# Analyzing the Prevention of Cross-Contamination and Allergen Control in Agriculture Within the United States

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**Abstract**

*Millions of Americans are affected by food-borne allergens, and the number of people with food allergies appears to be increasing from previous years. An allergic reaction occurs when an individual's immune system mistakes a protein from a food or ingredient as harmful and reacts abnormally. Some allergic reactions are relatively mild, while others can be life-threatening. Since there is no cure for food allergies, consumers and caregivers often rely on food labels to identify and avoid potential allergens. However, cross-contamination, the unwanted incorporation of different allergens, can make avoiding allergens challenging. Cross-contamination occurs due to insufficient cleaning procedures, crossover points during production, improper sequencing on the production line, the reuse of water or oil when cooking foods during processing, and dust and aerosols of allergenic foods. In order to address these issues, potential solutions include more intense and accommodating training programs, regular cleaning of equipment with intentional tools, and strategic separation of foods based on their allergens within vehicles. With research from reliable databases and federal organizations, this review aims to evaluate what factors must be considered when looking at the complex interplay between agricultural practices, food production, and cross-contamination of allergens to ensure food safety. By exploring these components, the United States can further mitigate health risks for individuals with allergies sustainably and equitably.*

## Introduction

On January 1st, 2015, the United Nations (UN) adopted 17 Sustainable Development Goals, which they projected to be achieved by 2030. These goals are interconnected and essential to improving the planet for future generations. Although the goals "Zero Hunger" and "Good Health and Well-Being" are listed and planned, the UN does not currently include measures to prevent cross-contamination, a problem within the food industry that negatively affects millions of Americans yearly and can lead to hospitalizations (National Institute of Allergy and Infectious Diseases [NIAID], 2023). Continued issues with cross-contamination in the food industry make the UN's goals increasingly challenging to achieve due to its effects on people's health.

Contaminated foods are known to host a variety of food-borne illnesses, such as *Escherichia coli*, also known as *E. Coli*, which can cause adverse effects on humans (U.S. Food and Drug Administration [FDA], 2019). Furthermore, contaminated foods can contain allergens that trigger unexpected allergic reactions in some individuals, preventing one of the United Nations' goals of "Good Health and Well-Being." In that regard, the UN's "Zero Hunger" goal is also negatively affected. Cross-contamination makes food dangerous for various reasons, such as food poisoning. For those with allergies, it can be deadly. Individuals

with allergies in less resourceful situations or lower income brackets may not have safe eating options. Factors to consider when observing the complexity of cross-contamination in agricultural practices and the food industry are the cleanliness of facilities, training of workers, transport used for food, and sustainability and equitability of all solutions. In the United States, the cross-contamination of allergens within the food industry could be solved with increased mandatory staff education on the dangers of cross-contamination, rigorous cleaning standards of equipment and vehicles, and separating vehicles by common allergens.

## Problem Statement

The threat of cross-contamination in facilities and farms during processing and manufacturing poses significant health risks that can lead to hospitalizations and even death. This cross-contamination issue closely connects to the United Nations' Sustainable Development Goals, or SDGs, of "Zero Hunger" and "Good Health and Well-Being." Many individuals are exposed to major food allergens despite their best efforts to avoid them. The SDGs outline that all individuals should have access to safe, clean food, which would only be possible by addressing cross-contamination. When considering solutions that eliminate cross-contamination in agriculture and food production, it is crucial to create fair and maintainable solutions so that facilities and farms may enforce them collectively. In order to create such solutions, it is essential to address the methods of farming, workforce, processing methods, restaurant handling, and transportation of goods.

## Methods

The information in this paper was obtained through research of different literature reviews from the databases EBSCO, Gale, and Google Scholar. The use of the keywords "food allergens," "cross-contamination," "manufacturing," "regulations," and "processing" helped narrow down the most relevant information related to the topic. Information was also utilized regarding regulations already in place through the Food and Drug Administration (FDA) and the Centers for Disease Control and Prevention. Using a fishbone diagram that determined the potential causes of cross-contamination of allergens guided the creation of the sections of this paper. Various options were listed to develop a possible solution for this issue. Then, given the available resources, the options were narrowed to the three most sustainable, equitable, and reasonable choices. Each solution was further examined to develop them and consider all possible results. Furthermore, a diagram was designed with the pros and cons to consider how the public would perceive each idea. These methods helped to provide a better understanding of the problem, the factors influencing what solutions officials can implement, and the background of cross-contamination in the agricultural industry.

## Background

Food allergies develop when the body's immune system reacts irregularly to a protein in a food or ingredient as if it were dangerous (FDA, 2022). According to NIAID, roughly 8% of children (1 in 13) and 11% of adults in the United States experience food allergies. The number of people affected by food-borne allergens seems to be increasing nationwide. Still, there is no cure for food allergies, and as of 2023, there are only medications to relieve allergic symptoms (NIAID, 2023). There are more than 160 food allergens, but the Food Allergen Labeling and Consumer Protection Act of 2004 (FALCPA) established fish, Crustacean shellfish, eggs, tree nuts, milk, peanuts, wheat, and soybeans as the eight major food allergens. A ninth major food allergen, sesame seeds, was identified by the Food Allergy Safety,

Treatment, Education, and Research (FASTER) Act in 2021. Some allergic symptoms are relatively mild and result in skin irritation, dizziness, shortness of breath, hives, nausea, lip swelling, and loss of consciousness. In more severe cases, exposure to allergens can lead to hospitalizations, anaphylactic shock, and death. Allergic reactions generally appear between a few minutes to a few hours after exposure and rarely take longer than that to show up (FDA, 2022). However, severity depends on exposure dose and additional factors, such as physical activity, specific medications, and existing viral infections. Additionally, past allergic reactions do not predict future allergic reaction severity (Turner et al., 2022).

Multiple sources report that consumers, caregivers, and people with food allergies can only protect themselves from an allergic reaction by paying close attention to food labels, so the FDA requires food manufacturers and packaging companies to follow labeling requirements (Jackson et al., 2007; NIAID, 2023; FDA, 2022). The FDA is not responsible for labeling meat and poultry products because the U.S. Department of Agriculture regulates these products. As of 2024, the FDA has not established a threshold level of allergens, meaning there is no "safe" amount of allergen that can be present in a product without having an adverse effect. Despite seemingly sound food manufacturing requirements and efforts made by consumers to avoid allergens, unexpected exposure to allergens can still happen due to cross-contamination (FDA, 2022). Also referred to as cross-contact, cross-contamination can occur from ineffective cleaning of shared equipment between food products, haphazard sequencing on the production line, crossover points during production, reuse of water or oil when cooking foods during processing, and airborne contaminants of allergenic foods (Jackson et al., 2007).

In order to reduce careless manufacturing practices, the FDA has conducted surveillance, compliance follow-up, and for-cause inspections throughout the years to address food safety. Surveillance inspections are regularly scheduled to assess the quality of FDA-regulated products and ensure the manufacturing, processing, and packaging have been completed safely. Surveillance inspections are further divided into two categories: routine inspections, which check whether or not companies are complying with current regulation policies, and target inspections, which generally take place after outbreaks or food safety trends. In comparison, compliance follow-up inspections assess how well facilities or farms follow regulations after a company has already had a prior violation or there have been questionable observations. Compliance follow-up inspections aim to assess a farm or facility's corrective measures. The third type of inspection, for-cause inspections, evaluates a farm or facility's compliance with regulations after a product recall, specific event, or complaint. For-cause inspections are often prioritized and scheduled quickly (FDA, 2023). Although the FDA performs inspections to improve food safety, these initiatives can take a long time and demand labor and time from the organization. It is critical to have more ways to keep farms and facilities accountable and address other solutions for companies to improve their manufacturing processes from the beginning.

**Existing Transportation Practices**

Transportation is vital to the United States' food industry; goods from farms in rural areas must be transported to urban areas where there is more demand and people to feed. Hence, it is essential to prioritize the conditions of trucks and the people driving them. Unfortunately, significant driver shortages and capacity issues in the transportation industry make it hard for companies to hold their products to the highest standards. One example of cross-contamination during food distribution is backhauling when a truck reaches its destination and then transports

a different load on the way back. The carrier must be sufficiently cleaned if an allergenic food is present (Ackerley, 2010).

Furthermore, 70.5% of food transportation is through commercial drivers, emphasizing the need for commercial trucks to follow safety protocols since most food travels through them. Trucks must follow food safety transportation standards so consumers can access food without disrupting producers and businesses in the form of product recalls or customer complaints. In 2005, the United States government created the Sanitary Food Transportation Act, and the FDA requires that food transported by any means cannot be under conditions that can negatively alter the quality of the food. In the Sanitary Food Transportation Act, various clauses ensure that products for consumption in transport are delivered hygienically. Different practices exist for each allergen, such as managing it properly and having specific procedures to eradicate it during cleaning. For example, the physical separation of allergen vehicles can significantly alleviate concerns about cross-contaminations. According to the FDA, various measures, such as the physical segregation of allergens, proper labeling standards, and color-coding tools, are necessary to minimize the possibility of mixups (FDA, 2019).

Likewise, these items should be stored in enclosed spaces, like coolers, because they strongly prevent cross-contamination. If multiple vehicles are not feasible and multiple allergens are required to be in the same transport, incorporating coolers and other enclosed spaces can minimize the risk of contamination while reducing the additional costs of multiple vehicles traveling to one destination. Another option is to control the temperature within the vehicle to avoid cross-contamination. An investigation conducted by the German Department of Allergology found that temperature is one of the most critical aspects in vehicles transporting food to prevent cross-contamination. Various experiments also presented a similar result—proper temperature management significantly reduced cross-contamination in vehicles and during food storage and preparation at the facilities. Industries dealing with perishable goods, such as food and pharmaceuticals, typically utilize cold chain management. Cold chain management manages temperature-controlled transportation and ensures that perishable goods are of the utmost quality.

However, it is mainly used in the food industry and provides valuable input for food management, especially in dealing with food allergen transportation (Rost et al., 2021). According to the World Health Organization, maintaining proper cold chain management can reduce the risk of allergen exposure due to cross-contamination during food transportation by approximately 50%, having a substantial impact (Jackson et al., 2007). A lack of proper cold chain management can cause specific allergens, such as shellfish and peanuts, to become more potent due to increased heat and bacteria, making it harder to contain them. Another statistic presented by the Centers for Disease Control and Prevention stated that improper temperature control causes 40% of foodborne illness outbreaks in the United States, further emphasizing the need for more robust cold chain management and the physical separation of vehicles, ensuring the public is receiving their food under the utmost care (Moritz, 2023).

## Current Cleaning Procedures

Even though various governmental actions have been set in place to identify allergens in food products, such as the Food Allergen Labeling and Consumer Protection Act, cross-contamination can cause numerous individuals to face unexpected allergic reactions. Research

studies have stated that even the slightest bit of an allergen protein can lead to an allergic reaction in individuals. For example, a literature review conducted by the Threshold Working Group of the FDA found that allergic individuals had an adverse reaction when they were exposed to as little as 0.13 to 1 mg of egg protein and 0.02 to 7.5 mg of tree nut protein, further proving that even a small amount of cross-contamination can lead to a significant reaction (Jackson et al., 2007). In order to ensure that cross-contamination is minimized, agriculture and food processing facilities must prioritize the cleanliness of their facilities.

However, since there is a variety of equipment in agricultural facilities and the way foods are introduced, there needs to be different ways to clean equipment to ensure that all the previous material has been cleaned. Water is generally considered the primary cleaning tool for food processing equipment. However, many dry goods manufacturing facilities do not include water in their cleaning processes due to the risk of microbial growth and premature equipment failure. Machinery is designed in various ways to serve its purpose, and typically, some types of machinery, such as electrical ones, can be prone to water damage. Thus, different cleaning methods exist for wet and dry environments (Jackson et al., 2007). For example, a “wet” cleaning method often uses alkali detergents and oxidizing agent solutions such as sodium hypochlorite to minimize disassembly. Disassembly, or the taking apart of a machine during cleaning procedures, is relatively common when cleaning large vehicles because it provides the most thorough cleaning, which is crucial to prevent cross-contamination. This approach is advantageous for automated cleaning, requiring significantly less staffing. However, disassembly takes longer, which can be inefficient in high-traffic periods. It also requires a lot of human resources, as disassembly has three main components: disassembling, thorough cleaning, andre-assembling. In order to make it easier for workers, this method is not executed as frequently since it is a lengthy process. Another method typically used is clean out of place (COP), which requires partial disassembly and cleaning parts in separate tanks. This method is beneficial as it targets individual components, thus reducing the possibility of small allergen particles lingering around.

Furthermore, different types of food require different cleaning techniques. For example, oil-based foods may require oil flushes before introducing water and alkali detergents to avoid leaving behind protein-containing material. In addition, there are also dry cleaning methods, such as using dry ice. Dry ice is released in freezing temperatures, expanding and contracting with the allergens, making the contaminants brittle and easy to dislodge. In addition to dry ice, there are various other dry cleaning methods, such as vacuuming. In agricultural facilities, high-efficiency particulate air (HEPA) vacuums are typically used to maximize efficiency and ensure the highest level of cleanliness possible. HEPA is a filter efficiency standard set in place to rank the performance of air filters, and they can remove approximately 99.97% of airborne particles. They can remove particles 0.3 microns or larger, which is extremely helpful for facility workers because these highly efficient vacuums can remove many potential allergens present in the equipment and remove dust and debris without water.

Another example of a dry cleaning method is the use of compressed air. Compressed air is typically pressurized to a higher pressure than atmospheric pressure and the air that individuals breathe. Compressed air is then released into various equipment areas in quick intervals to dislodge food residues from areas that are not easily accessible, allowing for a much more detailed cleaning procedure. Certain factors for wet and dry cleaning methods

must be considered to be fully effective and minimize the possibility of cross-contamination. For wet cleaning methods, the composition of the soil or food residue, such as carbohydrates or fat, must be considered to provide detailed information to facility workers on how to clean efficiently. In addition, the choice of detergents, such as an alkali-based or an acidic detergent, is also a factor in wet cleaning methods, as there are different ways of targeting leftover materials. For dry cleaning methods, identifying the type of contaminants such as dust, debris, and fats is crucial to determine the appropriate cleaning tool and method to ensure thorough material removal. Lastly, dust control and preventing recontamination is crucial; effective use of dust control measures, such as implementing HEPA filters and minimizing the use of compressed air, can ensure a clean environment with less chance of recontamination while reducing allergen and cross-contamination risks (Jackson et al., 2007).

**Employee Training Requirements**

The Food Safety Modernization Act (FSMA), created by the FDA, is a federal law that prevents food-borne illnesses and accidents. The rules put forth by the FSMA recognize the safety of the food processing industry and have specific laws in place to prevent cross-contamination. There are ten rules the FSMA regulates: produce safety, pre-harvest agricultural water, accredited third-party certification, food traceability, foreign supplier verification programs for importers of food for humans and animals, laboratory accreditation for analyses of foods, mitigation strategies to protect food against intentional adulteration, preventative controls for human foods, preventative controls for animal food, and sanitary transportation of human and animal food. The training that food industry facilities provide for their employees complies with the rules already in place by the FSMA. Companies must find ways to provide quality training curricula and ensure employees complete them (FDA, 2020).

Nine national standards are recommended for companies to thoroughly review with their employees to ensure everyone understands the foundations of food management and processing. Standard two out of the nine is the one that manages the essential aspects of staff training, and 90% of staff must complete a training that includes the following topics: public health principles, communication skills, microbiology, epidemiology, statutes, hazard analysis, and critical control points (FDA, 2015). Along with these topics, 90% of staff must also complete field training, which includes joint training inspections, independent inspections, and standardization inspections. To maintain the ability to work in these facilities, employees must complete 20 contact hours of continuing education every two years (FDA, 2015). Well-trained employees are the backbone for smooth and productive facilities. To maintain this level of productivity, not only do employees have to be trained well the first time, but they also need to be reminded of proper procedures regularly (Dagnew & Elanthiraiyan, 2023).

A study in Ethiopia was completed to examine how effective training programs were for employees and how it affected their overall performance. One of the objectives of this research study was to understand the need for pre-assessments in addition to employee training, the effect of training resource availability, and whether it impacts the employee's work performance. A total of 84.87% of the respondents disagreed with the frequency of training, and a majority of the respondents also said the lay-based training programs are not based on an initial assessment, meaning that everyone received the same training regardless of pre-set abilities (Dagnew & Elanthiraiyan, 2023). The same study showed that 87.39% of respondents

were also discontent with the length of the training sessions and felt they needed additional time. In addition, the employees said the number of resources available to complete a successful training needed to be increased, concluding that the available resources, or possible available resources, could have been more effectively used (Dagnew & Elanthiraiyan, 2023). Another study in Malaysia done with Company "X" showed that employees are satisfied with the training programs and resources provided and that the employers believe proper training is crucial for the success of the employees and products produced. (Deros et al., 2012). This study demonstrates a significant inconsistency in data from other parts of the world.

Regarding cross-contamination in the food processing industry, different foods are processed and manufactured in different parts of the world. Having consistent results with training programs and ensuring that all countries have equal and accessible training resources can limit cross-contamination and reduce unwanted allergic reactions. Studies show that outdated training programs and management can cause the opposite outcome. Using old methods, such as single-stage cleaning, which requires only one cleaning agent and can be inefficient in entirely eradicating allergies and it can increase the dissatisfaction of employees and employers, cause mismanagement of the facility and its functions, and lead to a loss of millions of dollars for the industry (Harris & Bonn, 2000).

Relating to the food processing industry and cross-contamination, the federal government created the Food Allergen Labeling and Consumer Protection Act in 2004 to address growing concerns about allergen identification. The FDA and Congress created FALCPA to enforce strict guidelines for identifying and labeling allergens to help those who suffer from allergies. The act emphasized the need for facility allergen control plans, focusing on minimizing cross-contamination risks through rigorous cleaning protocols and specialized, color-coded packaging. Despite governmental efforts, a study by the FDA found that only 75% of inspected facilities checked their labels for accuracy, and only 20% used approved and documented procedures to ensure correct labeling (Gendel et al., 2013). To minimize cross-contamination, there needs to be a higher emphasis on improving label-checking processes and utilizing approved procedures to ensure individuals are not exposed to allergens due to a lack of safeguards. These findings emphasize the ongoing need for consistent employee training to ensure food safety among the public. In addition, there should be a more individualized training system, as some individuals may be stronger in some fields and weaker in others, leaving room for error if corporations follow a uniform training system. Although the awareness of allergen labeling has increased in recent years, significant gaps remain in ensuring optimal regulation and safeguarding against cross-contamination.

## Solutions

After carefully evaluating literature reviews, research papers, and government sources, several solutions were reached to prevent cross-contamination. When choosing a solution, it is imperative to address limiting factors such as time, money, and labor requirements. The most effective and sustainable solutions were determined to be accommodating and purposeful employee training programs, intentional cleaning tools for machinery such as water and specialized detergents when applicable, and separating trucks or utilizing cargo blankets to prevent allergen exposure.

### Strategic Grouping of Transportation Vehicles

A variety of solutions exist for differentiating vehicles to avoid cross-contamination.

Firstly, Less-Than-Load (LTL) shipping consists of manufacturers choosing not to fill up their trucks to ensure there is less risk for cross-contamination. Less-Than-Load shipping consists of transporting goods at a cap to minimize the number of different allergens, reducing the chances of widespread contamination (Herron, 2022). Although this would significantly alleviate the cross-contamination issues, companies may lose money if their carriers do not hold their maximum potential, leading to less overall profit for the truck drivers. Another solution to avoid cross-contamination in vehicles is to separate different types of food in different compartments of the cargo area, such as raw food and ready-to-eat food, by using cargo blankets or pallet covers, reducing the possibility of spills, furthermore reducing the amount of potential cross-contamination within the same transportation carrier. This option may be more feasible as it still brings the same potential profit to the truck driver. However, the cost to invest in cargo blankets or pallet covers can be significant depending on the truck's size, leading to a significant initial investment (Rost et al., 2021). Additionally, if companies choose to hire drivers outside their organization, it is vital that the company effectively communicates and enforces cleaning requirements (Ackerley, 2010).

**Proper Cleaning Techniques**

Regarding cross-contamination, the most effective solution is often the most obvious: cleaning. One of the leading causes of cross-contamination within facilities is the use of standard tools and machinery, especially on raw products. Some researchers recommend that all pieces of equipment be designed to be taken apart and cleaned easily (Deibel et al., 1996). Those researchers have found through trials that a combination of manual scraping and washing with warm water prevents most cross-contamination. An experiment was performed in 2010 that studied hazelnut cross-contamination in shortbread cookies. Specifically, 1g of hazelnut protein per kg would be unintentionally added to the hazelnut-free batch of cookies. Two batches of cookies were utilized in the experiment. In the first one, only manual scraping was incorporated, and it was shown that hazelnut proteins were still present in the batch of cookies. The findings from the first batch proved that manual scraping is essential, but more work is needed to prevent contamination. In the second experiment, a hot-water wash was performed after manually scraping the machines, and the remaining hazelnut protein was significantly lower. The result was 1 mg or less of hazelnut protein per kg deposited into the shortbread mix, a dose too low to impact an individual with a food allergy (Roder et al., 2010). Water is a common technique for cleaning machinery after using allergens or other contaminants. However, the inclusion of water can be a problem for certain machinery. Typically, machines created for dryer mixes are not designed to incorporate water during a process. Using water on a machine not meant to be exposed to water could result in severe property damage and incur significant costs for companies. The best option in that situation is that the company replaces the machine with a model created to handle being cleaned with water and manufactured from a material with “nonabsorbent, noncorrosive, and nonreactive” properties, effectively reducing the risk of cross-contamination via machinery. However, if that is not an option for a producer, they might find that dry cleaning methods help them tremendously. Over 50% of companies use dry cleaning methods—specifically compressed air and nonallergenic cleaning foods (Jackson et al., 2007). Compressed air is one of the more popular dry-cleaning methods as it is easy to use, portable, and efficient. A main component of compressed air is blowing air at high-pressure levels, clearing out contaminants that can potentially be in vents or inaccessible places.

Furthermore, compressed air typically does not require specialized equipment, and operators can direct the airflow to a specific area. Lastly, utilizing compressed air eradicates drying times, ensuring vehicles can be put back into use immediately after cleaning. The main problem when using this method concerning allergens is the particles that spray all over the room. The air may dislodge the food, but where the food goes is unpredictable. This process is made slightly less dangerous in facilities when paired with a high-efficiency particulate air filtration vacuum system, which sucks the food particles out of the air (Jackson et al., 2007). It is not the most effective method to use in food safety, as it does little more than move allergens around.

Compared with tests done with water and other detergents, the results of this method are still dangerously high. Instead, some companies use non-allergenic food to bind with any allergenic particles left behind on the machines. These foods are typically salt, flour, or starch. When using non-allergenic food to clean the machines, an employer must consider what should be going into the foods they will use the machine to make. For example, using wheat flour to clean a machine that makes gluten-free cookies could be a disaster (Jackson et al., 2007). This method is not as popular because it costs money and wastes products. Considering these options, warm water washes are still the most effective solution. The hazelnut experiment proves that warm water washes prevent cross-contamination and make for quick and easy equipment cleaning. The machinery in the hazelnut facility was made to handle water and was far easier to clean (Roder et al., 2010). Water, however, is not the only cleaning method, and it should not be.

A study done on the different cleaning methods for differing allergens shows that the effectiveness of each cleaner on different allergens varied quite a lot. This study was performed on plates made of stainless steel, Teflon, polyethylene, urethane, or polycarbonate with a certain amount of food residue from allergens such as peanut butter or milk. The contaminated surfaces were then exposed to a cleaning solution of water, chlorinated alkali cleaner, or acid detergent cleaner at the ambient temperature of 62.8°C, or 73.8°C, for 30 minutes. This study found that chlorinated alkali cleaner was most effective at removing hot milk solids. It found that cleaning cold milk solids or peanut butter residue was more effective than using water at 62.8°C. These results show that while warm water is a highly effective cleaning method in commercial settings, it is essential to consider the food product individuals are removing and the surface it is on (Jackson et al., 2007).

Although the method of cleaning used in the hazelnut experiment was effective at removing the majority of soil from the machines, a company that produces a product in the same factory must include the possible presence of hazelnuts on the label of any product produced in that facility. This requirement can create a sense of dissatisfaction amongst consumers due to the undetectable doses of allergen protein. Some manufacturers are resentful that they have to include messages like “may contain_____” or “processed in a facility that also processes_____.” Some consumers also find these labels unnecessary or bothersome. While these labels may sometimes appear dramatic, the security some consumers feel about the safety of all products labeled similarly is misplaced. That mindset is unsafe and has been known to cause unexpected anaphylactic shock that leaves some hospitalized (Roder et al., 2010). The practice of correctly and effectively sanitizing equipment used in producing food with allergen ingredients and those without is critical. Labeling a food as unsafe for people with allergies is not enough. Producers must ensure that any accidental consumption will not

harm their consumers' bodies, and the best way to do so is to prevent the possibility of cross-contamination in the first place. In that regard, some researchers recommend that corporations use separate machinery and production devices to prevent cross-contamination (Deibel et al., 1996). While the complete segregation of allergens when it comes to creating food products in the same facility is a legitimate way to prevent cross-contamination, it is challenging to make the implementation equitable. The differences between smaller and larger facilities' abilities to combat cross-contamination are large. Not all facilities and companies can afford separate equipment and machinery for every product they make. Smaller facilities are less likely to use cleaning procedures than larger ones (Jackson et al., 2007). It is impractical to require all companies to implement a system of separate machinery, as it could force some of the smaller companies out of business. Instead of depriving smaller businesses and reducing the consumer market, it is more logical to mandate corporations to implement more stringent cleaning practices.

### Comprehensive Training Programs

The U.S. Food and Drug Administration completes routine inspections once every three years for domestic high-risk facilities and once every five years for non-high-risk facilities. The FDA also states that more inspections are needed to catch practices that could lead to cross-contamination (FDA, 2024). It has been shown numerous times that cross-contamination in the manufacturing line is mainly due to human error (Deibel et al., 1996). Whether improper cleaning, not being careful when separating foods, or needing to learn how to use specific equipment, employees have frequent training programs that teach them proper care when handling food. Not only is having training programs required but also ensuring they are effective in teaching methods has proven repeatedly to prevent employees in food processing facilities from making mistakes. These training programs should have modules that cover different reactions to allergens and how they affect human life, how common cross-contamination occurs in the workplace, proper use of equipment, and proper methods of human sanitation.

Providing employees insight into how severe allergic reactions are and how the issue is present at the processing level will increase awareness and cause people to take better precautions. Employees must also receive training on how easily allergens can spread. Documentation must also show that employees have completed the training, understand the information, and practice how the processing line should run. Some challenges can occur when there is constant training in the food service industry. The need for employees to constantly update their skills can cause stress for both the employer and the employee. The stress of remembering every safety measure involved in food processing can affect an employee's ability to meet the customer's requests. However, training programs and management are a few ways to identify problems in food processing facilities and prevent cross-contamination.

The United States also has a variety of highly diverse workplaces; as a result, there must be accommodations for all groups of people so that all employees understand procedures and can perform tasks the same way (Harris & Bonn, 2000). These training programs must be in different languages and accommodate different academic levels. They also need to be accessible in different formats and easy to read for those who want to look over the resources outside the given training time.

## Conclusion

People from all over the world deal with different food allergies every day, and the scale at which people are affected by them differs from person to person. Food safety and cross-contamination awareness are paramount when processing and manufacturing food products. Taking extra precautions to reduce the spread of allergens between food items can prevent unintentional allergic reactions. Of the 17 UN Sustainable Development Goals, “No Hunger” and “Good Health and Well-Being” are the most pertinent to cross-contamination of allergens in the food industry. “No Hunger” (UN Sustainability Goal 2) addresses proper food safety regulations and works to implement standards for safe production and consumption. “No Hunger” also corresponds with managing regulations and following food production, processing, and handling standards. This goal would reduce the risk of cross-contamination and ensure safety for all consumers, specifically those with allergies. It also promotes awareness for those who work in the food industry and strives to educate those who work closely with food. Adequate training and proper food handling correspond with “No Hunger,” so everybody of all ages worldwide can access food that will not cause health problems. “Good Health and Well-Being” (UN Sustainability Goal 3) promotes healthy lives and the well-being of people of all ages.

Unintentional cross-contamination of allergens risks the well-being of people worldwide since food is processed, manufactured, and sold to many different countries. Cross-contamination of allergens compromises food safety, leading to health problems and undermining the overall goal of providing people worldwide with safe food all year round. Addressing the cross-contamination of allergens also improves food production practices that contribute to more sustainable agriculture practices. Cross-contamination of allergens is an issue that has been prevalent for a long time and continues to be a problem. As of 2024, the FDA lacks regulations for what is considered a “safe” amount of allergen in products, which is a complicated concept to pinpoint because everybody has a different severity level for an allergic reaction, regardless of the concentration. Food is transported internationally through many different methods, so it is vital to prioritize how clean each vehicle is and how close in proximity different foods are to each other while in transport.

The FDA has sanitary regulations for vehicles and different tools used to separate foods, working to reduce the risk of cross-contamination. Cleaning methods within a facility are also an essential aspect regarding cross-contamination. Many different cleaning methods have been established, but it depends on the facility as to which method they choose to adopt. These solutions focus on each of these details in cross-contamination. They are practicing more efficient cleaning methods, grouping vehicles during transportation, and providing employees with more training programs and tools specific to cross-contamination.

Using methods such as Less-Than-Load shipping to not fill up trucks all the way, creating training programs that are beneficial and accessible for everyone, and thoroughly cleaning facilities that are more prone to allergens are ways that society can prevent the spread of allergens and increase the health of the general public.

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