

Case Study

International Food Safety Regulations in the Almond Industry: Insights, Regulations, and Strategies

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Abstract

International food safety regulations play an important role in almond exports, particularly when exporting to trading partners with stringent food safety regulations. Almonds are the leading agricultural export commodity from California and the number one specialty crop export from the United States. The California almond industry is the leading producer and exporter of almonds globally.

While the California almond industry has strong international market power and an established global market share, it remains highly sensitive to weather disruptions and aflatoxin contamination. These factors have caused disturbances in the US export market, particularly in regions with stricter food safety standards, such as the EU and Japan. Aflatoxin is a toxic substance produced by certain molds commonly found in nuts and grains. Preventing aflatoxin contamination is crucial as no processing step can remove aflatoxin residues from finished products. Almonds contaminated with aflatoxin can lead to economic losses in several ways, including increasing the cost of production and regulatory compliance.

This case is appropriate for undergraduate courses such as Agricultural Business, Supply Chain Management, International Agricultural Business Trade, and Agricultural Policy. It offers detailed insight into industry structure, international aflatoxin regulations, and their effects on producers, trade, exporters, and regulatory strategies. The teaching note includes a lesson plan, discussion questions, additional readings, and a sample assignment.

1 Introduction

International food safety regulations play an important role in almond exports, particularly when exporting to trading partners with stringent regulations. California almonds represent the third-highest value share among the state's leading agricultural commodities (CDFA 2023a). Almonds are the leading agricultural export commodity in California and the number one specialty crop export in the United States (CDFA 2023a). The California almond industry is the leading producer and exporter of almonds globally (CDFA 2023a). While the California almond industry has an established global market share, differences in food safety regulations, particularly aflatoxin tolerances, have caused disturbances in the US almond export market, leading to border rejections for almond shipments (Padilla et al. 2023). This case study explores the differences in aflatoxin tolerances between US trading partners from the trade and economics perspective, focusing on implications for the industry, regulations, complexity of the issue, and exporters' and regulatory agencies' strategies. This case study provides a real-world, data-driven setting that helps students translate regulatory differences into operational and economic insights.

2 Almond Industry

The California almond industry generates \$19.6 billion in gross revenue, contributing to the California economy directly, indirectly, and through induced effects (Matthews et al. 2020). It creates over 110,000 jobs and adds \$9.2 billion in value to the state’s economy (Matthews et al. 2020). California has a comparative advantage in meeting the growing global almond demand due to its Mediterranean climate, increasing investments in orchard expansion, and the application of technological advances. Almonds are the top crop by acreage in California (Matthews et al. 2020) and rank as the fourth most valuable crop in the United States (CDFA 2023a). As the global leader with a dominant position, the California almond industry generates most of its revenue from international markets, exporting more than 70 percent of its production (Matthews et al. 2020). Additionally, all US-supplied almonds come from California, making the US the largest single consumer market for California almonds, with nearly 30 percent of production consumed domestically (ABC 2023; Matthews et al. 2020).

California produces about 80 percent of the global almond supply, followed by Australia (9 percent), Spain (4 percent), and Turkey, Italy, Portugal, Morocco, China, Tunisia, Chile, and Greece, each with about 1 percent market share (ABC 2023a). The California almond industry exports to nearly 90 countries worldwide (Figure 1), with a total export value of \$4.5 billion in 2022. The main destinations include the European Union (EU) (\$1.5 billion, 33 percent),¹ India (\$833 million, 20 percent), United Arab Emirates (\$311 million, 7 percent), China and Hong Kong (\$264 million, 6 percent), Japan (\$244 million, 5 percent), South Korea (\$129 million, 3 percent), and Mexico (\$81 million, 2 percent) (ABC 2023a; FAO 2024b). Export product types include 68 percent shelled, 24 percent in-shell, and 8 percent manufactured almonds (ABC 2023a).

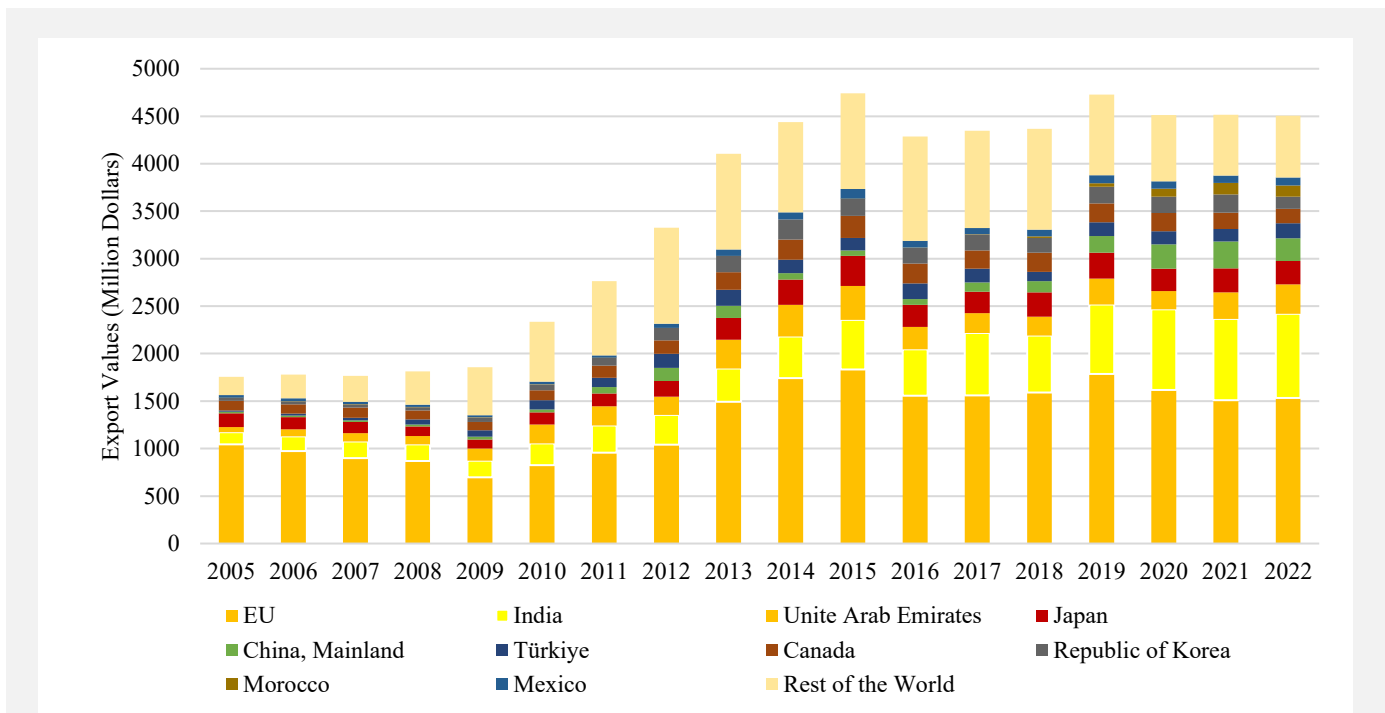


Figure 1. US Almond Exports, 2005–2022

Source: FAO (2024b).

¹ The EU consists of 27 countries; in this study case, the UK is included in the EU abbreviation because the UK defers to the EU standards.

CDFA data show that the value of almond production was \$3.8 billion in 2022 (CDFA 2023a; ABC 2023a). Around 7,000 growers produce almonds on nearly 1,380,000 acres of orchards, and 90 percent of almond farms are family-owned and -operated through several generations. Among these farms, approximately 30 percent have more than 100 acres, and 14 percent have 250 acres or more, indicating large-scale economic farming (ABC 2023a). California almond products are well-known for their availability in numerous varieties. Almonds can be used whole, sliced, slivered, chopped, diced, or ground, with either the skin on (natural) or removed (blanched). They can also be used in confectionery, bakery, dairy products, prepared foods, and snacks (ABC 2023a).

The California almond industry includes 99 almond handlers, many of which are also family-owned (ABC 2023a). These handlers are responsible for the initial processing of almonds produced by growers, as well as for marketing and selling the products. The industry is dominated by a few key players, with more than 57 percent of almonds processed and supplied by 11 companies (ABC 2023a), each operating on a large scale, processing over 50 million pounds of almonds, and in some cases, managing over 100 million pounds. Major market players include Blue Diamond Growers (a cooperative owned by approximately 3,500 growers), Wonderful Pistachios and Almonds LLC, Borchers Bros, Travaille and Phippen, Inc., Hilltop Ranch, Inc., and Treehouse California Almonds, LLC. Among these, Blue Diamond Growers and Wonderful Pistachios and Almonds LLC hold a significant share of the market (ABC 2023a). After harvesting, these processors play a critical role in the supply chain, managing large volumes of almonds from initial processing to marketing and distribution both domestically and internationally (ABC 2023a). The industry demonstrates some characteristics of an oligopoly but is more complex than a typical example of such a market structure. In an oligopoly, the market typically has only a few very large firms. In the almond industry, while a few large processors and handlers dominate, around 100 registered handlers operate alongside thousands of growers, leaving the producer side highly fragmented (ABC 2023a). In addition, about 70 percent of shipments are exported; as a result, prices and volumes depend on global demand and trade policy, unlike a simple domestic oligopoly. Hence, the industry does not fit neatly into the classic oligopoly model.

While the California almond industry has strong international market presence and an established global market share, it remains highly sensitive to weather disruptions and aflatoxin contamination. These factors have caused disturbances in the US export market, particularly in countries with stricter food safety standards, such as the EU and Japan (Padilla et al. 2023; Jin et al. 2020; Whitaker et al. 2010). A structural feature of California almonds is their reliance on irrigation in a drought- and groundwater-constrained setting. Almonds account for 9.5 percent of agricultural water used by crops (ABC 2016, n.d.a). Over the past 2 decades, growers have reduced the water required per pound by 33 percent, and micro-irrigation is used on about 70 percent of orchards (ABC n.d.d). Even with these gains, recurring drought and groundwater depletion remain a central constraint for the industry, alongside aflatoxin and market risks.

Alston et al. (1995) find an inelastic demand for California almonds in export market (domestically, more elastic demand), suggesting a short-run increase of almond prices would generate profits for the California almond industry.² While California almonds have dominated the EU market, Spanish almonds are considered a close alternative to California almonds; the Spanish almond industry is a major competitor for the EU markets. This implies that changes in Spanish almond production may have significant impacts on the California almond industry with respect to the European market specifically. In addition, recent shifts in trade policy may erode the US competitive advantage in EU markets. For example, in response to US steel and aluminum duties, the EU has approved 25 percent counter tariffs on selected US products, with almonds scheduled in the final phase on December 1, 2025

² An inelastic demand curve implies that quantity demanded is not very sensitive to price changes. Microeconomics theory indicates that for the inelastic part of the demand curve, increasing prices leads to an increase in revenue.

(Pacific Nut Producer Magazine 2024; Blenkinsop 2025; Rankin 2025). If implemented, this would increase trade costs for almonds, raise prices, and consequently reduce demand for US almonds in the EU, a leading importer of US almonds. EU producers (e.g., Spain) and non-US suppliers such as Australia, which are not subject to this specific 25 percent counter tariff, could gain share, further weakening US market share and global competitiveness (Pacific Nut Producer Magazine 2024; Blenkinsop 2025; Rankin 2025).

3 Aflatoxin

Aflatoxin is a naturally occurring substance produced by certain fungi (molds). The specific molds responsible for producing aflatoxins include *Aspergillus flavus* and *Aspergillus parasiticus*. *A. flavus* produces aflatoxin B1 and B2, while *A. parasiticus* produces aflatoxin B1, B2, G1, and G2. Among these, aflatoxin B1 is the most toxic. These types of aflatoxin are common worldwide (Bynum 2023).

According to the Food and Drug Administration (FDA) (2024), regularly consuming foods with aflatoxin increases the chance for liver cancer, kidney issues, and birth defects and in large amounts may even lead to liver failure and death. The most common way humans are exposed to aflatoxins is through the consumption of nuts and grains, prompting FDA and regulatory authorities in many other countries to establish tolerance limits and test foods for the presence of aflatoxin levels to protect human health. Almonds, in particular, have been vulnerable to aflatoxin contamination, posing significant challenges for growers and processors to produce safe, high-quality almonds in compliance with food safety regulations over the past 2 decades (Certified Laboratories 2019; FDA 2024).

Controlling and preventing aflatoxin contamination in crops is crucial, particularly given the lack of a processing step to remove aflatoxin residues from finished products. According to the ABC (n.d.b), the primary sources of aflatoxin contamination include soil, previously infested almonds (i.e., mummy nuts), and pests such as the navel orangeworm (NOW). Mold spores can be spread by these pests and grow on the nutmeats of damaged almonds, especially in environments with high moisture and temperature (WHO 2016; ABC n.d.b).

Almonds contaminated with aflatoxin at levels higher than allowed by regulators can lead to economic losses in several ways. These include production losses, disposal of contaminated products, and increases costs for regulatory compliance, health care, and analytical research (Pinotti et al. 2016; Owolabi et al. 2023). According to the USDA-AMS (2024), the cost of a single rejected consignment at the port of entry due to aflatoxin contamination can be up to \$10,000. These expenses will be even higher if the consignment must be destroyed.

4 International Food Safety Regulations

While globalization of the food supply benefits consumers through year-round availability, lower prices, and more variety and quality of food, it could also threaten human health and the spread of contaminated food across borders. Globalization increases countries' responsibilities to maintain the food safety of products, which impacts the entire food supply chain from producers to consumers. Food safety issues can increase production costs, influence reputation, close off the international market for food producers and increase the risk of consuming contaminated food for consumers (Buzby and Unnevehr 2003).

Despite some efforts, especially as part of the free trade agreement discussion, food safety regulations around the world are still inconsistent and vary widely. The Codex Alimentarius Commission ("the Codex") includes a set of standards and guidelines aligned with the World Trade Organization

(WTO)³ that are applicable to be used across borders.⁴ The Codex standards cover a wide range of issues, such as guidelines for preventing consumer fraud, standards on food additives, and tolerance levels for aflatoxin and pesticides (Hoffmann and Harder 2010). Yet Codex standards do not regulate all aspects of food safety, and countries have the flexibility to set their own requirements, which, in some cases, can be used to limit trade and protect domestic producers (Crivelli and Groeschl 2016).⁵ This causes significant difficulties in trade for agricultural products, placing foreign producers at a disadvantage and hurting consumers in the form of higher food prices (Josling et al. 2004).

Under the Agreement on Sanitary and Phytosanitary (SPS) measures of the WTO, countries are allowed to set their own standards to safeguard the health of consumers by achieving the appropriate level of protection. However, their regulations should be science-based, not discriminatory between countries with similar conditions, and not used as instruments for protectionism behaviors (Josling et al. 2004; Peterson et al. 2013). In addition, it encourages countries to apply internationally accepted science-based standards established by the Codex. While some regulations facilitate trade since they represent important quality and/or safety enhancement of the product (Xiong and Beghin 2012; Ishaq et al. 2016), there is evidence that SPS measures can, in some cases, be used as instruments to protect domestic producers (Crivelli and Groeschl 2016). Thus, the impact of SPS measures on trade has been mixed based on the evidence to date (Swann et al. 1996; Disdier et al. 2008; WTO 2012; Xiong and Beghin 2012; Beghin et al. 2015; Crivelli and Groeschl 2016).

In addition, to address the growing consumer awareness of food safety concerns, food safety standards are becoming more stringent. Trading partners often set different food safety standards and regulatory regimes, resulting in varying compliance costs across countries due to differences in regulatory requirements and implementation capacity. While these differences in food safety regulations may create conflicts and reductions in trade, they may also improve countries' food safety systems (Buzby and Unnevehr 2003).

Among many food safety concerns, contaminated tree nuts and grains with aflatoxin are becoming more pronounced because exposure to aflatoxin through contaminated food can sometimes cause fatal acute illness and is associated with increased cancer risk (Dohlman 2003). With the recognition of food safety regulations like tolerance level, most developed countries and many developing countries established (or are in the process of establishing) their own tolerance levels for total aflatoxins in food, with standards ranging from 0 to 50 parts per billion (ppb). Based on the experts in the Joint Food and Agricultural Organization and World Health Organization (FAO/WHO) Expert Committee on Food Additives, establishing tolerance on the allowable amount of aflatoxin is complicated (Dohlman 2003) by the fact that

Levels of contamination of foodstuffs vary tremendously around the world, and... with respect to trade, the perspectives of delegations differ profoundly. Those representing countries in which aflatoxin contamination is not prevalent want low standards because they do not wish to see the quality of their food supply degraded. Those delegations from countries in which aflatoxin contamination is a problem because of their climatic conditions naturally wish to have standards in which higher levels of contamination are permitted so that they can trade their products on world markets. (Herrman and Walker 1999, p. 3)

³ In 1995, the General Agreement on Tariffs and Trade (GATT), established in 1947, was transformed into the World Trade Organization (WTO).

⁴ The Codex Alimentarius Commission (CAC) "develops harmonized international food standards to protect the health of consumers and ensure fair practices in food trade" (FAO 2024a).

⁵ Sanitary and phytosanitary (SPS) measures can have both trade-restricting and trade-facilitating effects, depending on trade (see Swann et al. 1996; Disdier et al. 2008; Xiong and Beghin 2012; Beghin et al. 2015; Crivelli and Groeschl 2016).

Differing tolerance levels (divergent standards) between trading partners impose costs on food producers and suppliers in the country of origin. Table 1 reports aflatoxin tolerance levels established by the US and several major importing countries.

Country	Aflatoxin Tolerances $\mu\text{g}/\text{kg}$ or parts per billion (ppb)	Comment
United States	20	
European Union	10 (8 for B1*)	Ready to eat
	15	For further processing
India	10	Ready to eat
China	20 (5 for B1)	
Japan	10	
Canada	15	
Hong Kong	15	
	0.05	Children and infant food
United Arab Emirates	10	Ready to eat
	15	For further processing
Mexico	20	
Turkey	10 (8 for B1)	Ready to eat
	15	For further processing
South Korea	15 (10 for B1)	

Notes: *B1 is the most toxic type of aflatoxin (see Section 3). For more information on EU aflatoxin tolerance levels, see Commission Regulation (EC) No 1881/2006 source (EC 2006).
Source: ABC (2022).

5 Different Aflatoxin Tolerances: The Ongoing Issue with the European Union and Japan

The EU is the top importer of US almonds, followed by India, Canada, Hong Kong, China, the United Arab Emirates, Japan, Mexico, Turkey, and South Korea (Figure 1, FAO 2024b). Almost 40 percent of US almond production is exported to the EU and Japan, which have much stricter food safety regulations and aflatoxin tolerances (10 ppb) compared to the United States (20 ppb) (Table 1).⁶ Trade flow of almonds, particularly to the EU, is hindered due to almonds' susceptibility to fungal infestation and aflatoxin contamination (Alshannaq and Yu 2021). In the last 2 decades, border rejections and notifications for US almonds exported to the EU have increased due to aflatoxin contamination. On average, 88 percent of US almond shipments receiving aflatoxin notifications were rejected at the EU border (Alshannaq and Yu 2021).

⁶ There is a distinction in the EU for allowable aflatoxin for products for further processing versus at the retail level for consumers as ready-to-eat. In the US there is no such difference. All aflatoxin tolerances are 20 parts per billion regardless of whether the product is destined for the retail level or for further processing.

The Rapid Alert System for Food and Feed (RASFF) allows the exchange of information on the risks associated with food and feed among EU countries.⁷ Imported products into the EU are checked by the expert EU authorities. When risks to public health are detected, information is disseminated via the RASFF to the EU and their trading partners (exporters) (Alshannaq and Yu 2021). Despite extensive efforts to control aflatoxin contamination for almonds in the US (see more details in Section 6), a high number of consignments destined for the EU are still rejected due to aflatoxin levels exceeding not only the EU tolerance limits but even in some cases surpassing US limits (Alshannaq and Yu 2021).⁸

The RASFF categorized notifications into four different types: “alert notifications,” “information notifications,” “border rejections,” and “RASFF news” (EC 2018). Information notifications are further divided into “information for attention” and “information for follow-up.” An information notification is issued when a hazard (such as aflatoxin) is discovered in food or feed (e.g., almonds). Although no immediate action is required from the EU because the consignment has not entered the EU, consumers may be affected by a lack of product availability since the EU imports nearly 70 percent of its almonds from the United States (Owolabi et al. 2023; FAO 2024a). An information notification has a greater impact on exporting countries, as the consignment is rejected at the EU border and identified as hazardous (Laschkolnig et al. 2016; Pigłowski 2020; Kowalska and Manning 2021; Owolabi et al. 2023). Since aflatoxin became the most common reason for border rejections of almond consignments, it led to additional import monitoring at EU ports of entry. While the number of notifications remained low for a long time, there was a spike in RASFF notifications in 2018 (Table 2). This increase was due to unusually high levels of navel orangeworm (NOW) in the 2017–2018 crop. The presence of NOW can elevate aflatoxin risk, which helps explain the 2018 spike in RASFF notifications (Niederholzer 2018; Sacramento Valley Almond News 2018; ABC 2025).

The EC amended Article 15 of Regulation No. 669/2009, with the update published on July 22, 2019 (EC 2019). This amendment required that food and feed of nonanimal origin be subjected to increased official controls at designated points of entry, with nuts and products from the US subjected to a 10 percent increase in the frequency of physical and identity checks for aflatoxin contamination (Owolabi et al. 2023; EC 2024).

At the same time, the European Commission raised the allowable aflatoxin limits for ready-to-eat almonds in 2010,⁹ resulting in fewer shipments exceeding allowable levels and the number of notifications fell sharply from 2009 onward (Table 2). The European Commission also revised the official sampling scheme for tree nuts¹⁰ to align with Codex, and the number of notifications dropped significantly between 2011 and 2017¹¹. These two revisions, the higher limits and aligning with Codex sampling design, reduced the likelihood of higher RASFF aflatoxin notifications (USDA-FAS 2010).

In addition, California’s Voluntary Aflatoxin Sampling Plan (VASP) was introduced in 2007; under the EU’s special measures, consignments shipped with a VASP certificate moved from systematic (100 percent) to random checks (about 5 percent) while non-VASP shipments remained at full inspection (ABC n.d.c; USDA-FAS 2008). In 2015, the EU formally approved US pre-export checks (PEC) for almonds through Implementing Regulation (EU) 2015/949 (EC 2015); consignments carrying a PEC certificate are

⁷ For more information on EU food safety, see EC (2024).

⁸ In the US, the Federal Food Administration (FDA) is the regulatory agency responsible for establishing aflatoxin levels for products such as almonds.

⁹ The EU changed allowable aflatoxin limits for ready-to-eat almonds from B1 = 2 µg/kg and total = 4 µg/kg to B1 = 8 µg/kg and total = 10 µg/kg (EC 2010a).

¹⁰ Revised sampling plan for tree nuts (from 3×10 kg to 2×10 kg composite samples for ready-to-eat tree nuts (EC 2010b).

¹¹ While the number of notifications remained low for a long time, there was a spike in RASFF notifications in 2018 (Table 2). According to university and industry notes, this increase was due to unusually high levels of navel orangeworm (NOW) in the 2017–2018 crop. The presence of NOW can elevate aflatoxin risk, which helps explain the 2018 spike in RASFF notifications (Sacramento Valley Almond News 2018; Niederholzer 2018; ABC 2025).

subject to less than 1 percent physical checks at entry. These measures also reduced the likelihood that compliant consignment would be selected and flagged at the border (EC 2015; Poth 2020).

Table 2. Number of Aflatoxin Notifications for the US Almond Exports to the EU, 2005–2020

Year	Number of Notifications	Year	Number of Notifications
2005	28	2013	5
2006	37	2014	4
2007	68	2015	2
2008	N/A	2016	2
2009	46	2017	8
2010	23	2018	32
2011	5	2019	13
2012	6	2020	10

Source: EC (2024).

Japan also has a significant interest in California almonds and imports, importing an average of over 63 million pounds annually between 2005 and 2022 (Figure 1, FAO 2024a). Japan enforces a stricter policy on testing shipments for aflatoxin, requiring the entire shipment to be tested, with no opportunity for re-examination. If aflatoxin levels exceed the allowable limit, the shipment is rejected and must be returned to the United States. Japan’s food safety regime does not permit reprocessing or reinspecting shipments (ABC Industry News 2020a).

6 Programs to Prevent and Protect Against Aflatoxin Occurrence Above the Allowable Tolerances of the Main Importers

US almond exporters are consistently facing testing, reprocessing, or border rejections of their consignments. These issues are increasing over time, creating a higher risk for US almond growers and exporters. Protecting almonds from aflatoxin contamination is crucial, as monetary losses can be significant. Almond exports make major contributions to the California economy through international trade (CDFA 2023a; ABC 2024). Therefore, implementing a mandatory and enforceable legal framework would ease official export control procedures related to aflatoxin in almonds. To address the root causes of the problem and implement preventive measures, US authorities should adequately follow up on rejected shipments and collect comprehensive surveillance data on aflatoxin occurrence and levels in almonds. In response, the USDA and ABC have introduced several strategies in cooperation with the almond industry, focusing on programs and procedures to minimize aflatoxin occurrence at every production stage, rather than simply responding to sampling, testing, and processing (Alshannaq and Yu 2021; ABC 2024). Figure 2 shows a typical US almond value chain from US growers to importing markets (e.g., the EU).

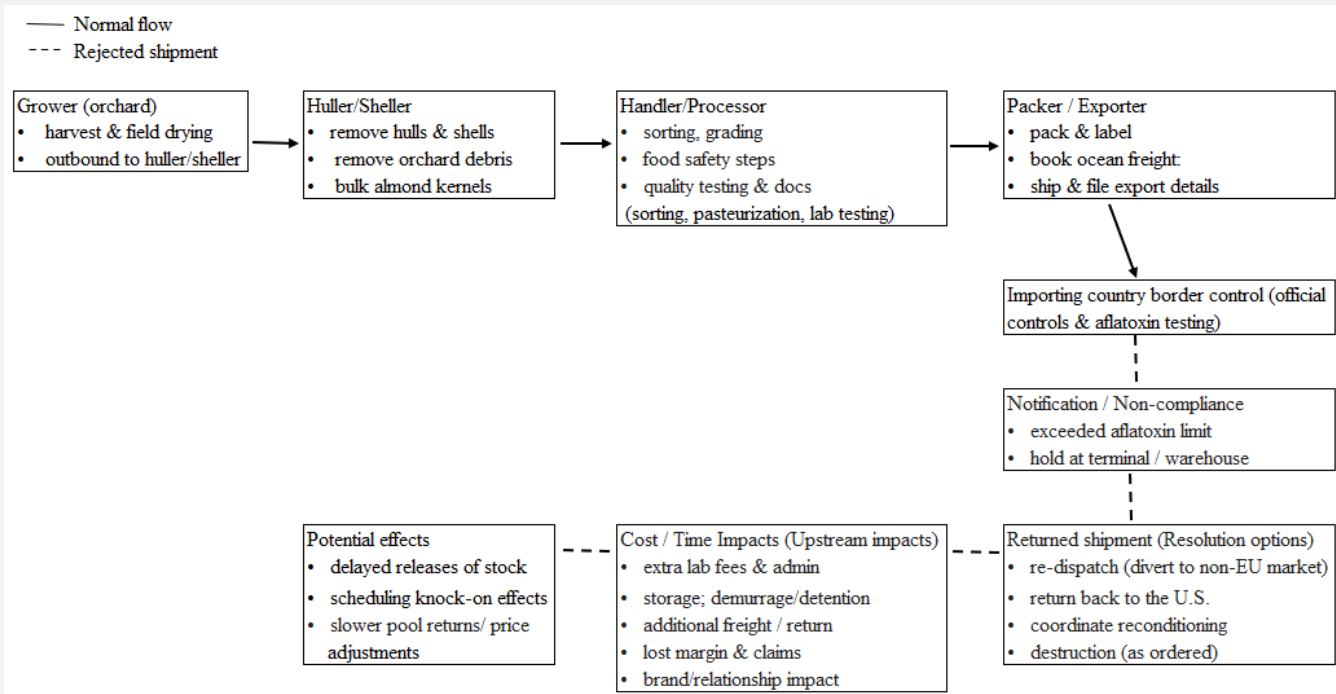


Figure 2. Typical US Almond Value Chain from US Growers to the EU

Notes: Dashed arrow shows a returned shipment path (e.g., aflatoxin noncompliance).

Source: EC (2010b), ABC (2024), USDA-FAS (2025).

6.1 Pre-Exports Checks (PEC) Certificate on Aflatoxin

Literature suggests that countries exporting nuts and nut products including the US must ensure that almonds exported to the EU are free from aflatoxin contamination by implementing compulsory legal standards for official export management procedures. To prevent an increase in RASFF notifications and as suggested by literature, exporting countries must guarantee that its sampling procedures, method validation, result reporting, and overall compliance meet the requirements set by the European Commission. Additionally, rejected shipments should be followed up adequately to assess the root causes of contamination and to implement preventive measures (Owolabi et al. 2023).

In 2015, the US Department of Agriculture (USDA) implemented an instrument known as aflatoxins certification for tree nuts and also adopted a third-country PEC certificate on aflatoxin. Aflatoxin certification is an import-compliance instrument for US tree-nut exports to the EU (such as almonds and pistachios) and is administered by the USDA Agricultural Marketing Service (AMS). The AMS Laboratory Approval Service supports these exports by accrediting laboratories to test for aflatoxin through its Laboratory Approval Program for Analysis (USDA-FAS 2025). The PEC program provides an aflatoxin sampling plan for the analysis of ready-to-eat products equivalent to official testing for incoming consignments used by the EU and is developed by the Almond Board of California (ABC) (Poth 2020). While most exporting firms in the US have signed a memorandum of understanding to follow these programs, participation is voluntary, and there are no official controls to verify compliance with this regulation. Additionally, there may be inadequate official supervision of shipments to verify compliance with aflatoxin contamination, especially for shipments to the European Union (EC 2017, 2019; Alshannaq and Yu 2021).

The EU, under Article 73 of Regulation (EU) 2017/625 (formerly Article 23 of Regulation (EC) No 882/2004), approved a PEC program managed by the USDA, AMS (EC 2017). Under this program, the EU

port authorities are required to inspect less than 1 percent of US almond consignments with a PEC certificate at the border. A PEC certificate is not required to import into the EU; therefore, shipments without a PEC certificate are subject to stricter inspection when imported into the European Union (EC 2018). The PEC certificate provides a significant advantage, as non-PEC certified shipments may face discretionary controls at the EU port of entry. The 1 percent inspection rate for shipments with PEC can also expedite entry and reduce the risk of delays at the border, which is an appealing factor for almond growers and exporters who prioritize consistency in shipment (ABC 2022).

The ABC (2022) reports that obtaining a PEC certificate facilitates shipments at the border; however, there are also costs and logistical considerations associated with it. While each PEC certificate fee is very low, compliance with detailed sampling and documentation protocols is required to confirm that aflatoxin levels meet EU standards and impose additional compliance costs.¹² Additionally, all necessary documents must be completed within 7 days after shipping the consignment. Thus, it is crucial for exporters to have efficient processes to obtain this certification. For each shipment, a USDA-approved laboratory must perform aflatoxin testing; if it does not pass the test (i.e., aflatoxin levels are higher than EU standards), additional sorting and retesting may be required by the laboratory, which is costly. Since the PEC is not mandatory, exporters who do not face frequent border rejections may prefer not to get the PEC certification. However, their shipments are more likely to be inspected upon entry, which could lead to delays or additional handling costs of handling of the shipments at the border (ABC 2022).

Since PEC is a voluntary program, the ABC¹³ implements more rigorous measures when exporting almonds to the European Union. The ABC ensures that aflatoxin levels are tested for consignments destined for export to the EU by administering the PEC program. California almond firms are required to sign an annual memorandum of understanding (MOU) with the ABC when shipping almonds (classified under Harmonized System codes 0802.11 and 0802.12 for bulk in-shell and shelled lots) to the European Union. The ABC facilitates the PEC certificate completion process, while authorized USDA-approved laboratories conduct PEC analyses and issue the certificates (ABC 2022).

In addition to signing the MOU, which indicates that firms have obtained the PEC certificate, ABC staff provide firms with a PEC program manual and a training program on how to use the e-PEC system. Both ABC and USDA oversee the steps to ensure that firms are following the rules and standards. The PEC program has been successfully implemented over the years, with any issues identified and addressed by the ABC to facilitate the shipment process, which resulted in fewer aflatoxin inspections and incidents (ABC 2022). These regulatory strategies by the USDA and the ABC may have contributed to the reduced notifications and border rejections reported by the RASFF between 2019 and 2021.

6.2 Pre-Harvest and Post-Harvest Management Strategies

In addition to the certifications addressed above, growers focus on reducing aflatoxin risk from the early stages of production through the prevention of mold contamination and managing conditions that

¹² While each PEC certificate fee is low, \$16 per consignment as of July 2023 (CDFA 2023), exporters also incur testing and process costs. Under PEC, the aggregate sample is split into two 10-kg laboratory subsamples that must be analyzed by a USDA approved lab (Poth 2024). Publicly posted US lab fees for total aflatoxin analysis are typically \$75 per analysis (routine) and \$95 for a low-detection-limit option (Trilogy Analytical Laboratory n.d.), implying ~\$150–\$190 for the two required replicates plus the certificate fee and any applicable shipping point inspection charges (e.g., \$50/hour, \$35 minimum, \$9.50 overtime) (CDFA 2023b). All PEC documents must be finalized within seven calendar days of the truck bill of lading date (Posh 2024). Based on these schedules, a reasonable direct out of pocket range is ~\$166–\$206 per consignment (two lab analyses + certificate), excluding sample shipping and any SPI hourly charges. These costs are often justified because consignments accompanied by a valid PEC certificate are subject to <1 percent import controls at EU ports (ABC 2024).

¹³ The ABC was established in 1950 and is dedicated to promoting California almonds to a domestic and international audience through strategic market development, global marketing programs, ensuring food safety, and funding and promoting research about almonds' health benefits, zero waste efforts and industry best practices. Almond Board programs are funded by a per-pound assessment on all almonds grown in California.

support aflatoxin production. The ABC, with support from the almond industry, identified the navel orangeworm (NOW) pest as one of the primary sources of aflatoxin-producing molds. The ABC developed the NOW prevention program to minimize NOW damage with the following steps: (1) winter sanitation, (2) early harvest, (3) in-season treatment, and (4) stockpile management (following Good Agricultural Practices to help prevent mold growth) (ABC 2024). The ABC guidelines for growers are to emphasize intensifying sanitation efforts to eliminate mummy nuts to disrupt the aflatoxin cycle and prioritize insect control for not only NOW but also for leaf-footed bugs and stink bugs. The ABC guidelines for handlers also emphasize effective stockpile management after almonds leave the orchard (ABC 2024).

According to Tim Birmingham, the ABC's director of quality assurance and industry services, the risk of contamination is sometimes inevitable due to rising insect damage, economic pressures, and unpredictable weather (e.g., heavy winter rains), which make winter sanitation difficult for growers. Frequent border rejections of US almonds have put the market under further scrutiny. Birmingham emphasized, "Basically, European authorities closely watch the rejection rates: the more rejections they have, the more they will test for aflatoxin. Even though we have a very robust protocol, every time a container is sampled and tested, there is a risk" (ABC 2023b). Therefore, preventive measures should be implemented to monitor almond quality closely and ensure it is within the allowable limits of aflatoxin when exporting to the European Union (ABC 2023b). Given that the almond industry is under EU scrutiny, a prompt and comprehensive response is necessary. Birmingham stated, "The more they recognize that the California industry understands the concern and is addressing it, the more confidence they have in our system. It is an issue that requires collective action and collaboration among growers, handlers, and the entire industry" (ABC 2023b). Therefore, the ABC is actively monitoring the situation by engaging with EU authorities and stakeholders (ABC 2023b).

In addition to implementing the NOW program to ensure the production of high-quality products, almond handlers and processors must increase surveillance for aflatoxin contamination to meet the standards of key export markets. ABC works closely with handlers, shippers, and government authorities to manage the safe distribution of products in key export markets. The good news is that the almond industry's comprehensive aflatoxin management system is recognized in the EU (ABC 2022). While other foods and feed have similar aflatoxin problems, almonds are the only product with a recognized system in the European Union (ABC 2022). Geoffrey Bogart, principal specialist in Global Technical and Regulatory Affairs at the ABC, said at the Almond Conference 2019, "The good news is that because we've had an improved crop and fewer rejections, European Commission authorities issued a notification to member states in September directing them to return to the less-than-one-percent inspection regimen for California almond shipments arriving in the EU." He also added, "This action taken by the Commission is a firm recognition of the quality of California almonds and the measures being taken to ensure compliance with European aflatoxin tolerances" (ABC 2020). The ABC has also been hosting EU officials in the US to better understand food safety procedures in the California almond industry.

7 Management Strategies on the Rejected Shipments

Putting in place programs and guidelines to prevent and control aflatoxin contamination is essential. However, when a consignment is rejected at the port of entry, it is important for US suppliers (handlers) to know how to manage the shipment to minimize economic loss for exporters. According to the ABC (2024), they need to evaluate the following questions and find the best strategy to minimize the loss while adhering to food safety regulations:

- Should the product be returned to the country of origin?¹⁴
- Can the contaminated almonds be resorted?
- Where should the contaminated products be sorted and retested?
- How much would it be worth, or is it sellable?
- Should the products be destroyed at the port of entry, or re-exported to another country with laxer regulations on aflatoxin?

The cost of demurrage is also significant if the rejected consignment must be returned to the country of origin. In addition, in some cases, the returned consignment is consumed by vulnerable populations, exposing them to higher aflatoxin levels and resulting in adverse health impacts (Gbashi et al. 2018; Owolabi et al. 2023). Another situation occurs when the rejected shipment is re-exported, usually to low-income countries with laxer or, in some cases, no established food safety regulations. The re-exported contaminated products expose consumers in these countries, who are already vulnerable to other health issues like malnutrition, to an even higher risk of aflatoxin contamination (Makun 2013; Owolabi et al. 2023). Therefore, implementing strategies to manage rejected shipments is critical, while alleviating economic losses.¹⁵ Figure 3 summarizes the operational options following an EU aflatoxin notification and is intended to guide discussion of time, cost, and compliance trade-offs across the available paths.

8 Discussion and Conclusion

Almonds are one of the most valuable crops in the US, primarily produced and processed in California, which has a comparative advantage in meeting the growing global demand. As the global leader in almond exports, California's almond industry generates most of its revenue from international markets, making it particularly susceptible to importing markets' regulations. Differences in food safety standards, especially the EU with stricter aflatoxin limits, have disrupted the US almond export market, notably leading to border rejections of almond shipments. Accordingly, US regulatory agencies should carefully consider their trading partners' food safety standards to protect human health and minimize economic losses while enhancing strategies to reduce border rejections of almond shipments.

The policy and managerial priorities are threefold: (1) prevention at origin, including pre- and post-harvest controls; (2) control at shipment, including PEC compliance; and (3) efficient resolution

¹⁴ Exporters who deal with rejected shipments should also take into account the fact that if they decide to return the shipment to the US, it will be treated as an import product and is subject to scrutiny by the Food and Drug Administration (FDA) and routine testing (Posh 2023).

¹⁵ For example, according to public reporting on an EU border rejection of a US almond container (aflatoxin), on May 16, 2024, Spain notified the EU's RASFF system of a lot of US almonds with excess aflatoxin (AFB1). The consignment was officially detained at the border (EC 2024; ECHEMI 2024; Food Safety Compliance Service 2024). Under the EU Official Controls Regulation, when a consignment is noncompliant, authorities detain it and may order redispach (return to origin), destruction, or special treatment; measures are at the operator's expense (EC 2017). Representative direct cost components for one 40' container include demurrage/detention while detained: container lines commonly charge about \$75–\$300 per container per day after free days (Freightos 2025; Freight Right Global Logistics n.d.). Official resampling/analysis costs depend on the lab; for reference, US lab list prices are typically \$75 per total-aflatoxin analysis (routine) or \$95 for a low-detection-limit option. (Trilogy Lab access 2025). There are also other costs such as return freight or destruction. In case of redispach or return freight, the new ocean move back to origin will add costs (EC 2017). If destruction (e.g., incineration) is authorized because the shipment remains noncompliant, it can be even more costly given evolving EU policy around waste-to-energy/incineration (EC 2017; Warringa and Manna 2025). According to industry estimates, "a single rejected consignment due to aflatoxin can cost approximately \$10,000, and more if the shipment must be destroyed" (USDA-AMS 2024). Shipments with a valid PEC certificate face less than 1 percent border controls at EU port (vs. discretionary sampling without PEC), reducing the chance of detention and associated costs (Posh 2023). Note that the RASFF publishes the hazard/date/action but not commercial identities or costs.

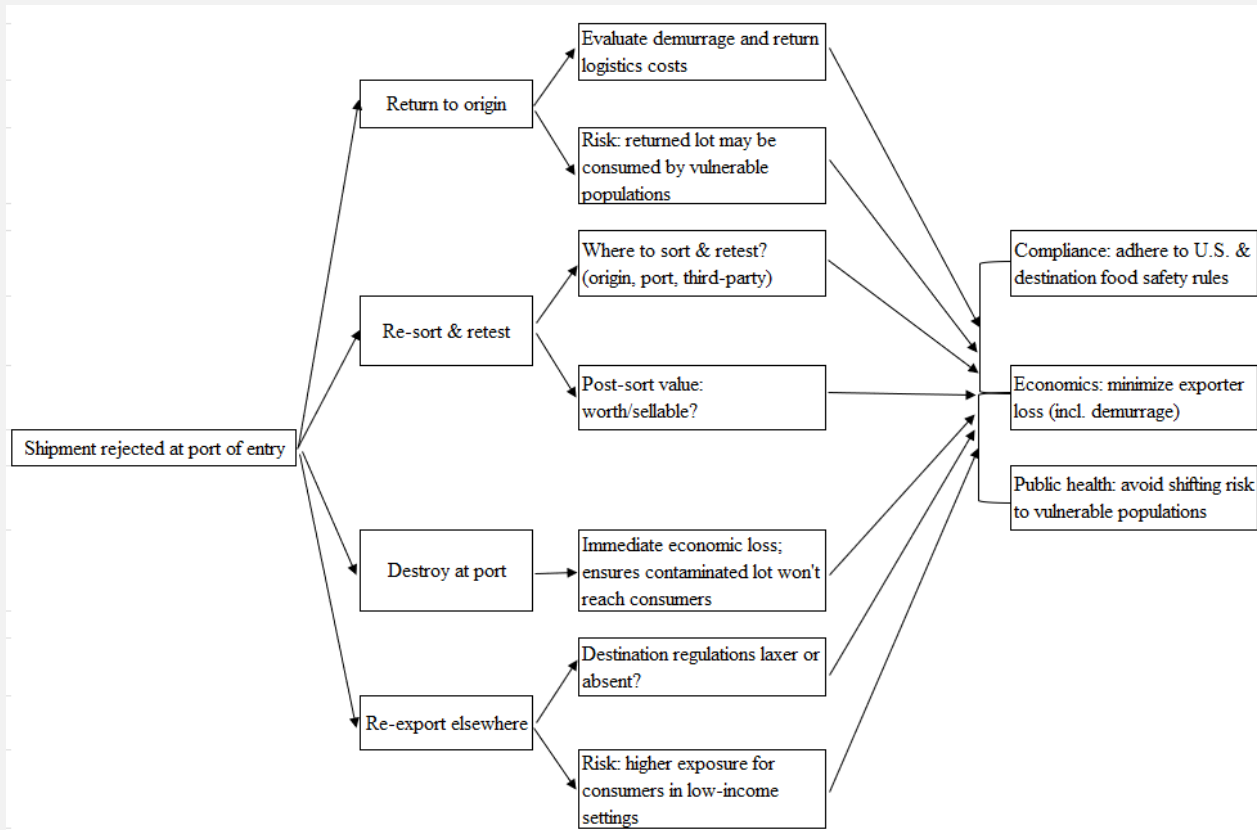


Figure 3. Simple Decision Tree for a Rejected Almond Consignment at the EU Border (Aflatoxin Noncompliance)

Source: ABC (2024a), EC (2010a,b, 2024), FAO (2024a), USDA-AMS (2024).

when failures occur, including clear decision rules for reconditioning, return to the country of origin, or destruction that minimize losses without externalizing public health risk. Improvement will be driven by tracking and meeting lower notification rates per shipment volume, a higher PEC-clearance share, and faster time-to-release, alongside alignment with importing market procedures and transparent handling of noncompliant shipments and sustained pre- and post-harvest controls that reduce baseline risk. Pre- and post-harvest controls, PEC compliance at shipment, and clear procedures for consignment rejection and disposition translate policy into practice across the supply chain. In short, the key challenge is determining how the almond supply chain can most effectively reduce aflatoxin risk across all stages while maintaining the reliability and efficiency needed to meet stringent food safety requirements and the demands of international markets.

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