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The Relationship Between Dietary Patterns and the Epidemiology of Food Allergy

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ABSTRACT

Food allergies are increasing globally, particularly in Asia; however, the etiologies of allergic diseases remain poorly understood despite comprehensive studies conducted across a variety of populations. Epidemiological research demonstrates that food allergy is more prevalent in Westernized or urbanized societies than in rural or developing ones. As such, comparing the distribution and patterns of food allergies as well as the environmental exposures between regions may provide insight into potential causal and protective factors of food allergy. Diet is an important exposome that has been shown to modulate the immune system both directly and indirectly via pathways involving the microbiota. Changes in dietary patterns, especially the shift to a Westernized diet with reduced dietary fiber and an abundance of processed foods, impact the gut and skin epithelial barrier and contribute to the development of chronic inflammatory diseases, such as food allergy. Although dietary intervention is believed to have tremendous potential as a strategy to promote immunological health, it is essential to recognize that diet is only one of many factors that have changed in urbanized societies. Other factors, such as pollution, microplastics, the use of medications like antibiotics, and exposure to biodiversity and animals, may also play significant roles, and further research is needed to determine which exposures are most critical for the development of food allergies.

1 | Introduction

The prevalence of food allergy (FA) has been steadily increasing in many parts of the world, including Asia [1]. As we enter the Anthropocene Epoch—a geological period defined by the transformative impact of human activities such as industrialization, pollution, deforestation, and species extinction—key environmental factors such as diet, allergens, and microbiota are also being reshaped, altering the host–environment interaction [2]. Notable markers such as elevated carbon dioxide levels and synthetic materials embedded in geological records further highlight the distinctions of this era [3]. One key gap in our understanding of FA pathophysiology is the complex interplay between genetic and environmental factors. Although certain genetic variants may confer increased susceptibility to developing FA, the specific gene–environment interactions that trigger the onset and

Abbreviations: AGEs, advanced glycation end products; ALADDIN, Assessment of Lifestyle and Allergic Disease During Infancy; aOR, adjusted odds ratio; APRA, Asia-Pacific Research Network for Anaphylaxis; CAGR, compounded annual growth rate; COCOA, COhort for Childhood Origin of Asthma and allergic diseases; EAACI, European Academy of Allergy & Clinical Immunology; FA, food allergy; FPIES, food protein–induced enterocolitis syndrome; HDACs, histone deacetylase; HK, Hong Kong; LMIC, low- or middle-income country; n-3 LC-PUFA, n-3 long-chain polyunsaturated fatty acid; ORs, odds ratios; OVA, ovalbumin; PARSIFAL, Prevention of Allergy Risk factors for Sensitization In children related to Farming and Anthroposophic Lifestyle; PIFA, prevalence of infant food allergy; SCFAs, short-chain fatty acids; SDS, sodium dodecyl sulfate; TCD, traditional Chinese diets; UK, United Kingdom; UPFs, ultra-processed foods; US, United States.

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progression of these conditions are not fully elucidated. This lack of knowledge hinders the development of targeted preventive strategies and personalized treatment approaches.

The process of modernization leads to the loss of protective factors that are commonly associated with traditional rural settings. Conversely, it brings about the emergence of risk factors that are correlated with modern urbanized living. Asia, as an incredibly diverse continent with significant economic disparities, has led to varied lifestyles and dietary patterns across the region, resulting in diverse patterns of FA and anaphylaxis in Asia. Approximately 2500 years ago, Hippocrates introduced the idea that "food is medicine," declaring "Let food be thy medicine and medicine be thy food." It is crucial for researchers to investigate the complex relationship between diet and the prevalence of food allergies in the region.

This review aims to dissect the epidemiological link between dietary patterns and FA prevalence, contrasting the trends observed in the West versus the East. It provides background on the global nutritional transition and how the processes of modernization in the East have impacted local dietary habits and the corresponding FA landscapes. The review will delve into the relationship between diets and the epidemiology of FA, highlighting the protective role of dietary fiber and the potential risks associated with processed foods, and discuss how changes in the epithelial barrier function related to emulsifiers in ultra-processed foods (UPFs) may contribute to increased FA risk.

Understanding the dynamic interplay between dietary patterns and the emergence of food allergies in Asia can provide valuable insights for developing targeted prevention and management strategies. Collaborative research efforts, involving epidemiological studies and mechanistic investigations, are necessary to elucidate the complex relationship between diet, the gut microbiome, and the immune responses underlying food allergies in this diverse and rapidly evolving region.

2 | Heterogeneity of FA and Anaphylaxis in Asia

Between 1990 and 2000, food allergies significantly increased in Western countries but have remained stable over the past two decades [4]. In the Isle of Wight, United Kingdom, peanut allergy prevalence increased from 1.3% to 3.3% between 1993 and 1998, but remained at 2% in 2005 [5, 6].

In Australia, two cohort studies indicated that the prevalence of peanut allergy remained stable at around 3% between 2007–2011 and 2018–2019 [7, 8]. This stability contrasts with earlier increases in peanut allergy prevalence observed in other regions and suggests that the rates may have plateaued rather than continued to rise. In contrast, the prevalence of FA in China appears to be rising in the past decade [9]. The rise was, however, not homogeneous across Asia. In rural parts of Thailand, FA remains uncommon over time [10]. Figure 1 illustrates the changing prevalence of FA between Eastern [11] and Western [12–14] regions over time.

The incidence of anaphylaxis serves as a useful marker of FA burden. A systematic review of 59 pediatric studies found that food-induced anaphylaxis rates ranged from 1 to 77 per 100,000 person-years globally, with 19 studies indicating an upward trend over time [15]. The incidence varied significantly by study and region, with Asia reporting lower rates of both total and food-induced anaphylaxis compared to other areas. However, the review's findings were limited by underrepresentation of studies from developing countries, differing methodologies, and high

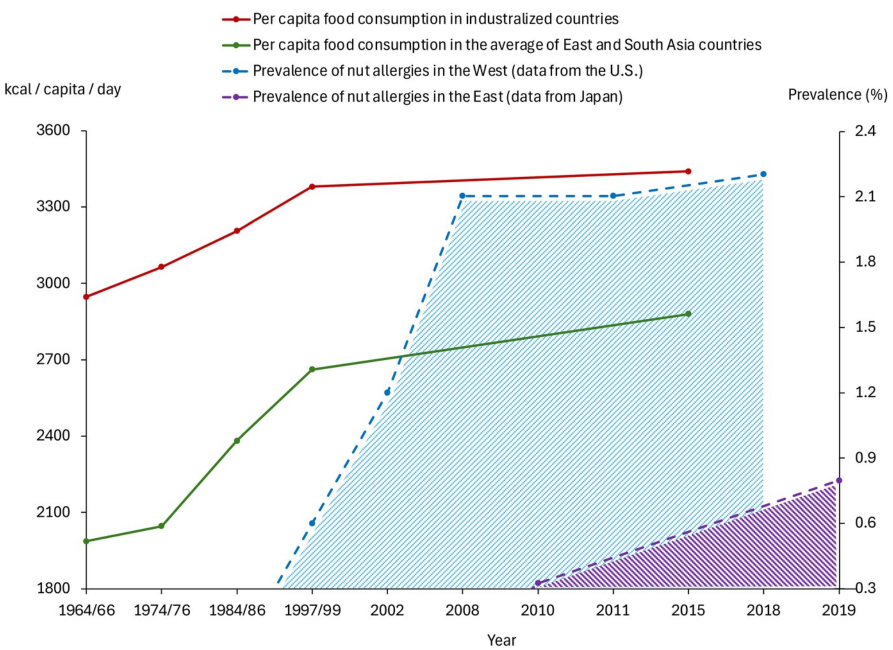

FIGURE 1 | The changing prevalence of food allergies in eastern and western regions over time. In Japan, the overall prevalence of food allergies increased from 0.325% in 2010 (95% CI, 0.311–0.339) to 0.797% in 2019 (95% CI, 0.790–0.804) [11]. For peanut and tree nut allergies among children under 18 years, the prevalence rose from 0.6% in 1997 to 1.2% in 2002, reaching 2.1% in 2008 in the United States [12]. Additionally, studies by Gupta et al. indicated that the prevalence of peanut allergies was 2.0% in 2011 (95% CI, 1.8–2.2) and increased to 2.2% in 2018 (95% CI, 2.0–2.5) [13, 14].

heterogeneity among the studies. Recent data from the Asia-Pacific Research Network for Anaphylaxis (APRA) shed light on food anaphylaxis patterns across Asia [16]. A pediatric anaphylaxis registry established between 2019 and 2022 captured 721 episodes from locations including Hong Kong (HK), Qingdao, Singapore, Bangkok, and Nakhon Nayok. Food was the most common trigger, accounting for 62% of cases among children under 18. Specific triggers varied by country: eggs and cow's milk were predominant for children under three, whereas shellfish was most common for those aged seven and older. Nut allergies were more common in HK and Singapore, whereas wheat allergies were more prevalent in Bangkok. Although peanut allergies were less prevalent in HK and Singapore [17, 18], peanuts were the leading cause of food-induced anaphylaxis in older children, likely due to their potential for severe reactions and their presence in various Asian dishes [19]. In Japan, early onset tree nut allergies, particularly to walnuts, are on the rise [20, 21]. Current limitations include the reliance on self-reported data for most prevalence studies on FA in Asia. Few studies are based on challenge-proven outcomes, and even fewer are time-trend studies.

Since the 2017 international consensus guidelines for food protein–induced enterocolitis syndrome (FPIES) [22], cases have increased in Europe, the United States, Australia, Israel, Japan, and Korea [23]. The first cases of milk-induced FPIES were documented in 1967, followed by rice-induced cases in 1963 and egg-induced cases in 1984. Common triggers now include milk, soy, egg, rice, and fish [24]. Although FPIES remains rare, with a prevalence of 0.015%–0.7% [24], there is preliminary evidence of a rising trend [25], particularly in egg-induced cases in Japan and emerging peanut-induced cases in the United States [26–28]. The epidemiology of FPIES and other non-IgE–mediated gastrointestinal allergies in Asia, however, remains unclear.

Overall, the global prevalence and pattern of FA, whether IgE or non-IgE mediated, are constantly evolving. Recent evidence suggests that the prevalence of IgE-mediated FA may be rising in the developing regions, although the pattern is highly heterogeneous across Asia. In contrast, non-IgE–mediated FA is rising in Westernized countries. Although the West generally supports the early introduction of allergenic solids, including peanuts [29–31], this approach may not be as relevant in the East [32], where the background prevalence of peanut allergies is much lower. Culturally, peanuts are not commonly used as first complementary foods in many Asian countries [33]. Moreover, evidence from Asian cities like Singapore indicates that despite the delayed introduction of peanuts, the prevalence of peanut allergies remains low [18]. This suggests that different dietary practices and cultural contexts may play a significant role in the development of food allergies in these regions.

3 | The Relationship Between Diet and FA

3.1 | Relationship Between Dietary Fiber and FA Protection

Urbanization and Westernized diets are believed to be major factors driving the disparity between the East and the West. Previous articles have summarized in detail the differences in the pattern of FA and anaphylaxis between the East and the West [34]. We propose that leveraging the modifiable nature of dietary habits is key to addressing the growing FA crisis and improving outcomes through region-specific, evidence-based approaches.

Early observational studies found that an anthroposophic lifestyle, characterized by a vegetable-rich diet and reduced use of antibiotics, may lower the incidence of allergic sensitization in children from these families. The PARSIFAL study compared farm children and those from anthroposophic families, finding a reduced prevalence of allergic symptoms and sensitization in both groups, although the difference was less consistent in the anthroposophic group. The ALADDIN birth cohort study further demonstrated that children from anthroposophic households had a significantly lower risk of atopic sensitization during the first 2 years of life compared to those from non-anthroposophic families [35]. The anthroposophic diet, similar to a Mediterranean diet, was identified as a potential contributing factor, although other aspects of the lifestyle, such as restricted vaccinations and antibiotics, may have also played a role. Moreover, these studies only demonstrated differences in atopic sensitization and not in the prevalence of FA specifically. In a longitudinal prospective cohort study conducted in the United Kingdom, the Prevalence of Infant Food Allergy (PIFA) study found that a high-vegetable, fruit, and home-cooked infant diet is related to a reduced risk of FA by 2 years of age [36]. A recent pre-birth cohort study, Healthy Start in the United States, involving 1410 mothers, found that a maternal diet high in vegetables and yogurt was protective against the development of airway and skin allergies in the offspring by age four [37]. However, the study did not find a significant association between the maternal diet and the later development of FA, likely due to the relatively lower incidence of FA compared to that of the other allergic conditions examined. Being another significant component of a Mediterranean diet, the effect of fish consumption was also examined in a prospective birth cohort of 4089 infants. In this study, regular fish consumption during the first year was associated with a reduced risk of allergic disease (OR 0.76) and sensitization (OR 0.76) by age four [38]. Despite these promising findings, an earlier systematic review and meta-analyses involving 62 articles, including cohorts, case–control, and cross-sectional studies, found weak evidence that vitamins A, D, and E; zinc; fruits and vegetables; and a Mediterranean diet are associated with protection against asthma, but not other allergic diseases including FA [39].

Interventional studies showed that supplementation with n-3 long-chain polyunsaturated fatty acid (n-3 LC-PUFA) was able to alter the plasma levels of fatty acid but did not translate into a reduced prevalence of FA and other atopic conditions in these studies on infants and children [40, 41]. Recently, a systematic review of 46 interventional studies during pregnancy, lactation, and infancy found no specific dietary components that significantly prevented FA. This includes vitamins, fish oil, and pre/pro/synbiotic supplements [42, 43]. Instead, the ways that cow's milk and eggs were introduced, and the timing of the introduction of eggs and peanuts were important factors in reducing the risk of specific FA.

It is interesting to note the disparity between the observed clinical findings in prospective cohort studies and the outcomes of interventional trials assessing the clinical impact of various dietary components. The reasons for the differing results are not fully understood, but it is likely that the overall dietary pattern plays a crucial role rather than isolated dietary components. This perspective aligns with the concept of "food synergy," which suggests that the health benefits of foods stem from the interactions among their various components rather than just individual nutrients [44]. Findings from the KOALA Birth Cohort Study in the Netherlands support this idea, showing that healthier dietary patterns associated with organic food consumption, characterized by a high ratio of vegetables to fast food, instead of the organic products themselves, were linked to a more favorable pre-pregnancy BMI and a lower prevalence of gestational diabetes [45]. Additionally, diet should be considered alongside changes in gut microbial composition and metabolic profiles. This highlights the connection between nutrition, immune function, and allergic disease, which is increasingly referred to as an "immune-supportive diet," referring to a diverse diet rich in fresh, whole, and minimally processed plant-based foods, fermented foods, and moderate amounts of omega-3-rich and animal-based products that can synergistically improve immune function and gut health [46]. Figure 2 summarizes the influence of dietary patterns on the risk of developing FA.

Dietary patterns consisting of a diverse array of dietary fatty acids and fiber types and sources have been proven more effective for managing allergy risk and symptoms than simply focusing on individual supplements [40, 44, 46, 47]. Dietary fibers are plant-based, nondigestible carbohydrates that provide nourishment for the gut microbiome, leading to the production of short-chain fatty acids (SCFAs) as a result of microbial fermentation. By forming SCFAs, dietary fiber-fermenting bacteria modulate the gut barrier's function and help build a tolerogenic environment through different cellular pathways in the epithelial, dendritic, and T cells [48, 49]. In a study that recruited healthy lactating women, butyrate in human breast milk reduced allergic responses in both in vivo and in vitro models [50]. A high-fiber diet has been shown to increase the production of SCFAs and provide protection against FA in a murine model [51]. Depriving mice of dietary fiber led to a gut microbiome signature characterized by increases in the mucin-degrading bacterium *Akkermansia muciniphila* [52]. This gut microbial profile was associated with impaired intestinal barrier function, elevated expression of type 1 and type 2 cytokines, and the presence of IgE-coated commensal bacteria in the colon. These changes exacerbated allergic reactions to food allergens such as ovalbumin (OVA) and peanuts. Furthermore, in a synthetic human gut microbiome in gnotobiotic mice, the presence of *A. muciniphila*, combined with fiber deprivation, resulted in stronger anti-commensal IgE coating and increased innate type 2 immune responses, further worsening FA symptoms. SCFAs diffuse passively and systemically, primarily acting as signaling molecules via binding to different GPCRs to exhibit anti-inflammatory actions [53, 54]. Through SCFA-GPCR activation and histone deacetylase (HDAC) inhibition, SCFA stimulated the growth and expansion of Treg [55–57]. Other experimental models have consistently demonstrated that SCFAs play a significant role in the growth of immunological oral tolerance and have potent anti-inflammatory actions in allergic disorders [55, 56, 58].

In human studies, Cait et al., using metagenomics sequencing, uncovered that infants who later developed allergic sensitization in childhood had gut microbiomes lacking the necessary genes for carbohydrate breakdown and butyrate production [59]. These findings suggest that a butyrate-producing gut microbiome in early infancy may protect against the development of childhood allergies. Children who had high amounts of butyrate and propionate in their feces at 1 year old had a lower risk of developing FA and asthma later in life [60, 61]. Researchers have also consistently observed that children with both IgE-mediated and non-IgE–mediated cow's milk allergies exhibited a state of gut microbial imbalance, or dysbiosis, characterized by reduced levels of the SCFA butyrate in their stool samples when compared to healthy control children without milk allergies [62, 63]. The resolution of non-IgE–mediated cow's milk allergies occurred more quickly in individuals with an abundance of butyrate-producing bacteria [64]. Despite the promising results from experimental models, mixed results were reported

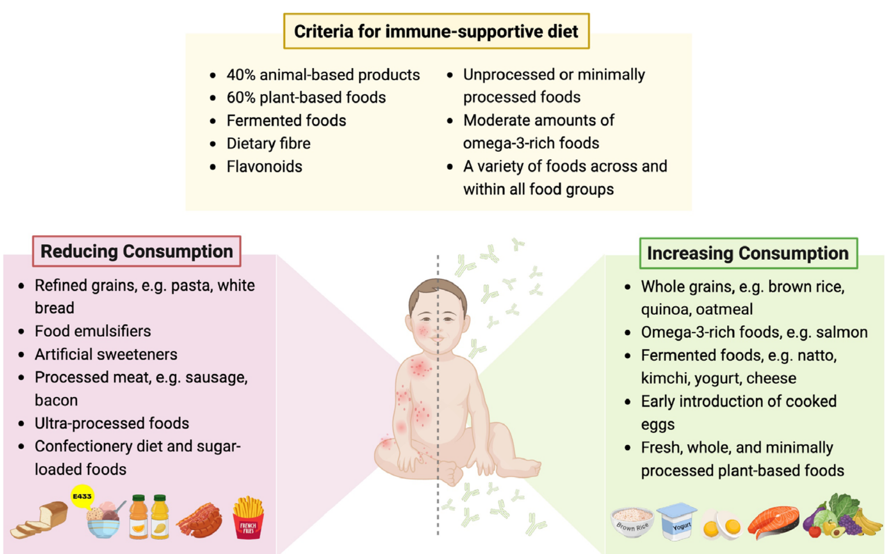

FIGURE 2 | The potential risk factors and protective elements related to various dietary practices, and how different foods and dietary patterns may influence the likelihood of developing food allergies.

in a systematic review and meta-analyses of observational and intervention studies that evaluated the relationship between the SCFA level and allergic outcomes, likely due to differences in methodologies used [65]. Figure 3 presents an outline of how diet may offer protection and pose risks for FA.

Overall, evidence has shown promise that a diet rich in fiber and diverse plant-based foods can foster a healthy gut microbiome, promoting immune tolerance and reducing the risk of FA. This needs to be considered alongside the timing and manner of introducing allergenic foods during early life, which can also influence the gut microbiome and the risk of developing FA [66]. This is supported by findings from the CORAL cohort, which demonstrate that the introduction of foods, such as beans, nuts, seeds, oils, and cow's milk, significantly impacts microbiota composition during early life [67]. Although the effects of oil, beans, and nuts were similar to those of breastfeeding and vaginal birth—promoting the growth of beneficial bacteria such as *Bifidobacterium* and *Lactobacillus*—animal-derived products, particularly cow's milk, shifted the microbiota away from a composition dominated by *Bifidobacterium* and *Bacteroides*. Further studies that evaluate how dietary patterns and the introduction of specific foods during early life may influence gut health and immunity are needed to inform strategies for preventing and managing food allergies. Clinical trials examining the targeted use of SCFAs as an intervention for treating FA are much needed [49, 66, 68].

3.2 | Evidence on UPFs and FA Risk

Although there is a strong interest in the role of dietary fiber and SCFA in protecting infants from developing an FA, there is concurrently an increased focus on the harmful influences of certain dietary components of allergic disease outcomes. Among 1628 infants born between 2007 and 2015 from the COhort for Childhood Origin of Asthma and allergic diseases (COCOA) cohort in South Korea, a maternal confectionery diet during pregnancy, characterized by a higher intake of baked and sugary products, was associated with a higher prevalence of FA (aOR = 1.517, $p = 0.02$) [69]. Furthermore, the research group found that the confectionery diet was more significant in infants with specific genetic polymorphisms in CD14 and

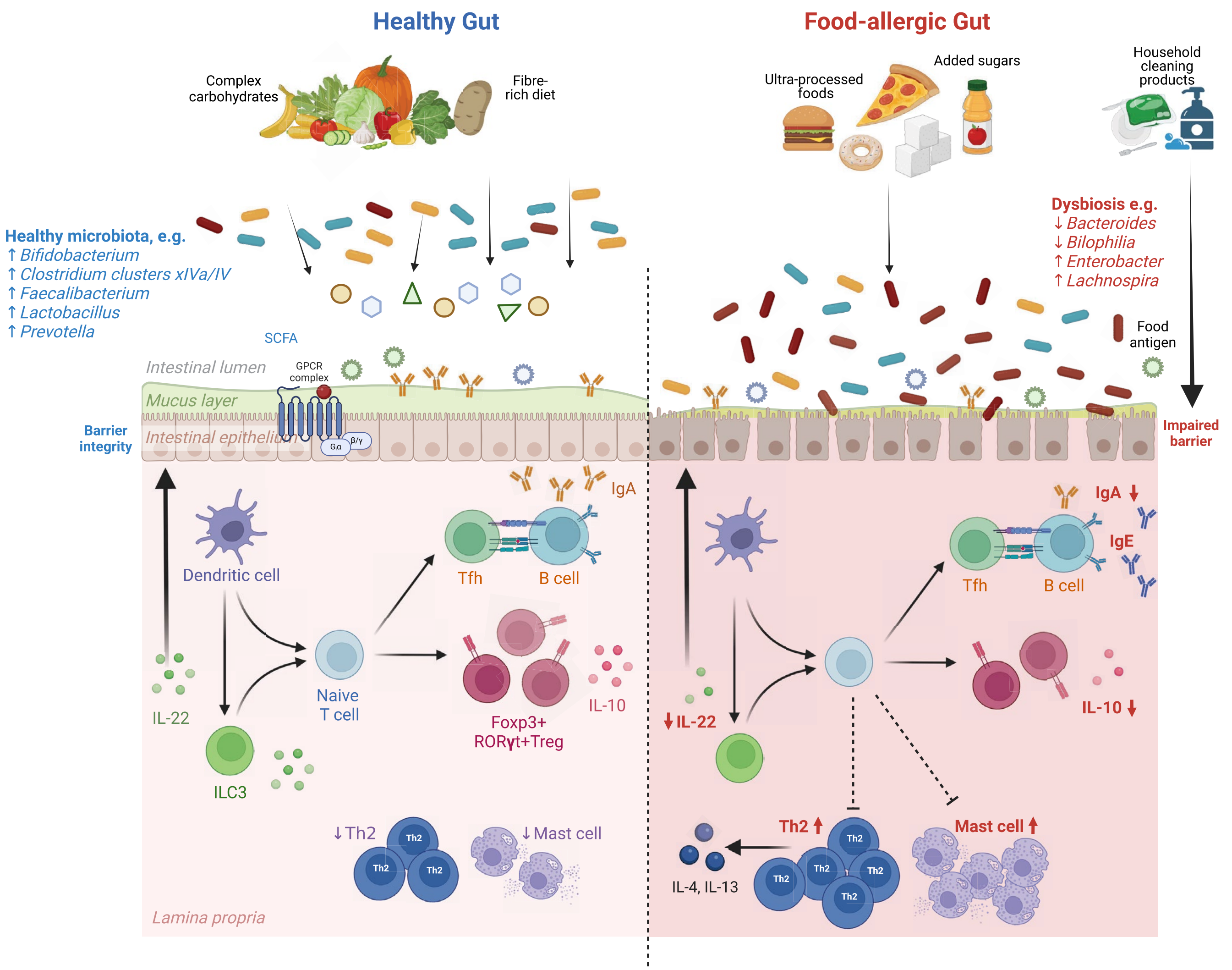

FIGURE 3 | The mechanisms by which diet can both protect against and contribute to the risk of food allergies. It illustrates how certain dietary components may enhance immune tolerance, whereas others could trigger allergic responses, highlighting the complex interplay between nutrition and allergy development.

GST genes. Researchers from the EDEN birth cohort analyzed the associations between the immune and growth factor concentrations in early breast milk and childhood FA outcomes [70]. A core cluster of the breast milk components was found to be negatively associated with a "Western" dietary pattern during late pregnancy, which was characterized by a diet rich in processed foods such as French fries and soda; sugar-loaded foods such as snacks, cakes, and chocolates; and processed meat. This implies that the immune factors passed to the newborn through breast milk were associated with the mother's dietary habits and lifestyle. This suggests that a Western lifestyle influences health from an early age. In a murine model, treatment with the artificial sweetener saccharin led to a dose-dependent increase in OVA-specific IgE and IgG1 antibodies in mice. Mice treated with 100 mg of saccharin and then challenged with 30 mg of the allergen OVA developed anaphylactic reactions [71]. Further analysis of the mesenteric lymph nodes of mice given 100 mg of saccharin showed that saccharin upregulated the Th2 cytokine IL-4 while downregulating the Th1 cytokine IFN-γ and the regulatory cytokine TGF-β. This suggests that saccharin disrupted the induction of regulatory T cells, which are important for oral tolerance. However, the amount of additive was much higher than the typical consumptive dose. In a study that included 2211 adult and pediatric participants, with a mean age of 39.5 years, from the United States, urine dichlorophenol levels (derived from pesticides) at or above the 75th percentile were associated with the presence of sensitization to food allergens (OR, 1.8; 95% CI, 1.2–2.5; $p = 0.003$) [72]. However, this was a cross-sectional study and the study did not include children younger than 6 years.

The increased risk conferred by a "Western diet" is considered a key contributor to the growth in FA prevalence. The Western diet typically features a higher intake of UPFs, refined carbohydrates, added sugars, unhealthy fats, and animal-based proteins, while comprising fewer whole, minimally processed plant-based foods such as fruits, vegetables, and whole grains. Western food cultures adopt frying, baking, and processed ingredients, unlike non-Western cuisines that favor traditional cooking methods and spices. UPFs have become central to modern diets, offering convenience and enhanced flavors, but are calorie dense and high in refined grains, added salt, sugar, and saturated fats [73, 74]. All nations are shifting toward UPF-dominated diets, especially in the West [75], where they now account for nearly half of total caloric intake in the United States [76–78], the United Kingdom [79], Canada [80], and Australia [81], with rising consumption also noted in Asia [82, 83].

UPFs, which frequently have added sugars, are considered to contribute to the production of advanced glycation end products (AGEs) [84]. In vitro studies have shown that roasting enhances the glycation and allergenicity of peanuts; as a result, peanut butter made from roasted peanuts with added sugar will result in AGEs [85, 86]. AGE-rich meals are also those that have experienced the Maillard reaction (also known as "glycation"), which explains a series of chemical interactions involving carbonyl chemicals, such as reducing sugar and amino compounds. They generally come from high-temperature–heated animal proteins and lipids, such as French fries, microwaved meals, and grilled meat. The innate immune system may then respond to AGEs as a "false alarm" in response to dietary antigens [84]. A receptor specific to the AGEs (RAGE) appears to be an important driver in priming the innate signaling, which results in allergic phenotypes [87]. It is believed that the increasing reliance on processed foods depleted from natural compounds can promote hormesis effects—a dose–response phenomenon characterized by low-dose stimulation and high-dose inhibition [88]. More research is needed to determine how consuming processed and high-AGE foods affects the development of atopy and FA mechanistically.

3.3 | UPFs, Emulsifiers, and the Epithelial Barrier

Research indicates that the first 3 years of life are critical for establishing the gut microbiome, primarily shaped by environmental factors rather than genetics [89]. Microbial maturation is essential for immune system development, with weaning marking a significant increase in gut microbiome diversity [90, 91]. Early onset dysbiosis and delayed microbiota maturation have been linked to later FAs [92, 93]. Thus, early life food choices greatly influence microbiota composition and long-term allergic outcomes [66].

Recent studies show that over 30% of infant food items in the EU and the United Kingdom are UPFs—products with additives including flavorings, and emulsifiers [94, 95], with 39% containing sugar [96]. Common first foods, such as baby biscuits and cereals, have high sugar content (14–16 g per 100 g of food), exceeding recommended limits for infants (7.6–9.4 g) [97]. In Brazil, 79% of infant meals were UPFs, including follow-up formulas [98]. Emulsifiers, such as lecithin and modified starches, are prevalent in infant formulas and raise concerns globally. Although the trend of consuming ultra-processed infant foods is evident worldwide, it is particularly pronounced in Europe and is rising in Asia (Figure 4a) [100].

The two most frequently researched emulsifiers are carboxymethylcellulose and polysorbate 80, both of which have been demonstrated to encourage bacterial translocation across mucosal surfaces, alter the composition of the microbiota, increase their pro-inflammatory potential, and trigger low-grade inflammation that leads to chronic gut inflammatory disease [101–105]. Polysorbate 80 has been demonstrated to disrupt the function of the tight junction at low cytotoxic levels, facilitating the ability for allergens to pass through the gut's epithelial barrier [106]. Besides, household cleaning products are popular consumer commodities utilized by a substantial portion of the global population. Soaps and detergents, in particular, have gone from a luxury to a necessity due to the rising influence of the modern lifestyle. Recent research has demonstrated that alcohol ethoxylates, a key component of professional dishwashing detergents called rinse aids, are harmful and damaging to gut epithelial cells, compromising their integrity and activating the pro-inflammatory response [107]. The detergent residue was present in substantial amounts on both washed and prepped dishware.

The "epithelial barrier hypothesis" provides further insights into how modern food processing impacts FA; emulsifiers in processed foods and detergent residue from dishwasher-prepped dishware can impair the epithelial barrier in the gut mucosa,

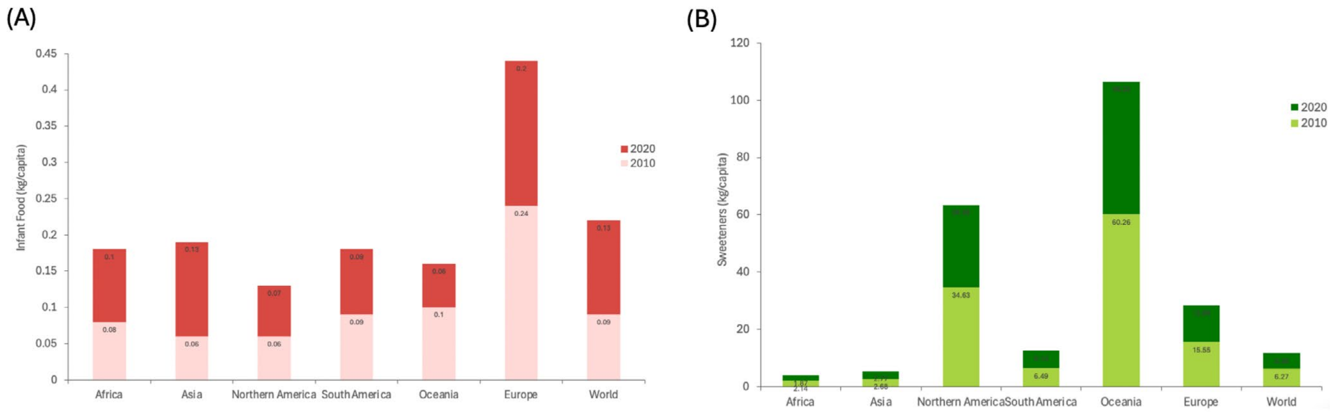

FIGURE 4 | The global food supply quantity (kg/capita/year) of (A) infant food and (B) sweeteners between 2010 and 2020 [99]. Although the total supply of commercial infant formula and sweeteners in Asia remained low, there has been a notable increase in sales of infant formula in Asia.

which becomes leaky, leading to microbial dysbiosis, bacterial translocation to interepithelial and subepithelial regions, and tissue microinflammation [108]. Recent experimental studies have shown that exposure to 5000 ng/mL sodium dodecyl sulfate (SDS) in a human esophageal epithelium air–liquid interface caused barrier dysfunction, an eosinophilic esophagitis-like pathology, increased innate and adaptive immune responses, and potential sensitization to food components [109].

In discussing the Western diet, the focus has primarily been on the lack of dietary fiber, UPFs, AGEs, and emulsifiers. However, it is important to recognize that many other chemically modified food substances may also have detrimental effects on allergic diseases, particularly food allergies. For instance, additives such as artificial colors [110], preservatives [111], and flavor enhancers [112] have been implicated in allergic reactions and sensitivities. A comprehensive examination of the components of the Western diet, along with further mechanistic studies, is essential to clarify how exposure to environmental substances brought about by contemporary food processing might harm the epithelial barriers and enhance susceptibility to FA [108].

4 | Epidemiological Link Between Diet and FA in West Versus East

4.1 | Introducing the Global Pattern of Nutritional Transition

The global phenomenon of "nutritional transition" has resulted in a shift from traditional, home-based, fiber-rich diets, which were believed to be beneficial for preventing allergic diseases, to modern dietary patterns that could have negative influences on the immune system. These modern diets are characterized by a high consumption of processed foods, refined grains, and animal products and a low consumption of fruits, vegetables, and nuts. At the same time, physical activity and energy expenditure decrease [113–115]. Income growth often leads to a shift towards a more diverse diet that includes a larger share of animal protein and fats and oils. However, this transition has concurrently resulted in a decrease in the diversity of grain consumption, with a predominant reliance on wheat. This phenomenon is also referred to as Bennett's law [116]. This transition occurs at different paces and is primarily driven by wealth but varies according to culture, tradition, geography, and religion.

The Industrial Revolution (1760–1840) transformed food processing in Western countries, leading to a diet dominated by dairy, cereals, refined sugars, vegetable oils, and alcohol, which now account for 72% of the daily energy intake for Americans—items that contributed minimally to pre-agricultural diets [117]. From the 1970s to the 1990s, the consumption of processed foods (refined sugar and vegetable oils [*trans-fans*]) surged [118]. Between 1999 and 2018, energy intake from UPFs consistently increased among US youths, now representing the majority of their total intake [78]. This shift from minimally processed foods to UPFs negatively impacts dietary variables such as glycemic load, fiber content, fatty acid composition, and acid–base balance. Although the mechanism by which diet impacts the gut microbiome is beyond the scope of this review, there is evidence that consuming an animal-based diet [119, 120] and omega-6 polyunsaturated fatty acids [121] can negatively impact gut health. This dietary transition in the late 19th and early 20th centuries coincided with rising cases of food allergies and anaphylaxis beginning in 1990 [12, 122, 123], marking a "second wave" of the allergy epidemic occurring 10–15 years after a respiratory epidemic [124].

China's agricultural output only started to rise after the famines of 1959 and 1961 through a "rural scientific-experiment movement" during the Mao period [125]. Between 1960 and 2020, wheat yields tripled, whereas rice and maize yields doubled [126]. The growth and production of peanuts increased by 10 times during this period [127]. Similar agricultural development has occurred in Malaysia, Thailand, and Indonesia since the 1960s, whereas that in Vietnam and Bangladesh only started in the 1990s. Since 1980, there has been rapid economic growth, but it was not uniform across Asia. The economic growth and protein transition were first notable in Thailand and Malaysia. This was quickly followed by rapid growth in China, succeeded by a slower pace in countries such as Vietnam, Indonesia, India, and Bangladesh [128]. A decline was observed in the consumption of cereals as a source of calories, whereas there was an increase in calories from animal products, sugars, sweeteners, and fats, mirroring that of the Western diet [129]. However, global trade only opened up during the structural reforms in the 2000s, leading to a "supermarket revolution" in different periods in Asia, which provided a conduit for processed food products to reach Asian populations [130]. From 2010 to 2020, the growth of packaged food revenue ranged from 5% to 34% across Asia, most notably in transitional countries such as India and Vietnam.

Although the "Westernized" lifestyle and diet took shape in the United Kingdom and the United States between 1970 and 1990, there was a significant increase in FA and anaphylaxis observed in these Westernized countries since the 1990s and peaked in the 2000s [124, 131]. On the other hand, many parts of Asia were still grappling with poverty and famine in the 1970s, and globalization only began to emerge and thrive in most parts of Asia in 2000–2020. Inferring from this observation, one can anticipate that FA prevalence in Asia will follow a similar pattern of increase in Western countries over the coming decade (2020–2030), parallel to the West. However, the rate of increase is expected to vary in different parts of Asia.

4.2 | Individualized Modernity in the East

A common understanding of "modernity" is that it refers to a state of perpetual societal progress, beginning with agriculture and continuing through urbanization, industrialization, and westernization, along with the advancement of technology and social structure [132].

Although there is a significant leap in modernization across Asia, the countries in the region are experiencing varying levels of economic growth. Meat consumption increased primarily in East Asia, such as China, Japan, and Korea, and was slower in South Asia, such as Thailand, Vietnam, and Indonesia [133]. In contrast, vegetable consumption in Asia continues to rise from 57 to 116 kg per capita per year, with rice and leafy vegetables being the most common food groups (Figure 5). Traditional Chinese diets (TCDs) are typically fiber rich and inversely associated with obesity risk and weight gain [134]. Sweetener consumption in Asia is low relative to the global average (Figure 4b) [99], but disproportionately increased in developing countries like India and Vietnam [126]. Meanwhile, although the total sales of commercial milk formula in South Asia remained low at 1.5 kg/c, there has been a significant increase in sales in East Asia and the Pacific (Figure 4a), approaching the levels of sales in Western countries [135].

Despite heavy global and Western influences, traditional customs and ideology continue to shape modernity in most Asian countries. In China, the rural poverty rate dropped from 97.5% to 0.6% between 1978 and 2019 [136], although income inequality persists due to rural–urban gap [137]. In rural China, homemade peanut oil remains the primary cooking oil, valued for its affordability and flavor [138, 139]. A recent study (2021–2022) carried out in Guangxi, southwestern China, found that 82% of 1611 pregnant women consumed homemade peanut oil, which was associated with a higher risk of low birth weight and preterm births [140]. Additionally, peanuts are commonly consumed peanuts for their rich folate content [141] and are significant in traditional Han weddings symbolizing fertility [142].

Despite significant global and Western influences, traditional customs and cultural norms continue to play a profound role in shaping modernity across most Asian countries. Although some parts of Asia have modernized quickly, they have not fully embraced Western culture. Importantly, there is still a proportion of populations in Asia who live in a rural environment and have retained their traditional dietary habits that may be protective against allergies. Further studies are needed to assess the impact of these dietary patterns on allergic outcomes.

5 | Conclusion

Unlike the pattern of FA observed in the Western world since 1990, with peanuts/nuts-induced anaphylaxis as a hallmark, the epidemiology of FA in Asia in the past decade has shown differences in prevalence and patterns. Even within the same country, the prevalence and pattern of FA and anaphylaxis differ between urban and rural areas in China. Although FA prevalence is gradually stabilizing in the West, there is preliminary evidence that FA is rising in the East, specifically concerning countries with rapidly developing economies like China. FPIES, which was once thought to be rare, is now increasing in incidence in Westernized countries. Anticipating the increase in the prevalence of FA in Asia in the next decade, it is crucial to identify the important environmental factors that may contribute to the development of FA.

The process of modernization, especially the industrialization of the food system, has resulted in the well-known "Western diet." Epidemiological evidence suggests that the shift towards a more Westernized, processed, and UPF-rich diet, as part of

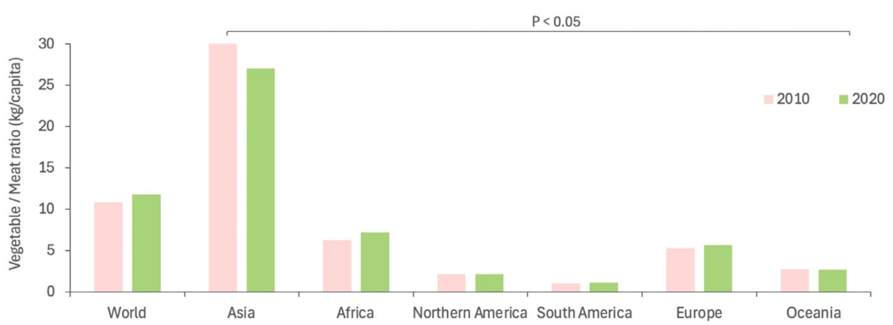

FIGURE 5 | The global ratio of vegetable-to-meat supply (kg/capita/year) [99], showing that this ratio has consistently remained higher in Asia over time compared to other regions over time.

the broader process of modernization, has been accompanied by a rise in the prevalence of FAs, autoimmune diseases, and other immune-mediated disorders in many parts of the world. The incorporation of emulsifiers, sweeteners, and other additives into processed foods and UPFs is particularly concerning. Emulsifiers are used to improve the texture, stability, and shelf life of these foods, but have been shown to harm epithelial barriers and increase susceptibility to FAs. On the other hand, a diet rich in fiber nourishes the gut microbiome and produces SCFAs through microbial fermentation, which in turn, modulates the gut barrier's function and builds a tolerogenic environment.

The delayed and accumulative effects of industrialization and the modern food system are akin to the gradual unfolding of climate change. Just as we are now witnessing the profound impacts of climate change that have built up over decades, the adverse effects of nutritional transition and the predominance of processed foods on human health may only become fully apparent in the coming decade. However, the implications could be equally devastating, leading to a rise in FAs and other immune-related disorders. This persistent interplay between tradition and modernity is a critical factor in understanding the regional variations in FA patterns between Asia and the West. We need to take proactive steps to address these issues and mitigate the adverse outcomes on the immune system related to the modernization of the food system.

Author Contributions

A.S.-Y.L. conceptualization and interpretation of relevant literature, and writing of first draft. Y.X., G.W.-K.W., and M.F.-R. conceptualization and critical revision of final draft. All authors have read and agreed to the published version of the manuscript.

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Consent

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The authors have nothing to report.

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