of Evidence (March 2009).

A robust body of evidence from narrative reviews and systematic analyses highlights the preventive efficacy of fermentable fibers and probiotic interventions in shaping immune tolerance via microbiota modulation. Jiang and colleagues [9], through a systematic review of 25 RCTs involving over 3000 mother–infant pairs, demonstrated a statistically significant

reduction in food allergy incidence among infants receiving probiotic supplementation. The observed benefits were associated with enhanced microbial diversity and increased production of short-chain fatty acids (SCFAs), supporting the role of microbial metabolites in early immune education.

Many narrative reviews [4,7,19] converge in identifying SCFAs—primarily butyrate and acetate—as key mediators in the suppression of Th2 and Th17 responses. These SCFAs are generated through bacterial fermentation of dietary fibers like inulin, pectin, and resistant starch and contribute to epithelial barrier integrity, immunoglobulin A production, and Treg expansion. Luís and colleagues [5] emphasized that fiber-enriched diets modulate mucosal inflammation by favoring beneficial microbial taxa, while Pascal and colleagues [19] noted reduced levels of *Faecalibacterium prausnitzii* in allergic individuals—a marker of dysbiosis potentially reversible through diet.

Perdijk and Marsland [37], based on ~30 preclinical and interventional studies, reported that early-life exposure to fermentable fiber or prebiotics alters microbial colonization patterns and reinforces tolerogenic responses. These findings were echoed by Cukrowska and colleagues [34], who detailed how microbial and nutritional programming during infancy is critical to allergy prevention. Collectively, these reviews support the integration of dietary fiber and probiotics into preventive frameworks, particularly during developmental windows of immune plasticity.

From a mechanistic standpoint, Zhao and colleagues [20] provided insights into the pathways linking dysbiosis and allergic sensitization. They reported that gut microbial imbalance impairs immune education and barrier function, while targeted nutritional interventions (especially fibers and probiotics) restore immune equilibrium and oral tolerance. These molecular and immunological insights form the rationale behind microbiota-directed strategies in allergy prevention.

In terms of clinical management of allergic patients, narrative and clinical reviews indicate a growing role for dietary modulation of the microbiome in symptom control. Balta and colleagues [33] synthesized data from ~35 studies, noting that probiotic strains such as *Lactobacillus* and *Bifidobacterium* can suppress IL-4 and IL-5, reduce histamine production, and increase Treg activity. Dargahi and colleagues [35] reinforced this conclusion by showing increased IL-10 and mucosal integrity across preclinical and pediatric studies following probiotic administration.

Di Costanzo and colleagues [36], in their review of over 30 clinical trials and cohort studies, reported improved tolerance and reduced symptom burden in allergic children undergoing microbiota-targeted interventions. The beneficial effects were attributed to a reduction in IgE sensitization and the expansion of anti-inflammatory microbial taxa such as *Bifidobacterium longum*. Although the strength of evidence remains limited by heterogeneity and inconsistent outcome measures, the convergence of clinical, mechanistic, and epidemiological findings reinforces the therapeutic utility of microbiota modulation.

In conclusion, microbiota-targeted strategies—rooted in sustainable, fiber-rich plant-based diets and supported by probiotic supplementation—offer compelling evidence for both the prevention and treatment of allergic diseases. The incorporation of legumes, whole grains, and fermented plant products into dietary regimens not only aligns with environmental goals but also promotes microbial diversity, barrier resilience, and immune tolerance. These outcomes make microbiota modulation a promising and biologically plausible approach to allergic disease management.

3.4. Adjunctive Dietary and Environmental Modulators of Allergic Outcomes in Sustainable Nutrition Frameworks

3.4.1. Food Processing and Allergy: Preventive and Symptom-Modulating Perspectives

Food processing techniques play a dual role in allergic disease: they can either enhance sensitization or reduce allergenicity, depending on how they alter the structure, digestibility, and immunogenicity of dietary proteins. This complex relationship is detailed in Table 11 (preventive effects) and Table 12 (symptom modulation), which synthesize key findings from both experimental and clinical-level evidence.

Table 11. Processing methods and their role in the primary prevention of food allergies.

Author and Year	Level of Evidence (CEBM 2009)	Study Population and Design	Main Findings
Wu et al., 2023 [8]	Level 5	Narrative review on food processing and allergy pathways.	Minimally processed diets maintain barrier integrity and promote immune tolerance. Industrial processing may increase sensitization risk. <i>p</i> -values not applicable.
Toda et al., 2019 [7]	Level 5	Review on SCFA production via fermentable fibers and its impact on immunity.	Processing that retains fiber integrity supports SCFA generation, critical for allergy prevention. Refined foods reduce this benefit. <i>p</i> < 0.01.
Zeng et al., 2023 [10]	Level 5	Review on processing-induced changes in allergen structure.	Polyphenol binding and fermentation reduce allergenicity and epithelial permeability. Benefits observed in food allergy prevention. <i>p</i> < 0.01.
Pan et al., 2022 [29]	Level 5	Review on allergen–polyphenol conjugation in processed foods.	Conjugation of polyphenols to food proteins reduces antigenicity and IgE reactivity. Preventive effects in sensitization models. <i>p</i> < 0.05.

Level of Evidence (CEBM 2009): Oxford Centre for Evidence-Based Medicine, Levels of Evidence (March 2009).

Table 12. Food processing techniques and their effects on allergic symptom modulation.

Author and Year	Level of Evidence (CEBM 2009)	Study Population and Design	Main Findings
Teodorowicz et al., 2017 [21]	Level 5	Review on Maillard reactions, enzymatic hydrolysis, and allergenicity in food proteins.	Processing methods can increase or reduce allergenicity. Some thermal treatments expose IgE epitopes; enzymatic hydrolysis tends to reduce symptom potential. <i>p</i> < 0.01.
Verhoeckx et al., 2015 [22]	Level 5	Review on digestion models and allergenic potential of processed foods.	Simulated digestion and Caco-2 assays show altered allergenicity after processing. Impact depends on food matrix and type of processing. <i>p</i> -values not applicable.
Xing et al., 2024 [23]	Level 3b	Experimental study on soy protein treated with transglutaminase and lactic fermentation; <i>n</i> = 36.	Combined enzymatic and microbial processing significantly reduced IgE-binding and β-sheet structure in soy protein. <i>p</i> < 0.01.
Biscola et al., 2017 [24]	Level 3b	In vitro and ex vivo evaluation of fermented soymilk proteins.	Fermentation reduced immunoreactivity of β-conglycinin and glycinin. Potential application in hypoallergenic food formulations. <i>p</i> < 0.05.

Level of Evidence (CEBM 2009): Oxford Centre for Evidence-Based Medicine, Levels of Evidence (March 2009).

Minimally processed diets—such as those recommended by the EAT-Lancet Commission—tend to preserve fermentable fibers, antioxidant bioactives, and protein

structures in forms that promote mucosal tolerance and immunological homeostasis. Two reviews [7,8] highlight how industrially processed plant foods, often stripped of fiber and micronutrients, can impair the production of short-chain fatty acids (SCFAs) by the gut microbiota. This results in decreased regulatory T cell (Treg) induction and weakened epithelial barrier integrity, both of which increase the risk of allergic sensitization.

Conversely, functional processing methods—such as polyphenol–protein conjugation, fermentation, and enzymatic hydrolysis—demonstrate promise in reducing allergenicity before symptoms appear. For example, Pan and colleagues [29] reviewed multiple in vitro and animal studies showing that the covalent binding of polyphenols to allergenic food proteins can mask IgE epitopes, decreasing both antigenicity and immune activation. Zeng and colleagues [10] further confirmed that fermented or polyphenol-modified proteins improve epithelial tight junction function and reduce intestinal permeability, two hallmarks of a more resilient gut–immune interface.

Incorporating these methods into preventive strategies may help reduce the sensitization potential of common allergens such as soy and nuts, provided they are applied in a controlled, evidence-based context.

In individuals with established allergic disease, food processing can significantly alter the clinical expression of symptoms. Some techniques—such as high-heat processing or Maillard reactions—can increase allergenicity by exposing or stabilizing IgE-binding epitopes, as extensively reviewed by Teodorowicz and colleagues [21]. Similarly, Verhoeckx and colleagues [22] demonstrated that simulated digestion of processed foods can result in peptide fragments with unpredictable immunogenic potential, especially when tested in Caco-2 or mast cell models.

However, emerging studies show that biotechnological approaches combining enzymatic treatment and fermentation can reduce IgE-binding capacity and immunoreactivity. Xing and colleagues [23] found that soy proteins subjected to transglutaminase pre-treatment and lactic fermentation exhibited significantly altered secondary structure and reduced epitope exposure in 36 individuals. Likewise, Biscola and colleagues [24] demonstrated that fermentation of soymilk with *Enterococcus faecalis* led to a measurable decrease in the allergenicity of β -conglycinin and glycinin proteins.

Notably, Zeng and colleagues [10] also identified that polyphenol–protein conjugation not only reduced allergenicity in sensitization models but attenuated basophil degranulation during active allergic responses. This effect was linked to MAPK signaling modulation and inhibition of histamine and β -hexosaminidase release, supporting a direct application of processed hypoallergenic foods in clinical management.

From a practical perspective, the selection of fermented, hydrolyzed, or polyphenol-modified plant-based foods offers a promising low-risk strategy to reduce allergen exposure and symptom burden in sensitized individuals—particularly when dietary interventions are tailored and supervised.

3.4.2. Food Diversity and Seasonal Plant-Based Diets as Supportive Strategies in Allergy Prevention and Management

The preventive and therapeutic contributions of dietary diversity and seasonal plant-based food intake in allergic disease contexts are documented in Tables 13 and 14.

Table 13. Food diversity, seasonal dietary patterns, and allergy prevention.

Author and Year	Level of Evidence (CEBM 2009)	Study Population and Design	Main Findings
Bi et al., 2024 [4]	Level 5	Review on dietary factors influencing allergenicity and immune modulation.	Exposure to varied plant-derived proteins and phytochemicals improves oral tolerance. Protective effects observed in experimental models of sensitization. <i>p</i> -values not applicable.
Luís et al., 2022 [5]	Level 5	Review on sustainable diets and immune function; includes preclinical and human observational data.	Greater plant diversity improves microbial richness and promotes SCFA production and immune tolerance. Seasonally diverse diets linked to improved Treg induction. <i>p</i> < 0.05.
Toda et al., 2019 [7]	Level 5	Review of immune and gut barrier effects of SCFAs derived from dietary substrates.	Dietary diversity increases fermentable fiber substrates, enhancing SCFA production and mucosal defense. Preventive mechanisms involve Treg expansion. <i>p</i> < 0.01.
Wu et al., 2023 [8]	Level 5	Narrative review on bioactives and diet diversity in immune programming.	Greater intake of diverse polyphenols from seasonal fruits and vegetables linked to lower allergic responses. Antioxidants and prebiotics act synergistically. <i>p</i> -values not applicable.
Zeng et al., 2023 [10]	Level 5	Review on food allergy prevention via bioactive compounds; includes plant variety, fiber, and flavonoids.	Dietary variety enhances tolerance through microbiota modulation and reduced epithelial permeability. Strong preventive signals in early-life models. <i>p</i> < 0.01.

Level of Evidence (CEBM 2009): Oxford Centre for Evidence-Based Medicine, Levels of Evidence (March 2009).

While the primary protective effects of sustainable dietary patterns such as Mediterranean, vegetarian, and EAT-Lancet-aligned diets are attributable to their fiber, polyphenol, and micronutrient content, food diversity emerges as an important—though not exclusive—factor in modulating gut–immune resilience.

Several narrative reviews provide converging evidence that dietary variety, especially when based on a wide array of seasonal and minimally processed plant foods, can support immunological tolerance mechanisms. Luís and colleagues [5], drawing on both human observational and preclinical data, reported that greater plant species richness increases microbiota diversity and promotes short-chain fatty acid (SCFA) production. These metabolic products, particularly butyrate and propionate, are key inducers of regulatory T cells (Tregs) and are associated with decreased Th2 cytokine signaling in allergic models. The review covered approximately 30 studies and emphasized how seasonal food variation enhances mucosal immune homeostasis.

Toda and colleagues [7] supported this mechanistic framework through an analysis of over 40 experimental and mechanistic studies. The authors documented how dietary variety, via its impact on fermentable fiber availability, amplifies SCFA production, improves epithelial integrity, and stimulates IgA production and Treg differentiation in murine models of food allergy. These immune adaptations are central to the maintenance of oral tolerance and reduced allergic sensitization.

Bi and colleagues [4] emphasized the immunological relevance of repeated and varied exposure to different plant proteins and phytochemicals during early life. The review synthesized data from in vitro models and animal trials, underscoring how antigenic diversity contributes to immune education and tolerance development via both microbial and epigenetic pathways.

Table 14. Dietary diversity and seasonal foods in symptom modulation.

Author and Year	Level of Evidence (CEBM 2009)	Study Population and Design	Main Findings
Bi et al., 2024 [4]	Level 5	Review on dietary allergenicity and immune modulation in plant-based contexts	Varied exposure to plant proteins and phytochemicals linked to oral tolerance induction via epigenetic and microbial pathways. Observed reduction in allergic symptom frequency in preclinical studies. Highlights the immunological relevance of dietary complexity. <i>p</i> -values not applicable.
Luís et al., 2022 [5]	Level 5	Review on sustainable diets and immune modulation; includes preclinical and human data	Higher dietary diversity, especially in unprocessed plant foods, increased SCFA-producing microbial species, improved mucosal barrier markers, and decreased systemic Th2 cytokines. Supports the role of seasonal diversity in dampening allergic inflammation. <i>p</i> -values not applicable.
Toda et al., 2019 [7]	Level 5	Review on SCFAs and their immunological effects; ~40 studies including murine and cellular models	Greater plant diversity led to enhanced fermentation of dietary fiber into butyrate and propionate, which reduced IL-4, IL-5, and eosinophil infiltration. Mice fed seasonally varied diets showed reduced allergen-specific IgE. <i>p</i> < 0.01.
Wu et al., 2023 [8]	Level 5	Narrative review of molecular pathways involved in immune modulation by dietary bioactives	Diverse polyphenols from seasonal vegetables and fruits enhanced Treg responses and reduced mast cell degranulation. Polyphenol–fiber co-delivery improved gut microbiota resilience. Studies support benefit in modulating allergic flares. <i>p</i> -values not applicable.
Zeng et al., 2023 [10]	Level 5	Review on food bioactives in allergy prevention; includes 60 studies	Varied plant-based diets rich in flavonoids lowered intestinal permeability, suppressed NF-κB signaling, and improved resistance to allergen-induced gut inflammation. Particularly strong effects seen in early-life models <i>p</i> < 0.01.

Level of Evidence (CEBM 2009): Oxford Centre for Evidence-Based Medicine, Levels of Evidence (March 2009).

Wu and colleagues and Zeng and colleagues [8,10], in their respective reviews of ~60 and ~50 studies, further highlighted that a diverse intake of polyphenol-rich seasonal plant foods not only increases the richness and functional stability of gut microbiota but also reduces epithelial permeability and modulates key inflammatory pathways such as NF-κB. These effects contribute to the maintenance of immune homeostasis and may reduce the risk of sensitization in early developmental stages.

Although the reviewed data are predominantly preclinical or observational, they collectively reinforce that plant food diversity—especially when integrated into broader dietary frameworks characterized by high fiber, polyphenol density, and limited animal protein intake—can support preventive strategies against food allergy.

In already sensitized individuals, the integration of seasonal food diversity into plant-based diets may contribute to symptom modulation. Luís and colleagues [5] documented how unprocessed, fiber-rich plant foods enhance the abundance of SCFA-producing microbial taxa and improve mucosal barrier function. In allergic subjects, these changes are associated with lower systemic inflammation and improved immune regulation.

Bi and colleagues [4] emphasized the role of dietary complexity in promoting immune tolerance and decreasing the frequency and severity of allergic symptoms. Their findings, based on multiple preclinical models, suggest that epigenetic modulation and enhanced microbial signaling contribute to a more balanced immune response, particularly in individuals adhering to diets with high plant food variety.

Toda and colleagues [7] confirmed that mice receiving seasonally rotated, fiber-diverse diets showed reduced infiltration of eosinophils and lower expression of Th2 cytokines (IL-4 and IL-5), alongside decreased allergen-specific IgE levels. These outcomes support the relevance of microbiota-mediated mechanisms in allergy symptom attenuation.

Wu and colleagues and Zeng and colleagues [8,10], further observed that seasonal intake of diverse flavonoid-rich vegetables and fruits contributed to reduced mast cell degranulation and improved mucosal resilience. These benefits were particularly evident in early-life models but also showed translational relevance for adult allergic populations.

It is essential to note that these immunological effects are not derived from food diversity per se, but from its role in amplifying the functional potential of plant-based diets—especially when characterized by a reduction in animal-derived products. This dietary shift favors the development of a non-putrefactive, eubiotic microbiota and enhances the intake of nutrient-dense, prebiotic foods rich in antioxidants and anti-inflammatory compounds. Such profiles align with allergy prevention and management principles grounded in mucosal tolerance and epithelial defense.

In conclusion, while food diversity is not the primary determinant of the efficacy of sustainable dietary models in allergy contexts, it remains a critical, modifiable element. When integrated into Mediterranean, vegetarian, or EAT-Lancet frameworks, seasonal plant food variety contributes to immune education, microbial balance, and inflammatory control—mechanisms essential for reducing both the risk and clinical burden of allergic diseases.

4. Discussion

This review highlights how sustainable plant-based dietary patterns—particularly those aligned with the EAT-Lancet and Mediterranean frameworks—may act as both preventive and therapeutic tools in the context of food allergies, through mechanisms that extend beyond allergen exclusion. Within this context, plant-based diets represent a valuable adjunct due to three key features: (1) the reduction or elimination of common allergenic foods such as dairy, eggs, and shellfish; (2) the enhancement of gut microbial health through increased intake of fermentable fibers, fructo-oligosaccharides (FOSs), and microbiota-derived short-chain fatty acids (SCFAs); and (3) the anti-inflammatory and immunomodulatory effects of polyphenols found in whole plant foods.

Among the most extensively supported factors, gut microbiota modulation, polyphenol intake, fiber-induced SCFA production, and probiotic supplementation emerge as key drivers of immune resilience. Microbiota-targeted strategies appear central to both allergy prevention and symptom modulation. Fermentable fibers present in legumes, fruits, and whole grains are metabolized by commensal bacteria into short-chain fatty acids (SCFAs), notably butyrate and propionate, which interact with G-protein-coupled receptors such as GPR43 and GPR109A on intestinal epithelial and immune cells. These SCFAs inhibit histone deacetylases (HDACs), promote Treg cell differentiation, enhance IgA secretion, and strengthen the intestinal barrier by upregulating tight-junction proteins including occludin and claudin-1 [4,7,19]. SCFAs also suppress the Th2 cytokine axis and reduce eosinophilic infiltration in allergic tissue models [20]. Polyphenols act synergistically on immune and epithelial compartments. In *in vitro* studies, flavonoids such as quercetin, epigallocatechin gallate, and resveratrol have demonstrated mast cell stabilization, suppression of IL-4,

IL-5, and IL-13, and inhibition of NF- κ B and GATA-3 signaling [8,30,31]. These effects are mediated in part via modulation of Toll-like receptors (TLRs), inhibition of oxidative stress, and direct binding to allergenic epitopes, although these findings are primarily supported by preclinical and in vitro studies [10,29]. Conjugation of polyphenols to food proteins also alters tertiary structure and masks conformational IgE-binding domains, decreasing antigenicity [8,29]. Probiotic supplementation during pregnancy or infancy, particularly with *Lactobacillus* and *Bifidobacterium* strains, has been associated with lower food allergy incidence in offspring. Meta-analytic data confirm that antenatal probiotic use increases microbial α -diversity and SCFA production, facilitating the development of oral tolerance [9,38]. Mechanistically, probiotics reduce Th2 polarization, promote IL-10 and TGF- β production, and enhance mucosal IgA responses [33,35].

Dietary diversity—especially when derived from seasonal, minimally processed plant foods—supports immunotolerance via microbial and antigenic variety. High plant-food diversity increases microbial richness and functional redundancy, enhances SCFA biosynthesis, and favors microbial communities enriched in *Faecalibacterium prausnitzii* and *Bifidobacterium* species, which are associated with decreased allergic sensitization [4,5,10]. While the aforementioned points represent core factors supported by robust data, several adjunctive elements warrant further attention. Food processing methods, for example, can either reduce or enhance allergenicity. Enzymatic hydrolysis and microbial fermentation of soy, legumes, and nuts reduce IgE-binding capacity and mast cell degranulation, in part by modifying protein conformation and reducing the stability of immunogenic epitopes [21,23,24]. In contrast, Maillard reactions may stabilize allergenic domains, increase resistance to digestion, and enhance antigen presentation by dendritic cells [7,22].

Plant-based diets also introduce novel allergenic exposures—especially from lupin, pea, and soy proteins—when adopted without clinical supervision [1,14]. Moreover, a high intake of omega-6 fatty acids from refined seed oils may promote Th2-skewing and IL-13 expression, whereas ALA-rich sources like walnuts and flaxseed offer anti-inflammatory and barrier-protective properties [4,5].

Taken together, the potential protective effects of plant-based sustainable diets appear to be influenced not simply by the exclusion of animal foods but by a combination of factors such as the density of immunomodulatory plant compounds, fiber quality, degree of food processing, and microbiota resilience. These components may interact to influence key immunological pathways—including dendritic cell activation, antigen sampling, epithelial integrity, and lymphocyte polarization—which could plausibly contribute to allergy prevention and symptom modulation.

4.1. Limitations

This review presents an integrated view of the current evidence but is subject to several limitations. First, the majority of the included studies were narrative reviews, observational cohorts, or preclinical experiments, which limits causal inference. The heterogeneity of study designs, outcome measures, and dietary definitions (e.g., “plant-based”, “vegan”, and “Mediterranean”) further complicates direct comparisons and may reduce internal validity. Second, much of the mechanistic evidence—particularly regarding SCFA production, polyphenol–protein interactions, and probiotic effects—derives from in vitro models or animal studies, such as murine sensitization protocols or Caco-2 assays. These models, while informative, may not fully recapitulate human immunophysiology, and their generalizability remains limited. Third, food processing methods are inconsistently defined across the literature. While this review distinguishes between minimally and ultra-processed products, operational definitions vary widely, and their clinical translation is often unclear. Additionally, many studies fail to report standardized endpoints such as serum IgE, ba-

sophil activation, or validated clinical symptom scores. Moreover, although we selected only studies that explicitly referred to sustainable plant-based diets or EAT-Lancet-inspired patterns, we acknowledge the existing definitional heterogeneity across the literature. This variability may hinder standardization and comparability across studies. However, rather than representing a methodological flaw of this review, we consider it a reflection of a broader gap in the scientific literature. At present, direct comparisons between specific subtypes of sustainable plant-based diets—such as vegan versus flexitarian or EAT-Lancet-aligned models—in the context of food allergies remain extremely limited. This reinforces the need for future research to refine and standardize dietary definitions in allergy-related studies. Finally, this review did not assess risk of bias quantitatively across all included studies, given the scope and heterogeneity of the data.

4.2. Clinical and Public Health Implications

Although this review does not aim to provide formal clinical recommendations, it includes several elements that may inform professional practice. These include the potential need for nutritional supervision in patients with restrictive plant-based diets, attention to hidden allergens in processed products, and emerging evidence on the immunomodulatory effects of dietary components. Given the heterogeneity and preliminary nature of the current evidence base, we believe that practical implementation strategies should be developed cautiously and only within a clinically supervised framework. This aligns with the purpose and methodological scope of a scoping review.

From a clinical perspective, the integration of sustainable plant-based diets into allergy management holds promise, especially when such diets are personalized and supervised by qualified healthcare professionals. Dietary interventions rich in fermentable fibers, polyphenols, and probiotics may reinforce gut barrier function, promote microbial diversity, and support immunoregulatory pathways. However, clinicians must remain alert to potential nutritional deficiencies (e.g., B12, zinc, and iron) and inadvertent allergen exposures—particularly in patients with complex dietary restrictions or in those consuming ultra-processed plant-based products.

Personalized strategies, including component-resolved diagnostics, structured food reintroduction, and microbiota assessment, may enhance the safety and efficacy of dietary interventions in allergic individuals. Particular attention should be given to pediatric populations, pregnant women, and patients with multiple food sensitivities. At the public health level, this review supports the alignment of allergy prevention frameworks with sustainable nutrition policies. Promoting microbiota-supportive diets within national guidelines, enhancing food literacy regarding allergen risks in plant-based products, and incentivizing the consumption of minimally processed, seasonal foods may reduce both allergy burden and environmental impact. Future research should prioritize randomized controlled trials assessing plant-based dietary interventions in diverse allergic cohorts. Particular emphasis should be placed on clinical endpoints (e.g., IgE and oral food challenges), biomolecular markers (e.g., SCFA levels and cytokine profiles), and long-term outcomes, including tolerance induction and quality of life. These studies will be essential to substantiate the translational potential of sustainable dietary patterns in allergy prevention and management.

5. Conclusions

This review underscores the integrative value of sustainable plant-based dietary models—particularly those aligned with the EAT-Lancet framework—in the context of food allergy prevention and management. Their clinical potential lies in three converging mechanisms: the natural reduction or elimination of common allergens such as dairy, eggs,

and shellfish; the enhancement of gut microbial homeostasis through fermentable fibers, fructo-oligosaccharides (FOSs), and short-chain fatty acid (SCFA) production; and the anti-inflammatory and immunomodulatory actions of polyphenols, including flavonoids such as quercetin, catechins, and luteolin.

These effects are mediated through core biomolecular pathways: increased regulatory T cell (Treg) differentiation via SCFA–GPR43 signaling, stabilization of epithelial tight junction proteins such as occludin and claudin, suppression of Th2-polarized cytokines (IL-4, IL-5, and IL-13), and inhibition of mast cell degranulation and NF- κ B-driven inflammation. Importantly, these benefits emerge most consistently when plant-based diets are rich in unprocessed, polyphenol-dense, and fiber-rich foods—thus aligning with both nutritional adequacy and ecological sustainability.

Complementary strategies—including dietary diversity, targeted fermentation, and hypoallergenic food processing—further enhance tolerance acquisition and symptom relief, particularly in sensitized individuals. Together, these findings support the EAT-Lancet framework as a holistic model integrating allergy prevention with sustainable nutrition and immune resilience.

While promising, these findings should be interpreted with caution. Sustainable diets may contribute to reducing the burden of food allergies through immunonutritional pathways, but further high-quality clinical studies are needed to confirm these associations and inform evidence-based recommendations.

Author Contributions: Conceptualization, M.R., G.M., C.C. and S.P.; methodology, D.A., T.A.A., and G.M.; validation, G.M., S.P. and M.R.; formal analysis, T.A.A. and D.A.; investigation, T.A.A., D.A. and E.P.; resources, M.R.; data curation, G.M. and C.C.; writing—original draft preparation, C.C.; writing—review and editing, M.R., G.M. and S.P.; visualization, G.M. and C.C.; supervision, M.R. and G.M.; project administration, G.M.; funding acquisition, M.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflicts of interest.

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