OCTOBER 2020

ALL ABOUT ALMONDS

FOOD SAFETY

WHAT THREATENS FOOD SAFETY IN ALMONDS[1]

CONTENTS

Introduction

Although almonds are not a readily perishable commodity, they are, like other fresh foods, subject to contamination of food safety concern. Almond contaminants are categorised as being chemical, biological, or physical in nature.

The 'cost' of contaminated nuts is multi-faceted. Not only is there a potential human cost in terms of health (and occasionally, life), but also significant costs associated with sorting and testing product, re-sorting and re-calling, loss of markets and consumer confidence.

Any surface in contact with almonds is a potential source of contamination. The premature fall of almonds (windfalls), the natural splitting of hulls (and shells, in some varieties), and the harvest practice of shaking mature almonds to the ground, make bacterial and fungal presence in almonds, unavoidable.

Risk management is required and the responsibility for safe and sanitary almonds is shared across the production and value chains, throughout the industry. Risk reduction strategies in the orchard relate to conditions, practices and hazards over which growers have control. Specific documentation and record-keeping maximise the value of your risk-reduction steps, and your capacity to identify early and trace threat sources.

This fact sheet outlines for almond producers, food safety threats and how they may be minimised in the orchard. The responsibilities of hullers, crackers and processors in almond food safety are detailed in other publications and quality assurance programmes.

Figure 1. Mould growth on stockpiled almonds.

Chemical contamination

Chemical contaminants include pesticide residues, allergens and mycotoxins. Aflatoxins are a specific form of mycotoxin. Pesticide residues are minimised by the correct use of registered (or permitted) chemicals. Worldwide, nut aflatoxins are of concern. Aflatoxins are natural but toxic by-products of fungi. They are odourless and colourless, and cannot be visually detected in a food product. They may enter the almond food chain in the orchard, in stockpiles or in storage, and persist in finished, raw product.

Biological contamination

Biological contaminants include parasites and pathogens that are usually fungal, viral, or bacterial in nature. The most important biological food safety contaminants of almonds are bacterial - *Salmonella* spp. and *Escherichia coli (E. coli)*. Both are indicative of food exposure to faecal material. These organisms have serious human health consequences, and therefore all food production and handling management must ensure such exposure is minimised.

Physical contamination

Foreign matter of concern in almonds is that which is solid, and capable of causing human injury or illness, e.g. stones, glass, plastic, metal fragments. These may be from the orchard floor or equipment, and are generally removed during hulling and cracking.

Aflatoxins - chemical contaminants of concern

Aflatoxins are derived from fungi, primarily *Aspergillus flavus* and *Aspergillus parasiticus*. They are carcinogenic and mutagenic, even in low concentrations. Aflatoxin B_1 can be found in almonds, and it is the most potent natural carcinogen known.

Humans are exposed to aflatoxins by eating Aspergillus-contaminated food. Historically, corn, peanuts, cereals, figs, tree nuts and milk (from animals that have eaten contaminated grain), have been the main sources of aflatoxin ingestion. Recurring consumption of such food has serious human health effects, especially on the liver and immune system. As such, internationally-traded commodities, including almonds, must comply with aflatoxin monitoring and regulations regarding acceptable levels of detection. World food authorities have extremely low tolerance levels for aflatoxins in food. Australia's limit is 10-15 ppb (parts per billion), depending on the product. Some other markets are even lower.

Some commodity processors impose significant economic penalties on aflatoxin-affected deliveries. The Australian peanut industry for example, deducts 40% of the clean value, from aflatoxin-affected loads.

Prevention of aflatoxin production has a greater chance of success than corrective action, and therefore risk reduction strategies are the basis of on-farm contaminant management programmes.

Aflatoxins in almonds

Aspergillus growth causes aflatoxins

Both *A. Flavus* and *A. Parasiticus* are present in Australian agricultural environments. There are no almond varieties resistant to infection by these fungi. To manage Aspergillus growth and aflatoxin production in almonds, the influence of orchard conditions and agricultural practices, need to be understood.

Fungal growth and aflatoxin production occur in almonds pre-harvest, but may proliferate in stockpiles, and continue in the handling stage. Almonds are vulnerable as soon as the fruit is exposed following damage (e.g. insects) or hull split. Aspergillus spores from the soil, dust, or air enter the exposed hull, shell or kernel while nuts are on the tree, ground and/or in stockpiles.

The growth of the fungi inside hulls and shells are affected by temperature, humidity and moisture levels. In mild-warm temperatures (15-37+C), spores of *Aspergillus* spp. Can germinate and produce the heat stable aflatoxin within 24-48 hours of nut exposure to a moist environment (≥7% kernel moisture). Once inside the shell, the nutrients of the kernel provide a rich growth environment. Affected nuts are not always 'mouldy' but one should be suspicious of any kernels that display yellow-green growth. Not all moulds however are *Aspergillus* spp.

Risk reduction and prevention

Orchard practices and aflatoxins

Almond producers must minimise food safety threats in the orchard. Producers can best manage risk by understanding the potential contribution of orchard design, winter sanitation, orchard floor conditions, nut damage (mechanical, vermin, pest and disease), harvest operations and stockpile conditions, on almond contamination. For example, tree density, canopy size, and irrigation techniques, affect humidity and soil populations of fungi, light penetration and nut drying times. Orchard size and the relative demands on equipment may affect the timing of crop protection applications and harvest activities.

Aflatoxin risk management in your orchard requires focus in several specific areas, and documentation of your inputs and activities.

Pest and vermin management

- Damaged nuts with the white meat of the kernel exposed are susceptible to fungal contamination.
- Bird, vermin and insect damage provide entry points for fungi
- Birds, vermin and insects are sources and vectors of fungal spores and bacteria
- In Australian orchards, the larvae of Carob moth (Ectomyelois ceratoniae Zeller) have been shown to carry *Aspergillus* spp.
- A strong and significant correlation of Carob moth and aflatoxin in Australian almonds is possible, as there for the navel orangeworm (NOW) and aflatoxin, in Californian almonds.

Figure 2. Aspergillus growth on almonds
Source: T. Michailides, University of California, Davis

Figure 3. Mould growth from kernels. The dense, pale yellow mats are those of *Aspergillus spp*. Source: T. Michailides, University of California, Davis.

Insects and aflatoxins in Californian almonds

In California, in both almonds and pistachios, aflatoxin contamination has been strongly correlated with insect presence, especially navel orangeworm (NOW) - Amyelois transitella. Kernels of mummies with A. parasiticus, in the presence or absence of NOW larvae, have been compared. Those with NOW larvae had aflatoxin levels six times higher than those without larvae (Higbee and Siegel, 2009). Navel orangeworm infestations clearly increase aflatoxin detections in almonds.

Once hulls split, NOW larvae feed on shells or penetrate the developing kernels in soft-shelled varieties (e.g. Nonpareil). Curtis et al. (1984) found that the longer nuts remained in trees after maturity, the more likely was NOW infestation. Overwintering mummies carry most of the NOW eggs for the next season. Larval infestations and mummy numbers are strongly correlated.

Orchard-wide removal of mummies has reduced insect damage the following season, and aflatoxin detections. Fewer than 2 mummies/tree has been until recently the goal of NOW (and aflatoxin) management in Californian orchards. However more recent winter sanitation research has suggested 0.2 mummies/tree (i.e. 1 mummy in five trees) and no more than 4 mummies/tree on ground by budswell is needed to minimise NOW damage the following season.

Dormant sprays are not effective on NOW larvae harboured in mummies. Integrated management practices are needed. Moth trapping, pheromone and egg trap monitoring, degree day calculations, mating disruption and pre-harvest nut assessments allow strategic spray applications.

Attempts to 'displace' aflatoxigenic *A. flavus* strains at the soil surface, with non-toxic strains, is being trialled in some Californian orchards. This form of 'biological control', based on soil-borne population manipulation and competition for infection sites, has shown promising results in other aflatoxin-affected food crops (e.g. corn and peanuts), but it is only in the early research phase for almonds and pistachios.

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Orchard floor management

- *Aspergillus* spp. in the top 1-2 cm soil under the tree canopy, threaten almonds
- Slow drying and re-wet soils (e.g. under large, shaded canopies) potentially harbour more fungi and bacteria
- Dust from this area reaches tree nuts, so minimise dust movement
- Minimise the time nuts are in contact with the soil
- In nuts exposed to direct sunlight, NOW larvae and pupa survival is reduced (in California)
- Canopy density influences direct sunlight exposure, nut drying times and internal temperatures
- Scattered nuts dry faster than those in shaded windrows
- Soil and organic matter incorporated into windrows slows the drying of nuts
- Windfalls harbour more fungi than mature nuts on trees

Harvest timing

- Minimise cross-contamination. Early windfall pick-up may be beneficial
- Harvest on time whenever possible
- 'Optimal harvest' guidelines suggest 95-100% hull split (30-40 days after hull split initiation) at 1.8-2.5 m in the canopy
- Delayed harvests (and re-wetting of mature nuts on the ground or in trees) increase fungal infection

Stockpile management

- Starting (before stockpiling) moisture levels in hulls and kernels is very important
- High humidity and temperatures in stockpiles increase incidence of moulds and aflatoxins
- Fungal growth and aflatoxin production increase in poor stockpiles primarily at top and bottom of stacks
- Minimise cross-contamination. Segregate re-shakes and mummies from others
- Do not stockpile nuts with wet hulls (>12% moisture) or kernels (>6%)
- Shells, hulls and kernels snap when bent at suitable moisture levels BUT moisture monitors are more accurate and reliable.

Figures 4 & 5. Carob Moth larvae in almonds

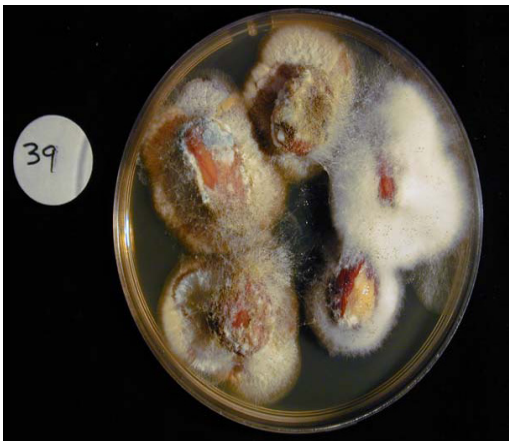

Figure 6. Moulds associated with insect/vermin damaged almond kernels, despite surface sterilisation.

Figure 7. Two 'generations' of almond fruit, mummies from last season (black, mouldy almonds) and new season fruit (green fruit).

Figure 8. Harvested, re-windrowed almonds on a drying exclusion zone.

Figure 9. Two 'generations' of almond fruit, mummies from two seasons ago (black, mouldy almonds) and from previous season (brown fruit). Three 'generations' of almond fruit will exist once the new season begins.

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- Stockpiled nuts dry slowly because of air movement limitations, condensation and/or re-wetting
- In Australia, run stockpiles north-south and minimise furrows and valleys in them
- Drying time in stacks is influenced by height, shape, orientation and covers, of stockpile
- The diurnal temperature range (day –to-night) influences condensation – and therefore moisture in the top nuts, and run-off down to the base of the stockpiles
- Slope the stockpile base/pad to reduce pooling of condensate and run-off, and rain entry
- Cover stockpiles only when rain threatens and during evenings - remove covers in daylight
- Monitor stockpiles at top, middle and bottom of piles with moisture, humidity and temperature readers

Winter sanitation

- Mummies harbour fungi and insects
- Remove all mummies before budswell of the next season
- Minimise cross-contamination. Segregate re-shakes and mummies from others
- Destroy (e.g. with flail mower) mummies

Treatment (decontamination) potential

There are no efficient means of degrading or removing aflatoxins from contaminated food. There is some evidence that removal of the skin of almonds (e.g. blanching) can reduce the level of aflatoxin present, but the heat stability of aflatoxins limits the effectiveness of other cooking or roasting.

Decontamination and clean-up efforts, even if effective, are very expensive and the net value of nuts requiring such treatments, is greatly reduced.

Biological contaminant - Salmonella

Salmonella is the leading cause of food-borne illness in many countries. The USA reports on average, 1.79 million cases/yr. Various strains of Salmonella are common in the environment and food chain, and people usually come into contact with these bacteria via wildlife, pets, and consumption of unpasteurised or raw animal food products (e.g. dairy, poultry, meat, eggs). Several significant outbreaks of 'salmonellosis' (a form of gastroenteritis) due to consumption of nuts, including almonds and pistachios, have been reported in the USA and Europe.

Salmonella and almond contamination in California

Orchards with high planting densities (i.e. 370 trees/ha), shading, and greater areas of wet ground (e.g. from mini-sprinklers) have high humidity within and around each tree. Rainfall extends the conducive conditions, especially in summer when windfalls may be in contact with the ground over a long period, or when shaken nuts are re-wet on the ground

The Salmonella outbreak in California in 2001 was traced to an orchard that had soil infested with the same Salmonella strain. The orchard was, and remains, productive but its orchard floor is fully shaded. UC Davis academic, Bruce Lampinen has suggested the lack of direct light, use of mini-sprinklers, conducive soil temperatures, and natural rainfall resulted in the clay loam topsoil retaining moisture and providing a suitable environment for Salmonella proliferation. Salmonella was still detectable in the soil in 2007, and the orchard therefore remains quarantined.

Salmonella in almonds

The primary habitats of *Salmonella* spp. are the intestines of birds, animals, some insects, reptiles and humans. The persistent on-farm sources of *Salmonella* spp. Are soil, sediment, dust and 'open' water; organic inputs (e.g. manure, biosolids, effluent); exposed produce, feed and waste piles; farm workers, equipment and containers.

Salmonella spp. rapidly proliferate in wet almond hulls and free moisture allows bacteria sitting in dust on hulls, to move onto shells and into kernels. Once inside shells, the bacteria are protected from drying conditions and direct sunlight, and they rapidly multiply.

Salmonella spp. Grow over a wide temperature range (5-45C) at moisture levels above 10%, but even at lower moisture levels these bacteria remain a problem because their high temperature tolerance is increased at low moisture levels. Nut contamination levels are highest in warm, moist nuts, but the capacity of *Salmonella* spp. To survive in water, soil and on organic and plant matter, makes them an on-going concern in almond production, handling, processing and storage.

Research on one Salmonella strain (*Salmonella Enteritidis* phage type [PT] 30) has demonstrated its survival for 550+ days in finished almonds, under normal storage conditions.

Risk reduction and prevention

Salmonella risk reduction in orchards, requires particular focus on water sources; soil and nutritional amendments; hygiene of orchard and product handling personnel; bird, animal and vermin management; harvest operations and cross-contamination.

Orchard history

- An orchard's history requires early and careful consideration because it alone may overwhelm subsequent risk management efforts
- Animal, human and vermin manure carry *Salmonella* spp. which may persist even when dried
- Orchards with a history of grazing or dairy/livestock (including sheep) operations, are at greater risk. Trees and orchards on or near landfill, septic tanks or sites that have incorporated manure (as soil amendments) are at greater risk
- Orchards sharing water channels or dams with livestock/grazing operations are at greater risk, especially if there is potential for overflow or leakage from them

Water sources and quality

- Almonds are in contact with water in orchards via irrigation and foliar spraying, and rain
- Water may introduce and spread microbial contaminants, like *Salmonella* spp.
- Protect dams, holding ponds, open channels from wildlife (including birds), wherever possible
- Use mains or protected (ground, bore) water only, for foliar spraying

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- Test for and record 'total faecal coliform' bacteria and generic *E. coli* in surface water
- Know the bacterial thresholds at which water quality becomes unsuitable for spraying or irrigation
- Keep all water test results especially if open, re-cycled water is used

Soil and nutritional amendments

- *Salmonella* spp. survive long periods in soil, sediments, and dust
- Manure, whether fresh or aged, carries Salmonella
- Do not use equipment that has contacted or carried animals, animal products, soil or organic matter exposed to animals, for collection or movement of almonds
- Avoid manure (also biosolids, effluent) use, storage or distribution on or near almond trees
- Use only fully-composted amendments meeting Australian standards – if necessary

Worker hygiene

- Personal hygiene of workers directly affects transmission of contaminants, and food safety
- Properly-serviced facilities are necessary in orchards or within easy access, for every worker
- Use of the facilities must be a requirement of all orchard workers.
- Do not place facilities near irrigation sources
- The contents of portable toilets must be disposed of off-site – outside the orchard
- Hands, clothing, shoes, and equipment require proper cleaning
- Training in food safety practices is recommended for all staff

Orchard floor management

- *Salmonella spp*. in surface soil threaten the safety of almonds that contact it
- Minimise wildlife movement through orchards
- Minimise dust. Dust movement and aerosols spread contaminants
- Dust carries fungi and bacteria, including *Salmonella* spp.
- Avoid standing water in orchards through irrigation management, orchard floor grooming (remove low spots), and canopy management
- Avoid nut contact with wet /damp soil and nuts becoming wet on the ground
- Minimise slow-drying of nuts and the time windrows are shaded
- Avoid creating preferred habitats for wildlife (e.g. waste piles, vegetation cover)

Wildlife, bird and vermin management

- Birds, animals (and insects) in orchards and processing facilities, threaten food safety
- Animal and human faecal deposits contaminate soil, dust, plant material, water sources and equipment
- Every nut that comes into contact with a surface shared by animals, is at high risk
- Warm and cold-blooded animals carry *Salmonella* spp.
- Clear weeds and ground around orchards, because rodents and other vermin avoid open spaces
- The size, shape, colour of some excrement makes its physical separation from almond kernels difficult and it may not be achieved until late in the handling and sorting stages
- Do not allow equipment scrap heaps, waste piles in the orchard, as they become hiding and nesting refuges for vermin and birds

Harvest operations

- Minimise dust; dust movement spreads contaminants
- Manage windrows to ensure nuts are drying as rapidly as possible
- Do not stockpile damp nuts
- Separation of windfalls, wet nuts, re-shakes from other nuts will reduce cross-contamination
- Avoid fumigation of warm, moist nuts, as this can result in dark kernels

Treatment (decontamination) potential

Salmonella contamination, unlike aflatoxin, may be reduced by heating and washing, depending on the bacterial strain present. Steam pasteurisation, hot water blanching and oil roasting may effectively reduce Salmonella populations in almonds. Pasteurisation reduces rather than kills all the bacteria and therefore the starting population in the kernels, determines if a 10,000-fold reduction in the population is sufficient to meet food safety standards.

Pasteurisation

In 2007, the Almond Board of California in recognition of the food safety re-calls of raw Californian almonds since 2000 determined that industry-wide, aggressive measures to increase the safety and quality of their almonds were justified. They mandated pasteurisation of domestic almonds to achieve a 10,000-100,000-fold reduction in Salmonella, on the basis of decontamination research by Danyluk et al.

A validated procedure to achieve the minimum 10,000-fold bacterial reduction is required to be undertaken before product shipment, by all almond processors selling raw almonds in USA, Canada and Mexico. Those being sold elsewhere are marked 'unpasteurised'. The actions have been mandated (with USDA support) to ensure full adoption, auditable compliance, and the use of approved technology. Mandatory pasteurisation does not absolve growers of their orchard responsibilities. Almond producers in California are still expected to follow Good Agricultural Practices (GAPs), and hullers and crackers, Good Manufacturing Practices (GMPs).

Orchard guidelines for aflatoxin and Salmonella management

As almond producers, you and your employees are the people most capable of influencing and managing aflatoxin levels and Salmonella contamination, in your almonds. Crackers and processors can maintain the quality of almonds delivered to them, but can rarely improve it.

There are several documents that include recommended food safety practices for producers and processors of almonds. Good Agricultural Practices (GAPs) were prepared in California, but have direct relevance also to Australian almond orchards. The guidelines of the United Nations Food and Agriculture Organisation (FAO) and the CODEX code of practice for the prevention and reduction of aflatoxin contamination of tree nuts are also useful.

A summary of recommendations relevant to Australian almond orchards is tabled in Table 1.(overleaf)

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Table 1. Risk reduction steps for aflatoxin and Salmonella contamination

Stage	Risk reduction category	Risk reduction steps	
In the orchard			
Orchard - plan	Knowledge and traceability	• Avoid orchards with land use history involving animals • Map adjacent land use, water courses, drainage patterns	• Map orchard layout, harvest sequence • Document all activities and weather events • Consider equipment capacity and availability • Train workers in food safety practices
Orchard – Pre-harvest	Damage minimisation	• Minimise habitats and hiding places • Control insect pests	• Avoid bird, insect, disease, vermin, mechanical damage
	Minimise introduction of contaminants	• Enforce highest worker hygiene standards in orchard and handling areas • Clean anything that contacts almonds -equipment, hands, shoes, clothing • Test (or access results) water quality and record results • Foliar spray only with ground or mains water	• Do not apply manure, biosolids, or untreated effluent • Minimise animal, bird, vermin presence in orchards • Minimise bird life in water courses, dams • Do not irrigate with water sourced or held near animal operations • Minimise pet presence in orchards and on almond equipment
Orchard -Harvest	Maturity of crop	• Harvest in good conditions, at full maturity • Avoid rain, re-wetting, delayed harvests • Dry rapidly; manage windrows • Minimise time on ground • Re-shake to remove all mummies and stick-tights before budswell	• Destroy winter re-shakes on ground • Destroy re-shakes with high insect infestation • Isolate re-shakes, mummies, wet nuts from others
Orchard – After shaking	Stockpile management	• Test nut moisture before stockpiling • Orient piles north-south • Stockpile low moisture (< 6%) nuts only • Monitor nut moisture (top, middle, bottom) in stockpiles	• Manage covers and stockpile form (height) to achieve low moisture equilibrium • Slope stockpile pad to avoid pooling of condensate or rain at base
Beyond the orchard			
Hulling and cracking*	Cross contamination	• Do not share equipment with animal operations • Train workers in food safety and handling requirements • Isolate late season nuts - mummies, windfalls, re-shakes from others	• Isolate organic nuts from others • Do not mix (or process) loads of moist and dry nuts • Remove 'inedibles' and physical contaminants early in handling stage • Clean all equipment and contact surfaces thoroughly
Processing*	Cross contamination and re-contamination	• Focus on QA and GMPs requirements • Clean surfaces and equipment between lots • Clean with low moisture, fast-evaporating sanitisers	• Ensure personnel trained in hygiene • Linear directional flow in plant – air, product • Re-mediate, treat 'at risk' lots (Salmonella) • Do not combine re-runs
Storage*	Product protection - moisture	• Use dry, clean, protected (from rain, dust, vermin), ventilated storage	• Maintain low moisture (<6% water activity)
	Product protection- temperature	• Store at low temps and monitor for 'hot spots'	
Transport	Contamination - equipment hygiene	• Use only dry, sanitised/lined containers, vehicles, machinery	• Do not use equipment or transport used in animal industry
	Product protection - temperature	• Monitor	• Avoid long periods/distances without temperature control

Source: adapted from FAO; CODEX code of practice (CAC/RCP 59 –rev 1-2006); GAPs

*Summary only. Specific QA and food safety requirements must be met for all food handling activities beyond orchard.

[1]This factsheet has been updated from the original paper written by Dr Prue McMichael, Scholefield Robinson Horticultural Services - 2012

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OTHER RESOURCES

Managing Food Safety Risk in Almonds

Access here: https://bit.ly/3kkCw6H

PROJECT CODE

AL09027 - Almond Food Safety

This project has been facilitated by HAL in partnership with the Almond Board of Australia and has been funded by the Research & Development levy. The Australian Government provides matched funding for all HAL's R&D activities.

MORE INFORMATION

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