2023

THE ALMOND CONFERENCE

Connecting the Dots

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Food Safety Hot Topics: Aflatoxin Factors and MOSH/MOAH

Moderator: Brian Dunning (ShoEi Foods),

Speakers: Dawit Gizachew (Purdue University), Tim Birmingham (ABC), Guangwei Huang (ABC)

Analysis of Fungal Growth and Aflatoxin Production on California Almonds

Dawit Gizachew, Ph.D.
Associate Professor of Chemistry
College of Engineering and Sciences
Purdue University Northwest

Mycotoxins

- Mycotoxins are mainly secondary metabolites produced by various fungal species.

- These metabolites allow fungi to either increase their own fitness or decrease a surrounding organism's fitness, ensuring survival and reproduction.

- Secondary metabolites may also play a role, for example, in initiation, regulation, and process of sporulation in *Aspergillus* species.

The six major mycotoxin groups include:

- **Aflatoxins**
- Ochratoxins (Ochratoxin A)
- Fumonisins
- Deoxynivalenol (DON)
- Patulin
- Zearalenone

Harmful effects of aflatoxins

- Aflatoxin B_1 is a known carcinogen
- Growth impairment
- Depressed immune system
- Decrease in appetite

Aflatoxin is produced mainly by *A. parasiticus* and *A. flavus*

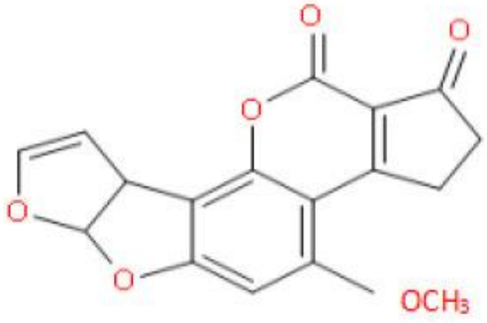
Aspergillus parasiticus

Aspergillus flavus

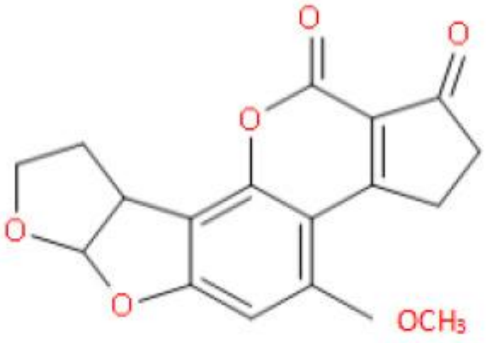
An example of preharvest infestation by *A. flavus* on crops such as corn.

Maize breeding program at Texas A&M Univ

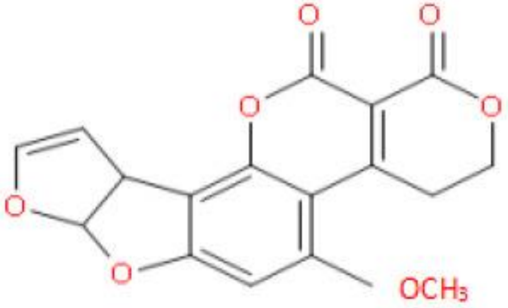
The four main types of Aflatoxins:



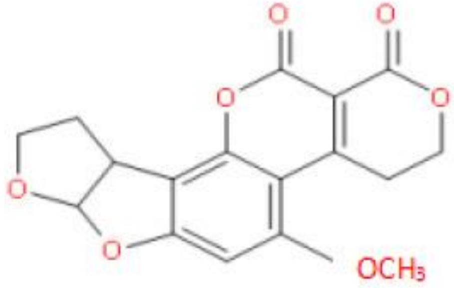
AFB_1



AFB_2



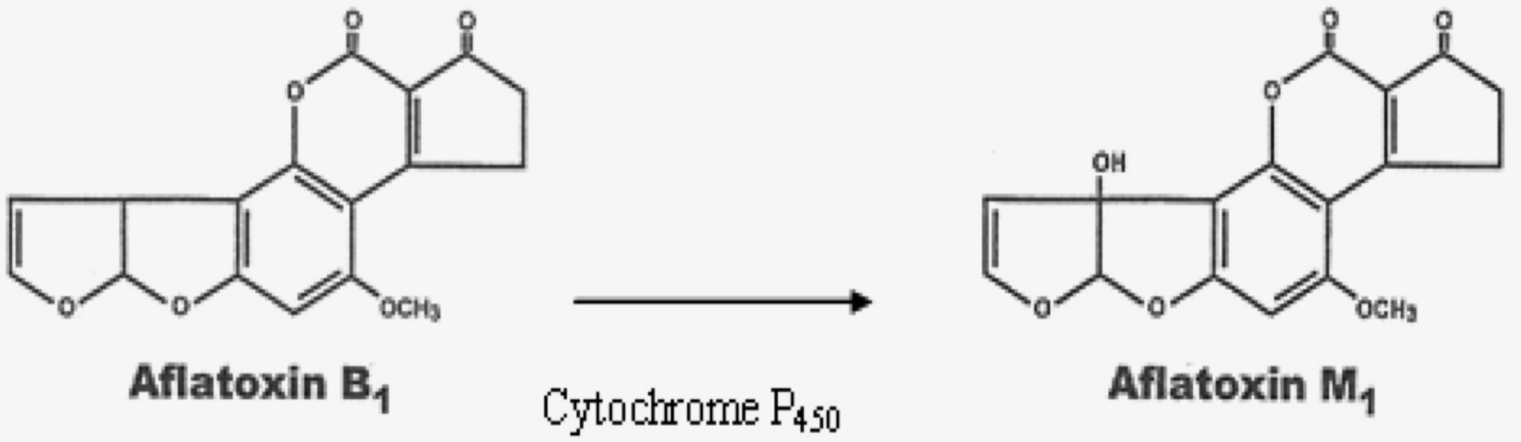
AFG_1



AFG_2

Conversion of AFB_1 to AFM_1

- Animals under the influence of the cytochrome P_{450} oxidase system found in their micro-flora and own cells hydroxylate aflatoxin B_1 (AFB_1) to aflatoxin M_1 (AFM_1)



FDA Action Levels for Total Aflatoxins*

Commodity	Aflatoxin level (ppb)
All products for humans, except milk	20
Aflatoxin M1 in fluid milk	0.5
Corn for immature animals, dairy cattle and all food for dairy animals	20
Corn and peanut products for breeding beef cattle, swine and mature poultry	100
Corn and Peanut products for finishing swine	200
Corn and peanut products for finishing beef cattle and cottonseed meal (as an ingredient)	300

*IAFP Annual meeting, July 2023, Toronto, Canada.

Factors that affect fungal growth and aflatoxin production:

- Temperature:
- Water Activity
- Incubation Period
- Type of Kernels
- Fungal Species

Our objectives are to answer the following questions:

- What are the optimum temperatures and water activities for fungal growth and aflatoxin production on almond kernels?
- What are the differences in fungal growth and aflatoxin production on different types of almond kernels?
- What happens if we change the incubation period of the fungal strain with the almond?
- What are the differences between the two fungal species in terms of fungal growth and aflatoxin production on almond kernels?

Conditions and parameters used in the study:

- Temperature: 20, 27 and 35°C
- Water Activity: 0.65, 0.80, 0.85, 0.90, 0.95, 0.99 a_w
- Incubation Period: 10, 20, 30 days
- Type of Kernels: inshell, shelled, split
- Fungal Species: *Aspergillus parasiticus*, *A. flavus*

Experimental methods

Fungal culture, spore suspension

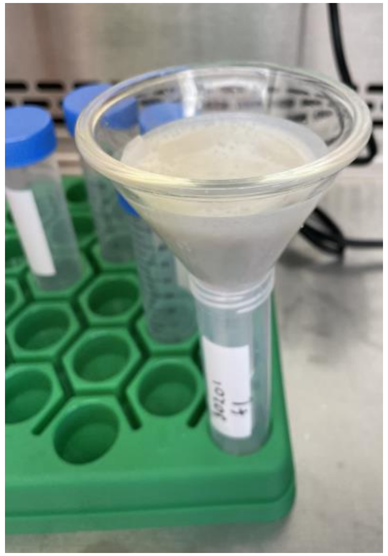
Aspergillus parasiticus (NRRL 465) and *A. flavus* (NRRL 3357) were grown on potato dextrose agar (PDA) at 27°C for 5 days.

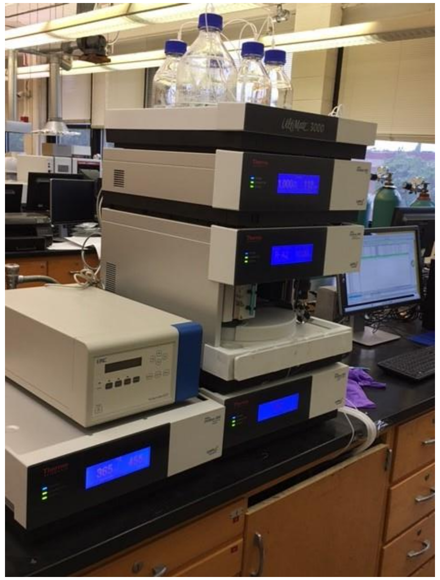
Aspergillus parasiticus

Aspergillus flavus

Preparation of almond nuts and incubation

Homogenization, Purification and Analysis





Results

Aspergillus parasiticus (NRRL 465)

Inshell kernels:

- At 0.65, 0.80, 0.85 and 0.99 a_w, there was no fungal growth at 20, 27, 35°C. There was no aflatoxin production under these conditions.

- There was some growth at 0.90 and 0.95 a_w at the three temperatures.

Diffuse greenish growth of *A. parasiticus* at 27^{0}C and 0.90 a_w on inshell kernels. Also seen: white hyphae and black spores of presumed *R. stolonifer.*

Shelled whole kernels:

- At 20^0C, the fungus barely grew or not at all at 0.65, 0.80, 0.85 and 0.99 a_w.
- *A. parasiticus* showed initial growth at 0.90, 0.95 a_w and 27°C but then another fungus (presumptively *Rhizopus stolonifer* and/or *Aspergillus niger)* species started to grow.

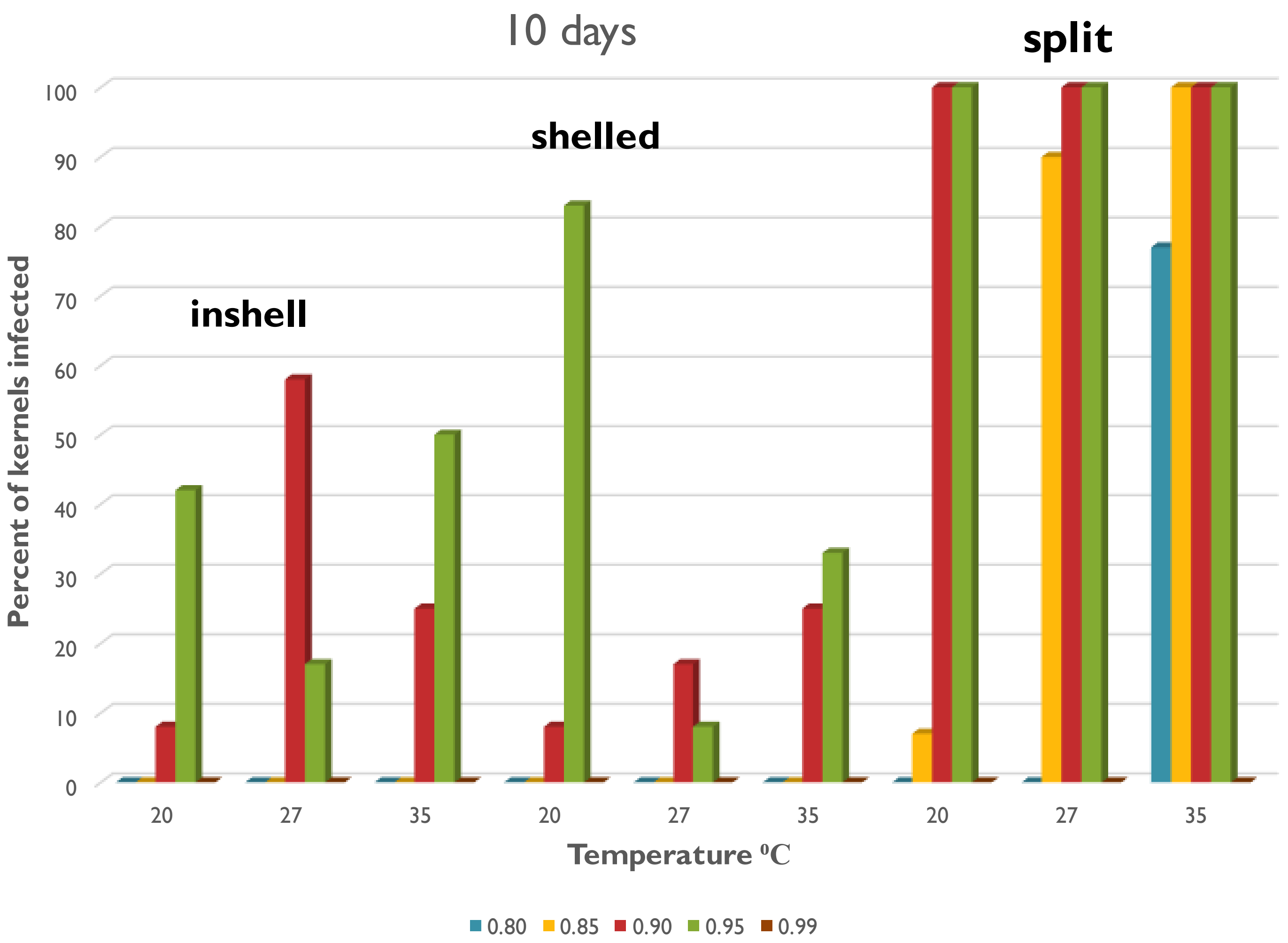
- At 35^0C, *A. parasiticus* showed some growth at 0.90 and 0.95 a_w.

Split kernels:

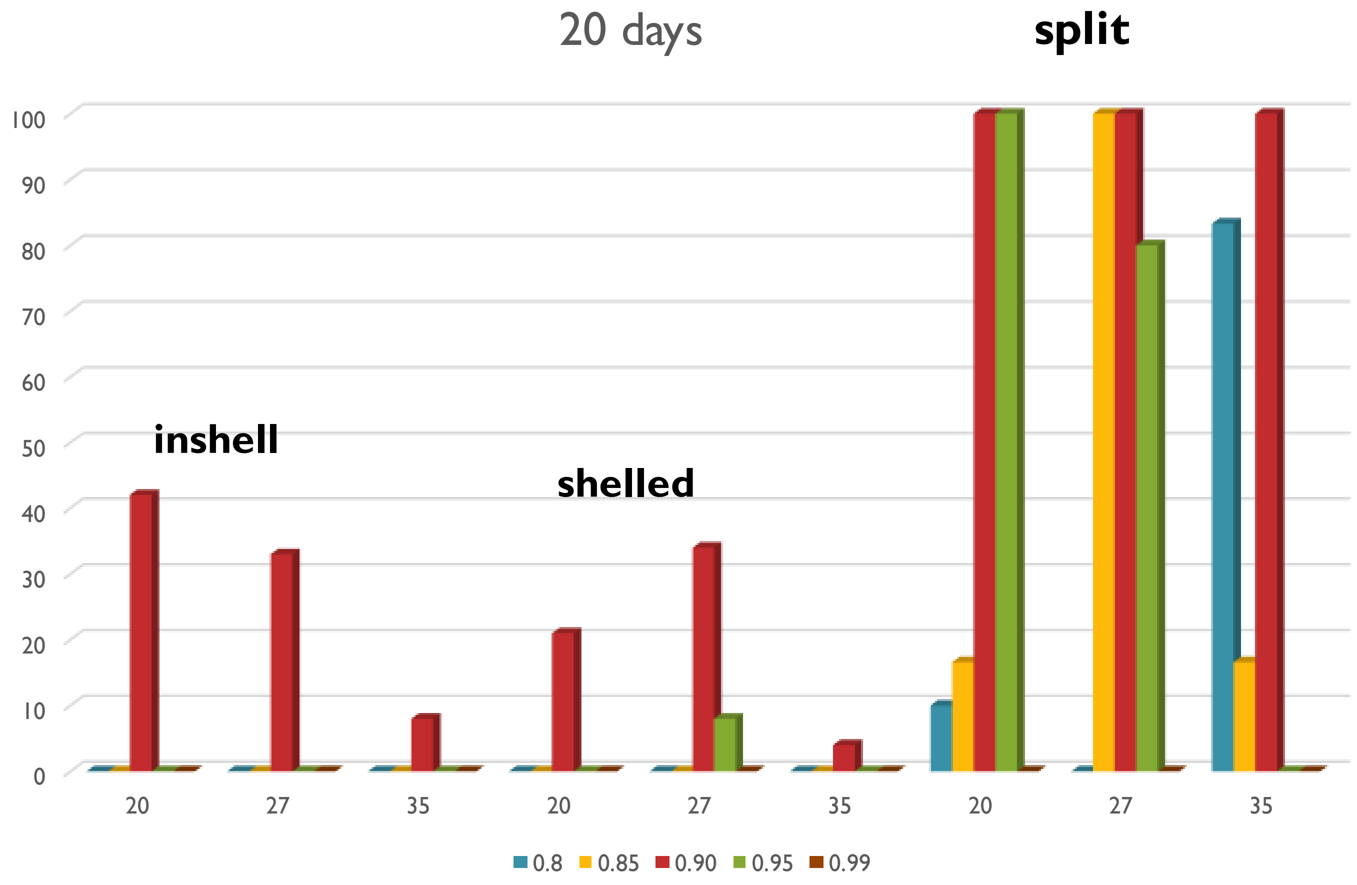
- No fungal growth at 0.65 a_w on split kernels at 20, 27 and 35°C.
- Fungal growth was high on the split kernels at 0.80, 0.85, 0.90, 0.95 a_w at the three temperatures.

Growth of *A. parasiticus* at 27⁰C and 0.90 a_w on split almonds.

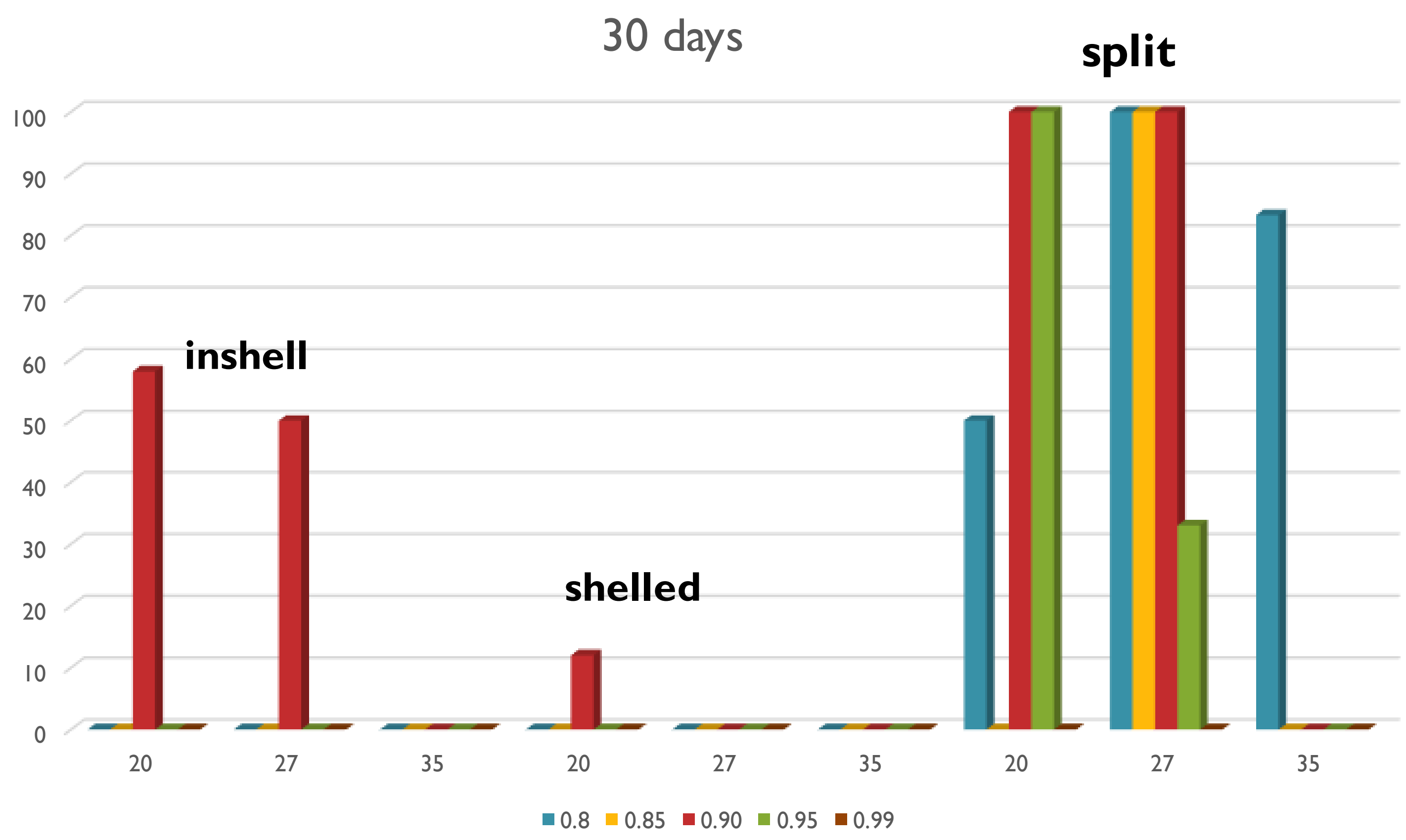
A. *Parasiticus* growth on almond kernels



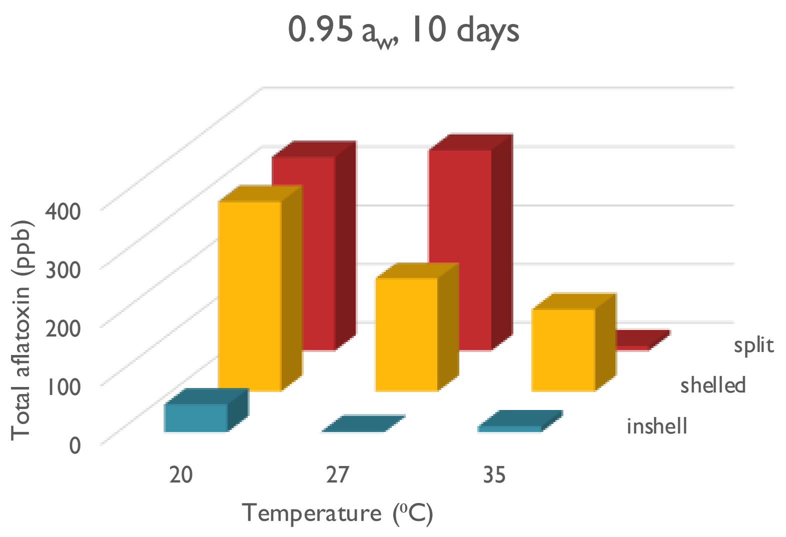
A. *Parasiticus* growth on almond kernels

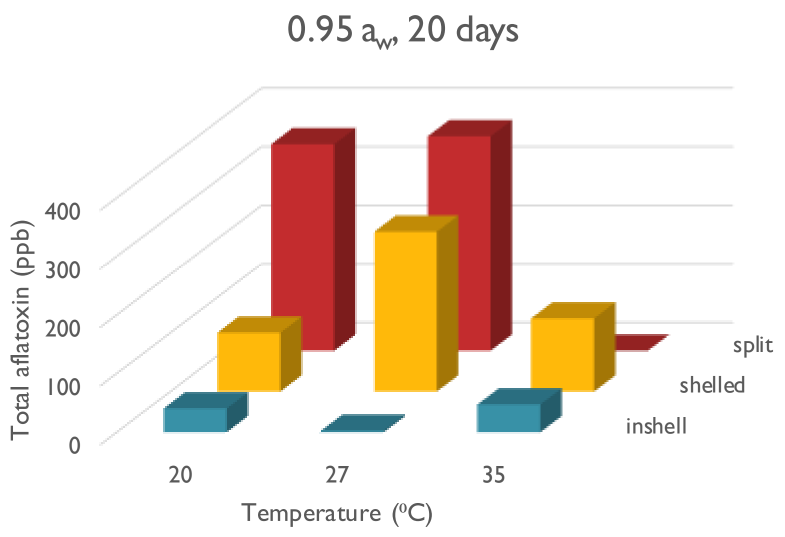


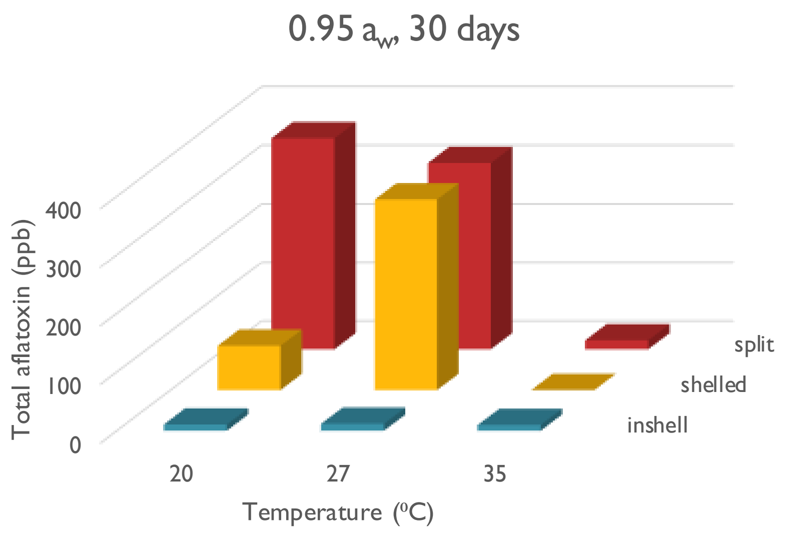
A. *Parasiticus* growth on almond kernels



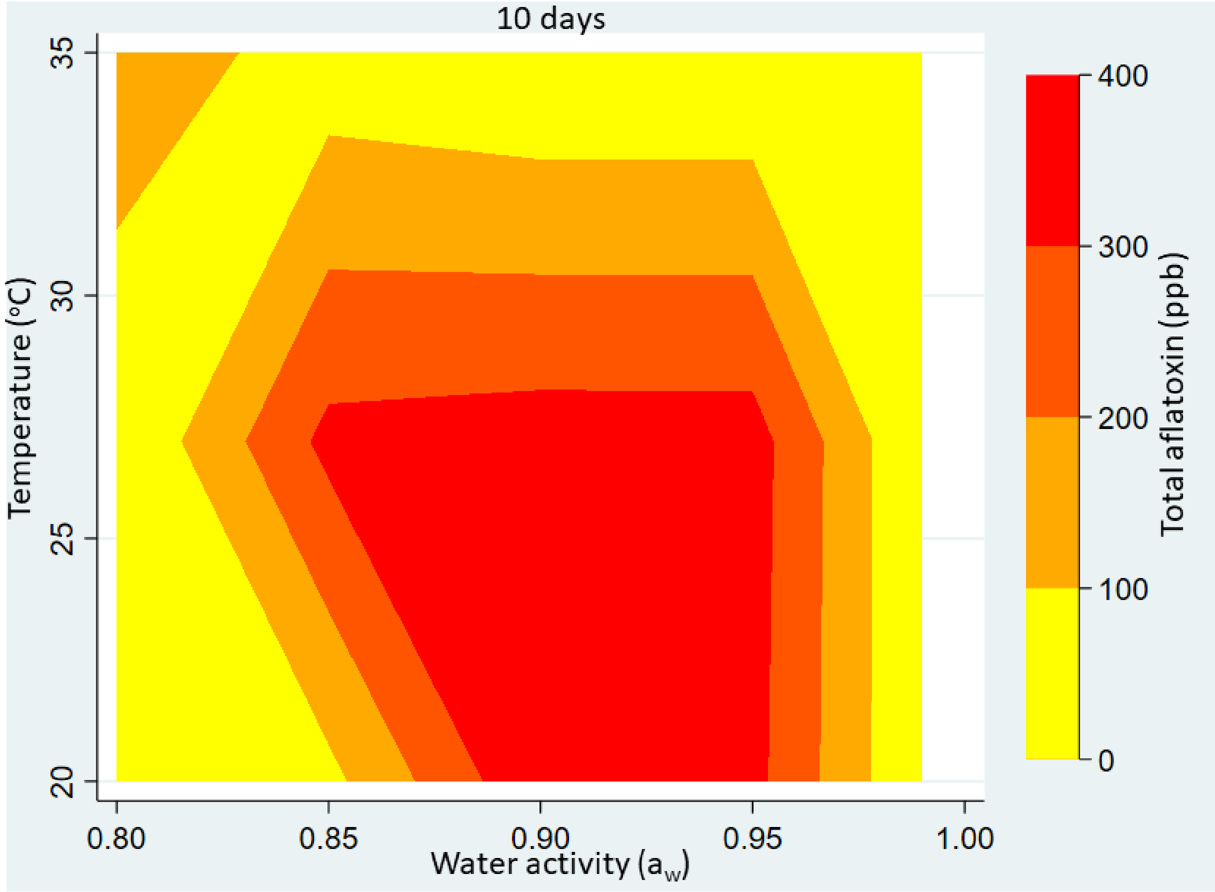
Aflatoxin was produced only at 0.95 a_w on inshell and shelled kernels by *A. parasiticus* while it was produced at 0.95 and other water activities on split kernels







Aflatoxin levels produced by *A. parasiticus* on split kernels varied depending on water activities, temperatures and incubation period



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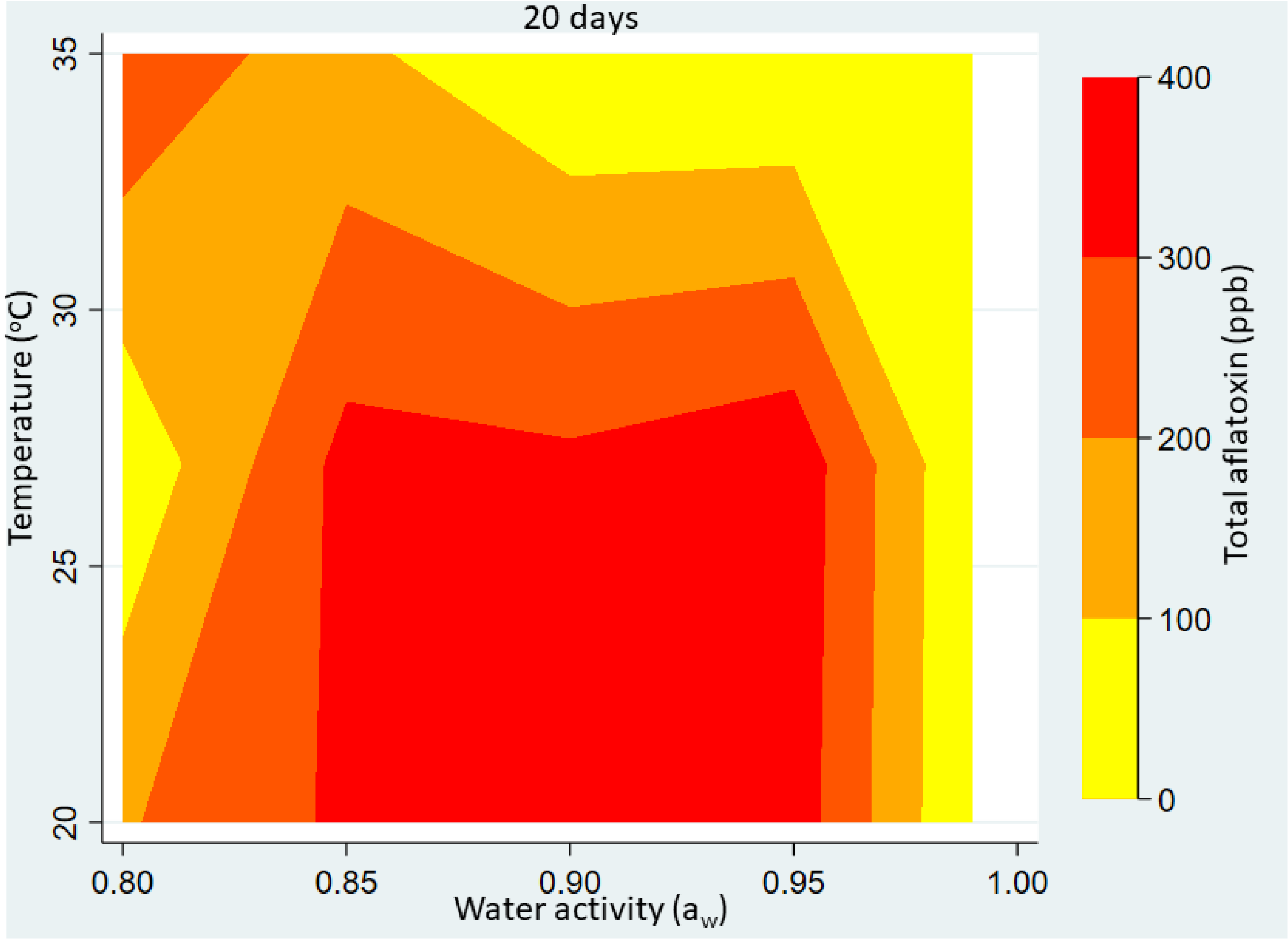

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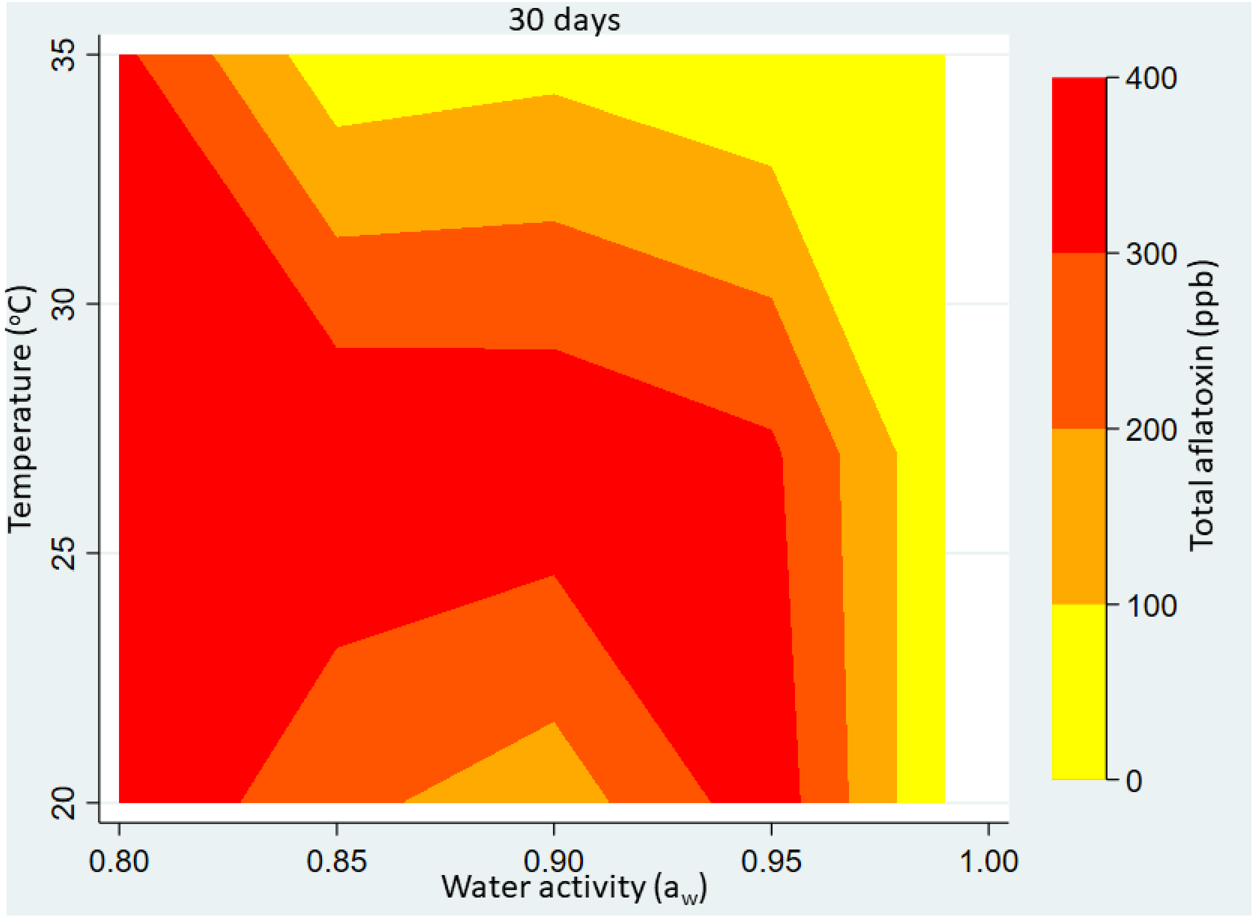


Aspergillus flavus (NRRL 3357)

- There was no fungal growth at 0.65 a_w and 0.99 a_w at 20, 27 and 35°C for inshell, shelled and split kernels for 90 days.

- At 27⁰C and 0.90 a_w, *A. flavus* showed significant growth on inshell, shelled, and split kernels.

Growth of *A. flavus* at 27⁰C and 0.90 a_w on inshell, shelled and split kernels.

Summary of Results

- Both *A. parasiticus* and *A. flavus* show no fungal growth on inshell, shelled and split almond kernels at 0.65 a_w and temperatures 20, 27, and 35°C for 90 days.

- *A. Parasiticus* shows some growth on inshell, shelled at 0.90 and 0.95 a_w at the three temperatures while it shows high growth on split kernels at these conditions. The fungus also shows high growth on the split kernels at 0.80 and 0.85 a_w at 35°C.

- Total aflatoxin production by *A. parasiticus* on inshell and shelled is limited to 0.95 a_w at all the three temperatures.

- The fungus produced high levels of aflatoxin in a wider range of a_w and temperatures on the split kernels.

- Optimum conditions for aflatoxin production on split kernels is at 0.90-0.95 a_w and 20-27°C.

- At 0.99 a_w, both *A. parasiticus* and *A. flavus* didn't grow well on all the three types of kernels for 30 days. However, there was high growth of another type of fungus probably *R. stolonifer.*

Study in Progress

- Determination of *A. parasiticus* growth and aflatoxin production at 0.65 water activity at 20, 27, 35°C incubated for 180 days.

- Determination of *A. parasiticus* growth and aflatoxin production at 0.75 water activity at 20, 27, 35°C.

- Fungal growth and aflatoxin analysis of *A. flavus* at various water activities and temperatures.

- Statistical analysis of the correlation between temperatures, water activities, and incubation period and their effect on fungal growth and aflatoxin production on the almond kernels.

Aflatoxin and Climate Change

The contamination of crops with aflatoxin is likely to increase in the future because of climate change due to

- an increase in temperature.
- increased presence of insects that damage crops.
- change in the frequency and amount of rainfall.

Therefore, we need to closely monitor fungal growth and contamination of crops with aflatoxin.

Future Research Plans and Recommendations

- Characterization and growth conditions for *Rhizopus stolonifer* and/or *Aspergillus niger* in order to understand their effects on the growth and aflatoxin production of *Aspergillus parasiticus* and *A. flavus*.

- Considering the high levels of aflatoxin on the split almonds, it will be important to determine fungal growth and aflatoxin production on naturally insect damaged kernels.

- Also, we recommend the studies of fungal growth and aflatoxin production on whole blanched almonds.

- We plan to study fungal isolates from the soil of almond trees and/or kernels. These isolates will help us study how to mitigate the contamination of almonds with aflatoxins.

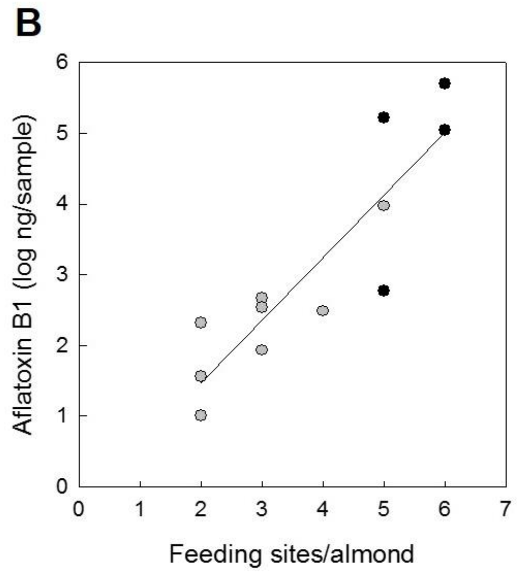
- We plan to study the mitigation of fungal growth and aflatoxin contamination of almond kernels both pre- and post-harvest are important.

Acknowledgment

- Funded by the Almond Board of California: 22-GizachewD-AQFSS-01

- Barbara Szonyi, Research Assistant

Aflatoxin Correlation with Damaage



Palumbo, J.D., Mahoney, N.E., Light, D.M., Siegel, J., Puckett, R.D., Michailides, T.J., Spread of Aspergillus flavus by Navel Orangeworm (Amyelois transitella) on Almond

Aflatoxin by Grade Factor Study: 50 Almond Lots (44,000 Pound Lots)

Grade Category	Weight (%)	Aflatoxin (%)
High Quality	83.7	3.2
Mechanical Damage (Chip/Scratch)	7.4	7.9
Insect Damage	7.2	76.3
Other defects (i.e.. Gummy/Shrivel)	1.5	11.8
Mold	0.2	0.8
Total	100.0	100.0

Whitaker et al., 2010. Correlation between aflatoxin contamination and various USDA grade categories of shelled almonds. J. AOAC Int. 93(3):943-947

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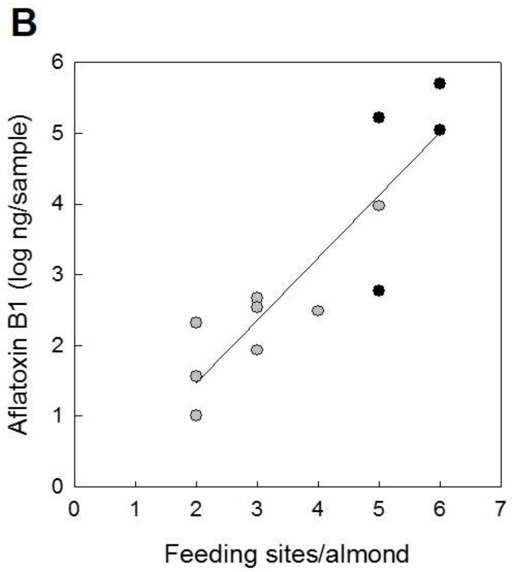
Aflatoxin – Correlation with Defects / Inhibitory Factors for Growth / Moisture during Transit

Aflatoxin Correlation with Damaage



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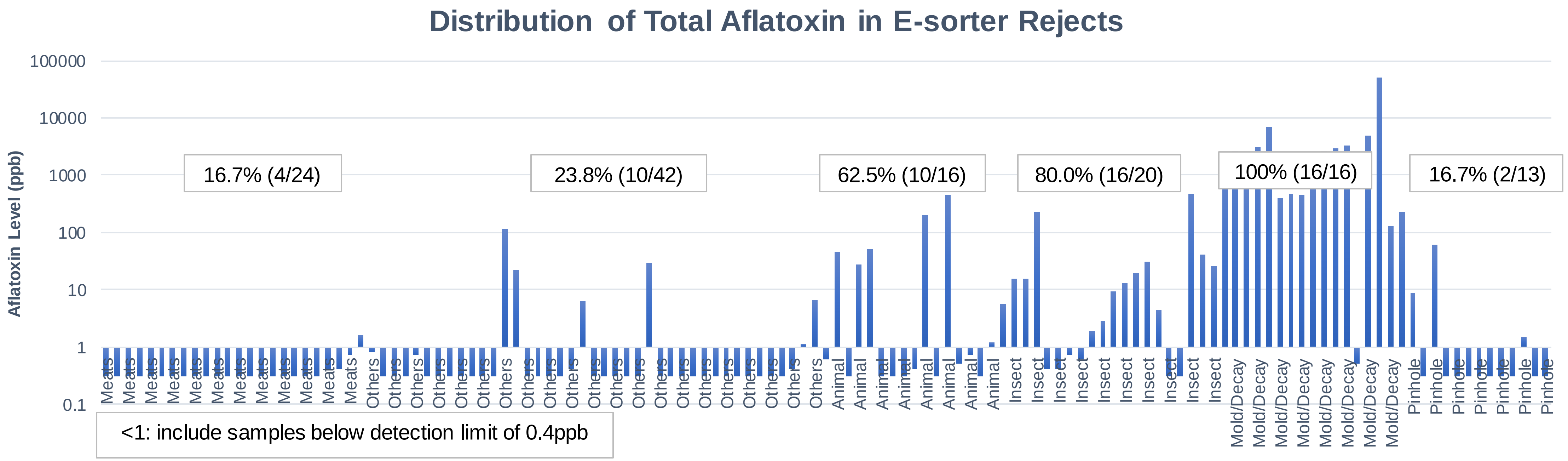
Aflatoxin Contamination by Reject Types

SAMPLES WERE SORTED FROM SORTER REJECTS OR PICKOUTS FROM THE SAME DAY OR WEEK PRODUCTION

- Prevalence and levels of aflatoxin in serious and other defects:
  - Mold/decay/rancid >>Insect damaged >>Animal bitten >> Others.
  - Random positive hits in Other Defects with one hit each of brown spot, discoloration, gummy, shrivels.
  - Serious and other defects can be effectively sorted out by e-sorters.
- Rejected good meats (kernels and broken):
  - Low prevalence and levels of aflatoxin may be due to contact cross contamination.
- Pinhole damaged kernels:
  - Low prevalence indicates a less concern for aflatoxin contamination.
  - A similar prevalence as for good meats may indicate a potential cross contamination.
  - May be further verified and confirmed by more sample testing.
- G1, G2 and B2 also detected in most of mold defect samples.

Aflatoxin Distribution Among Rejects

GOOD MEATS AND DEFECTS SORTED OUT FROM ELECTRONIC SORTER REJECTS



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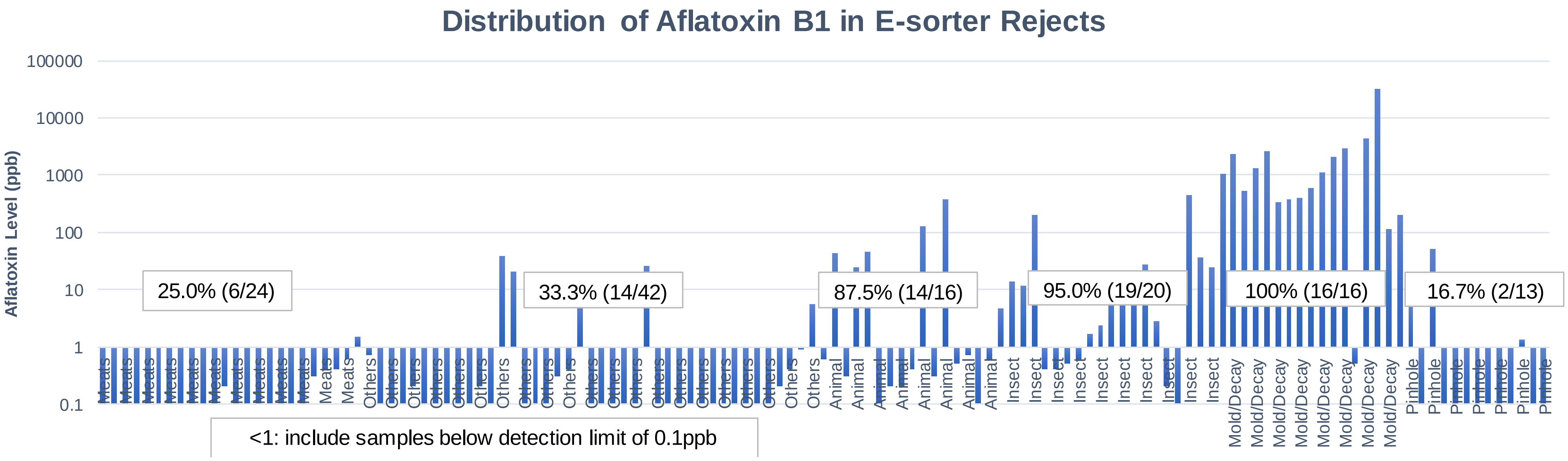
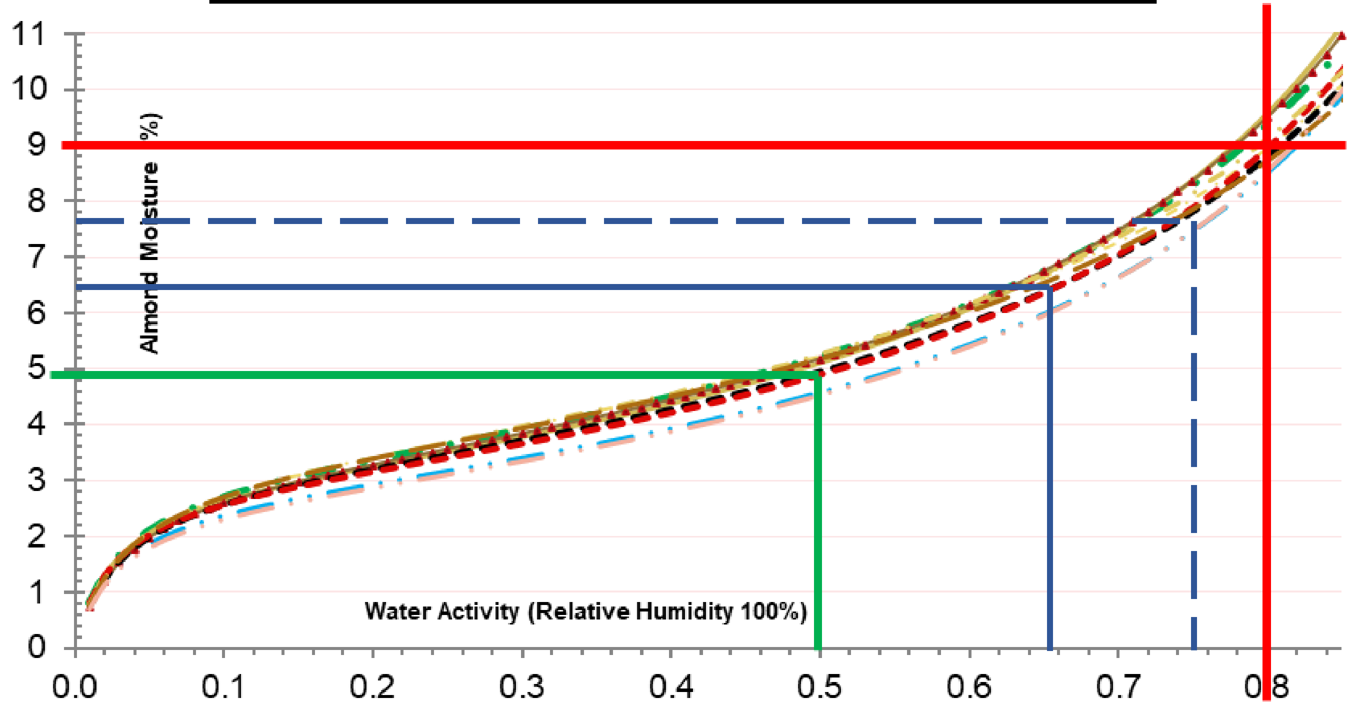


Post Harvest Aflatoxin Control – MOISTURE IS KEY!

Inhibitory Factors For Mold Growth and Aflatoxin Development

Almond Moisture Isotherm Curve; Dr. Ted Labuza, University of Minnesota



Previous Assumptions:

- Minimum aw required for growth of *A. flavus / A. parasiticus*: >0.80 aw
- Minimum aw required for aflatoxin production by *A. flavus*: >0.90 aw

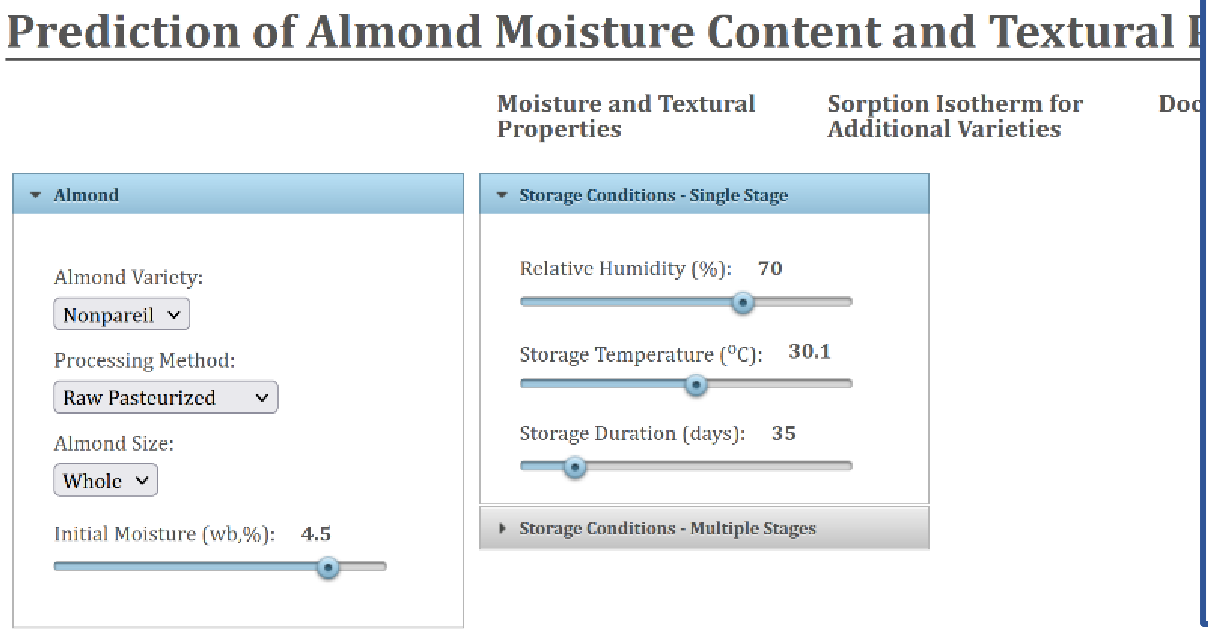
Gibson et al. Predicting fungal growth: the effect of water activity on Aspergillus flavus and related species. Int J Food Microbiol. 1994 Nov;23(3-4):419-31. doi: 10.1016/0168-1605(94)90167-8. PMID: 7873341)

Gallo et al. Effect of temperature and water activity on gene expression and aflatoxin biosynthesis in Aspergillus flavus on almond medium. Int J Food Microbiol. 2016 Jan 18;217:162-9. doi: 10.1016/j.ijfoodmicro.2015.10.026. Epub 2015 Oct 26. PMID: 26540623.)

Current Study on inshell, shelled and split almond Kernels – Dr. Dawit Gizachew; Purdue University Northwest: No A. flavus growth at 0.65 water activity after 90 days @ 20, 27 & 35°C; Additional work underway at 0.75 water activity

What Happens to Almond Moisture Over Time?

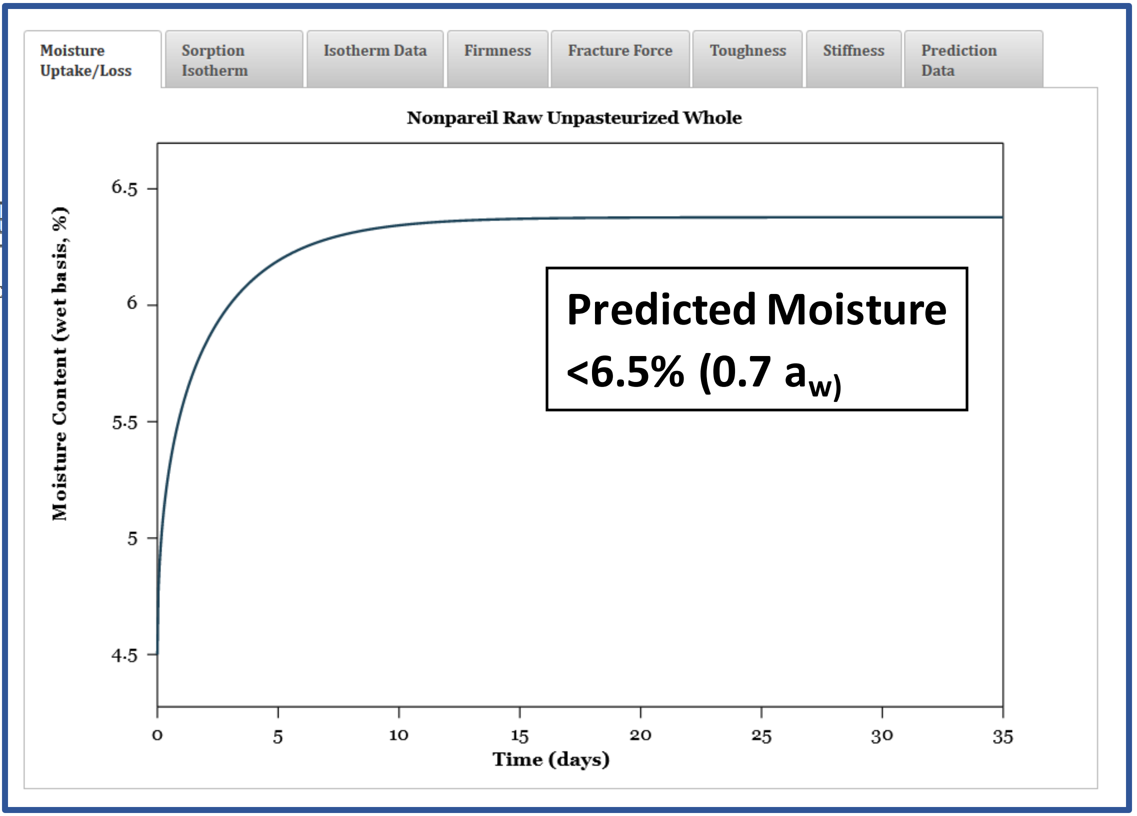
- Almond moisture will increase or decrease (to a certain point) given environmental conditions and type of packaging
  - Moisture Calculator Tool to predict moisture
  - https://www.almonds.com/almond-calculator/index.html



Example/Model Inputs

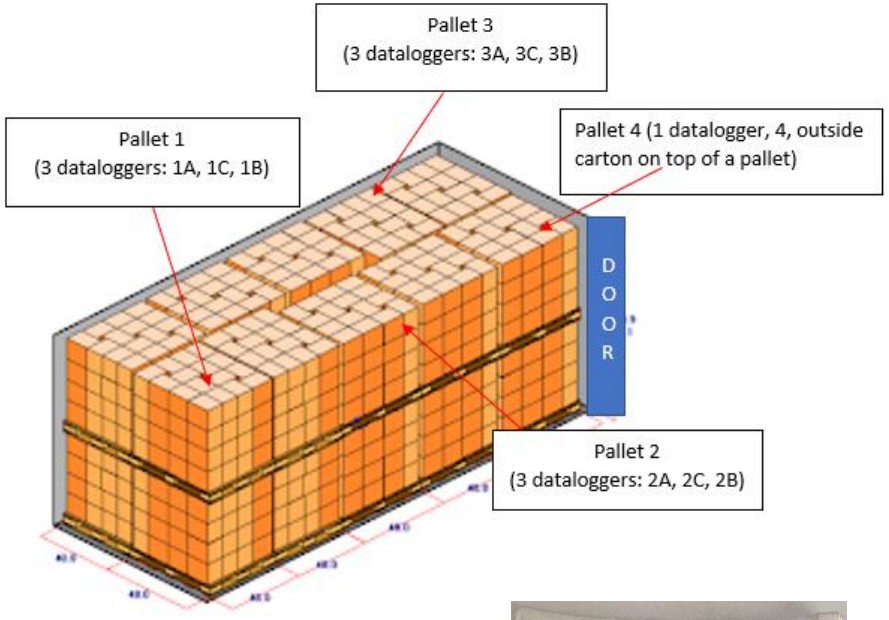
- **70% relative humidity exposure and storage**
- **Temperature of 30.1°C (86.2°F)**
- **Initial moisture content of 4.5%**

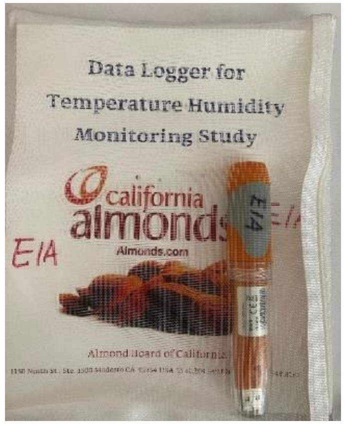
Note: Predicted >10 days to reach equilibrium moisture after constant exposure to 70% humidity at 30.1°C (86.2°F).



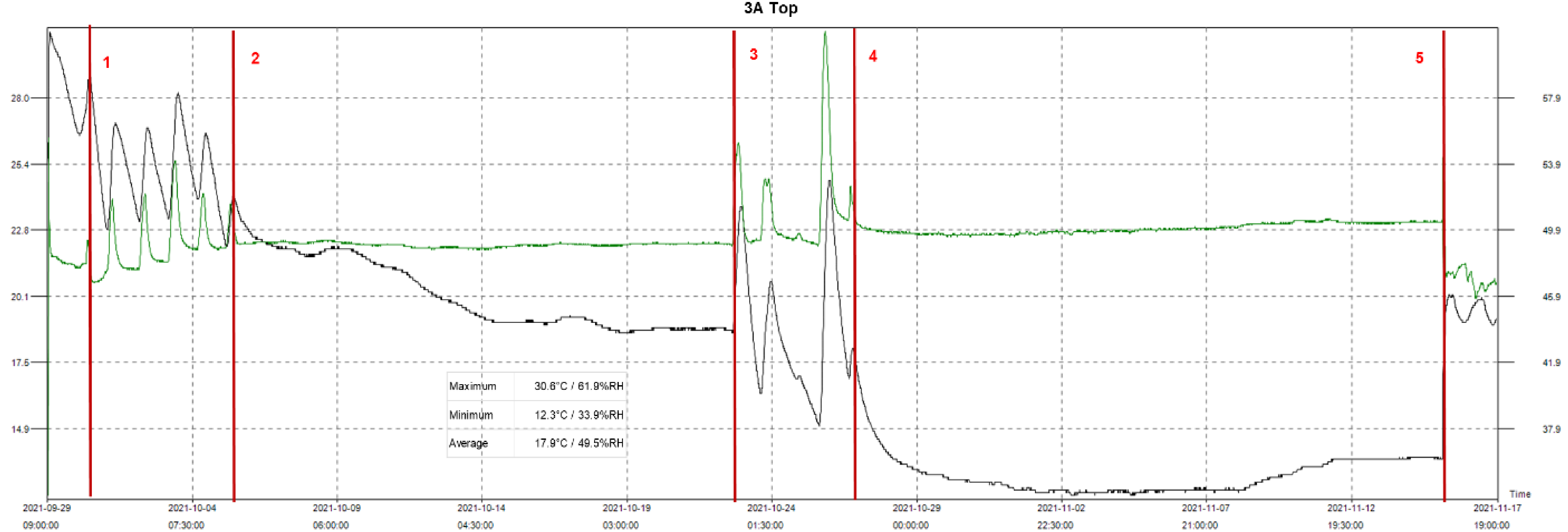
Transit Studies (Temperature and Humidty During Shipping

- Objectives – To gather data in order to demonstrate that shipping is not a concern for mold growth / aflatoxin development
- Studies Conducted
  - May/June 2022 ongoing**:** Oakland, CA to Rotterdam, The Netherlands (In and outside packages)
  - March-April 2022: Oakland, CA to Tokyo, Japan
  - September/October 2021: Oakland, CA to Tokyo, Japan
  - July-August 2021: Oakland, CA to Italy
  - April-June 2018: Long Beach, CA to Rotterdam, The Netherlands
  - May-June 2011: Oakland, CA to Rotterdam, The Netherlands



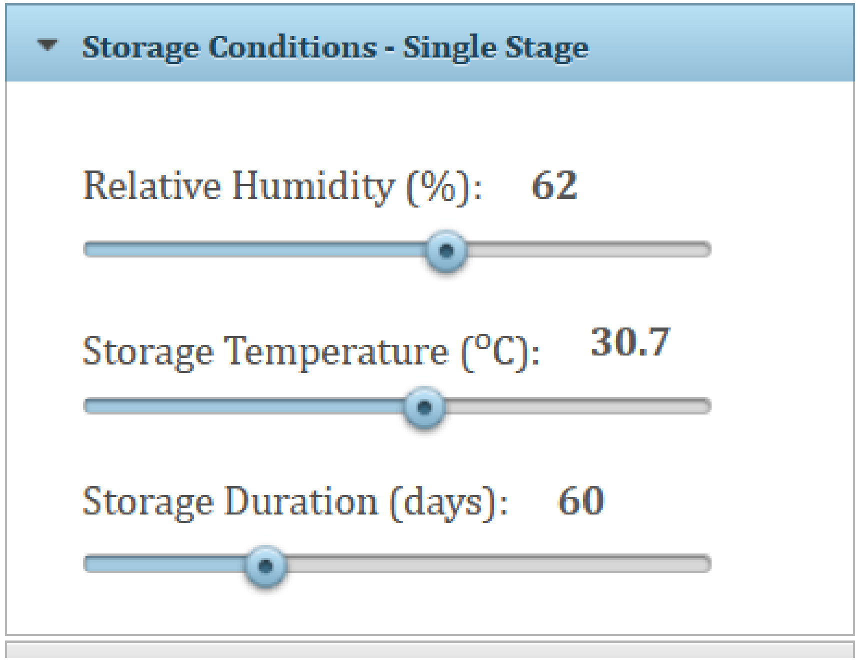


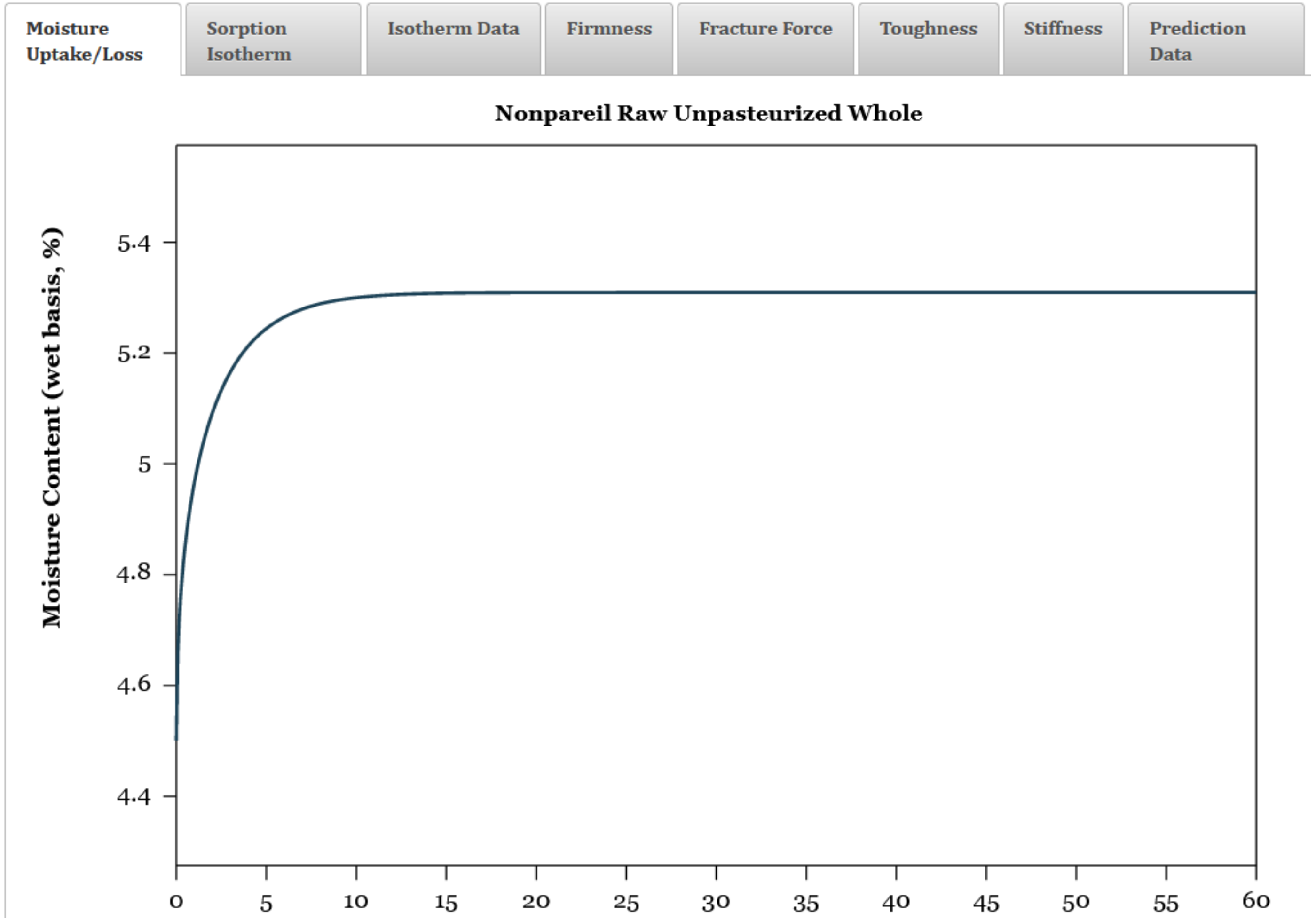
Oakland, CA – Tokyo, Japan – October 2021



Pallet #	Logger #	Logger Location	*2Max. Temp °F/ °C	Min. Temp °F/ °C	Avg. Temp °F/ °C	Max. % Relative Humidity	Min. % Relative Humidity	Avg. % Relative Humidity
3	3A	Inside end of carton/ top layer/ top pallet/ back container	87.1 / 30.6	54.1 / 12.3	64.2 / 17.9	61.9	33.9	49.5

Equilibrium Moisture Well Below that Required for Mold Growth and Aflatoxin Development





MOSH/MOAH in Almonds

GUANGWEI HUANG,

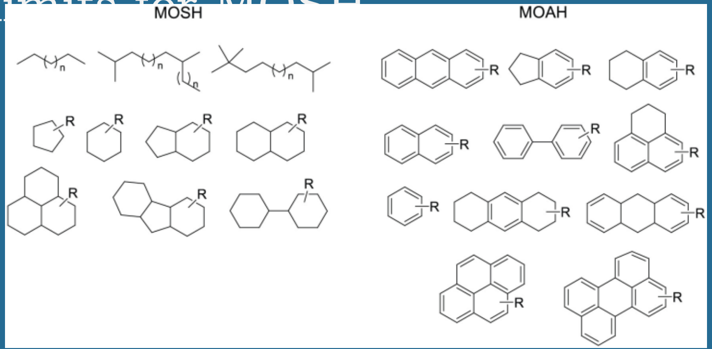
TAC 2023, DECEMBER 5, 2023

MOSH/MOAH Concerns in Europe

ANY CONCERNS FOR ALMONDS?

MOSH: mineral oil saturated hydrocarbons: linear and branched alkanes, and alkyl-substituted cyclo-alkanes

- EFSA assessment: MOSH do not pose a risk to public health at the current levels of exposure.
- No recommended limits for MOSH



MOAH: mineral oil aromatic hydrocarbons: alkyl-substituted polyaromatic hydrocarbons;

⩾ n-C10 to ⩽ n-C16, > n-C16 to ⩽ n-C25, > n-C25 to ⩽ n-C35, > n-C35 to ⩽ n-C50

- EFSA assessment: one type of MOAH may contain genotoxic substances.
- EFSA recommended limits for MOAH in all foods:
  - 0.5 mg/kg for dry foods with a low fat/oil content (⩽ 4% fat/oil)
  - 1 mg/kg for foods with a higher fat/oil content (> 4% fat/oil)
  - 2 mg/kg for fats/ oils (>50%)

Connecting the Dots 2023

MOSH/MOAH Survey for Almonds

Potential MOSH/MOAH Contamination Sources

- Environmental (soil contact)
- Processing line (lubricant),
- Packaging (ink from recycled cardboard carton)

ABC MOSH/MOAH Survey in 2018

- 3/25 samples >.5 ppm MOSH C16-C20 (parameter)

Current Survey Objective:

- To survey prevalence of MOSH/MOAH in almonds
- To understand contamination exposure sources of MOSH/MOAH

Sample Type and Source:

- Incoming shelled (sized or unsized): 60 samples in total with one from each of 60 orchards.
- Manufactured product forms: 30 manufactured form samples of any sliced, slivered, diced or flour, with one from each lot or production run.
- Packaged shelled almonds: 60 samples of any finished grades in total with each from a single packaged lot of 50lbs cardboard cartons.

2023

MOSH Detection in Finished Almond Products					
Finished Product Type	No of Postive Detection	No of Analytes Detected	Low Level (mg/kg)	High Level (mg/kg)
Bl Dc	2/2	4	0.61	1.63
Bl Fl	1/2	3	0	0.51
Bl Slc	5/7	4	0	2.01
Bl Slv	4/5	1	0	0.86
IS	0/4	0	0	0
Nat*	4/16	3	0	1.12

EU has limits on MOAH, but there is no MOSH.

- EU has no limits or concerns for MOSH
- Low levels of MOSH in almonds
- More prevalence in manufactured products or natural almonds from long-time stored cartons

- A total of 36 samples of finished product tested
- No sample detected of MOAH
- 16/36 detected of MOASH with 1 to 4 compounds
  - 12/16 blanched samples (diced, flour, sliced, slivered)
  - 0/4 inshell samples
  - 4/16 natural kernel samples: 3/6 from long stored (>1 year) cartons vs. 1/10 from short stored (2 months) cartons

Connecting the Dots 2023

Almond Oil

GUANGWEI HUANG

TAC2023, DECEMBER 5, 2023

Almond Oil, Why?

Problem

- Almond oil adulterated with other seed oils
- Low value of oil from recovered products, low demand
- Lack of differentiation of higher health composition of oil from defatting good quality kernels

Almond Oil Types

- Out of spec or upcycled byproducts: refined
- Byproduct from good quality almonds for high protein powder: pure, crude, virgin, cold press, specialty, refined…

Compositional Uniqueness by Type

- Levels of tocopherols (vitamin E), phytosterols and unsaturated fatty acids

International Standards

- Codex, US and European: on refined oil with focus on fatty acids & phytosterols
- Codex limits of tocopherols for refined oil too wide and low to value virgin/cold press oil

Almond Oil Taskforce

- Nine members with 1st meeting on November 21.

Almond Oil Taskforce Consensus and Recommendations

Consensus

- Produce a technical factsheet
- Create an insert for Technical Kit
- No need for new industry standard
- Allow the market to differentiate virgin or cold press from refined

Requests

- Research and promote benefits of almond oil
- Educate/market uses of almond oil

Considerations

- Labs including tocopherol levels would distinguish adulterated & refined from cold press/virgin

Almond Oil Processing and Type

QUALITY OF ALMOND OIL IS AFFECTED BY QUALITY OF FEEDSTOCKS, PROCESSING AND AGING OF OIL

Approach	Feedstock	Processing	Finished Products
Oil Extraction or Recovery →	Out of Spec Products and/or Upcycled Byproducts →	(Blanching) (Roasting) Grinding Pressing or Expelling (Filtering and/or Refining) →	Refined Oil + Pressed Cake
Defatting for High Protein Powder Specialty Oil →	Good Quality Kernels, Broken & Pieces →	(same processing steps as above) →	Crude Oil Virgin Oil Cold Press or Specialty Oil Refined Oil + Defatted Meal

Fatty Components in Almonds

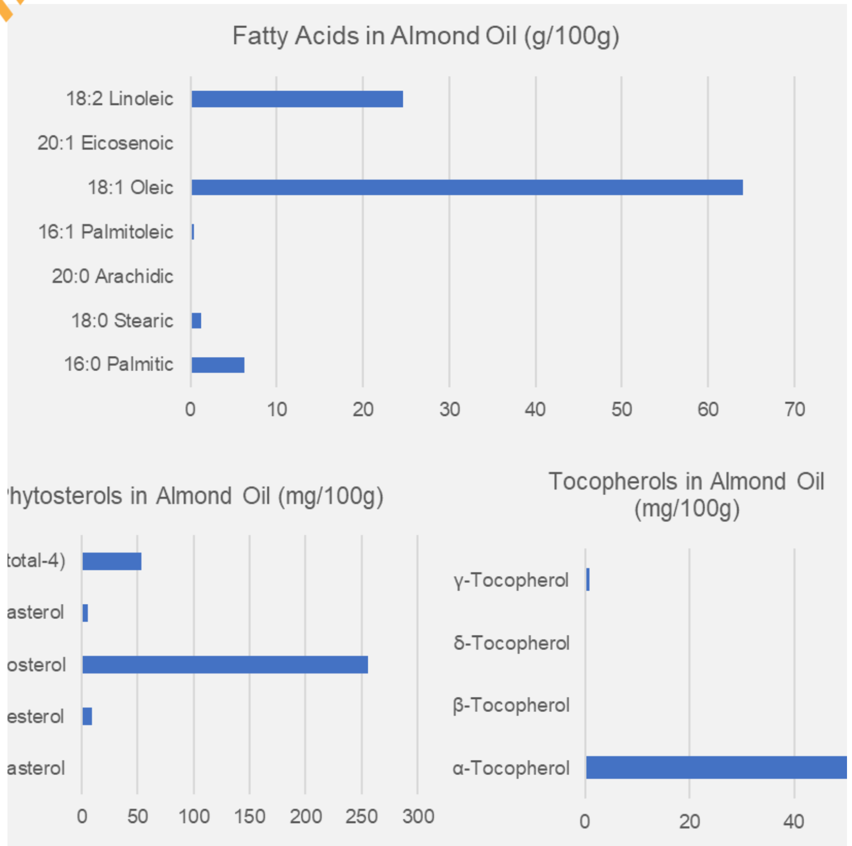
AN AVERAGE OF 48.1% FAT IN CA ALMONDS OF 15 PRIMARY VARIETIES, IN A RANGE OF 40.1-56.8%.

Major components in fatty acids:

- High: C18:1
- Moderate: C18:2, C16:0
- Low: C18:0
- Trace: C16:1, C18:3
- None or trace: C20:0, C22:0, C24:0, C20:1, C24:1

Minor and important components:

- Phytosterols: high in β-sitosterol, moderate in δ-5-avenasterol, low in campesterol and stigmasterol, none in brassicasterol
- Tocopherols: dominated by α-tocopherol, low in γ-tocopherol, trace in β-Tocopherol, none in δ-tocopherol



Unique Compositional Characteristics of Almond Oil

Almond oils are characterized as high in oleic acid, moderate in linoleic acid and palmitic acid, and low in stearic acid

The high percentages of β-sitosterol (average of 78.5%) and α-tocopherol (average of 97.3%) and the absence of brassicasterol, δ-tocopherol, and a few minor fatty acids (C22:0, C24:0, and C24:1) make almond oil distinct from other plant seed oils.

The percentages of individual components in terms of total fatty acids, sterols and tocopherols are good parameters to differentiate almond oil from other plant oils and blended or fortified oils.

The actual levels of α-tocopherol, total tocopherols, β-sitosterol, 5-δ-avenasterol and total phytosterols offer a clear indication of quality and aging of the oil and/or almond feedstock, and the authenticity of almond oil.

Almond Oil Standards

CODEX, US PHARMACOPEIA (USP) AND EUROPEAN PHARMACOPOEIA (EP) LIMITS

Comparison of Codex and Pharmacopeia Standard				
Analyte	**Codex (Refined Oil)**	**US Pharmacopeia (Refined Oil)**	**European Pharmacopoeia (Refined Oil)**	**European Pharmacopoeia (Virgin Oil)**
Fatty Acids	**% of Total Fatty Acids**			
<16:0	ND - 0.1	⩽0.1	⩽0.1	⩽0.1
16:0 Palmitic	4.0 - 9.0	4.0 - 9.0	4.0 - 9.0	4.0 - 9.0
17:0 Margaric	ND - 0.2	⩽0.2	⩽0.2	⩽0.2
18:0 Stearic	ND - 3.0	⩽3.0	⩽3.0	⩽3.0
20:0 Arachidic	ND - 0.5	⩽0.2	⩽0.2	⩽0.2
22:0 Behenic	ND - 0.2	⩽0.2	⩽0.2	⩽0.2
24:0 Lignoceric	ND - 0.2	⩽0.2	⩽0.2	⩽0.2
16:1 Palmitoleic	0.2 - 0.8	⩽0.8	⩽0.6	⩽0.6
17:1 Heptadecenoic	ND - 0.2	⩽0.2	--	
18:1 Oleic	62.0 - 76.0	62.0 - 76.0	62.0 - 86.0	62.0 - 86.0
20:1 Eicosenoic	ND - 0.3	⩽0.3	⩽0.3	⩽0.3
22:1 Erucic	ND - 0.1	⩽0.1	⩽0.1	⩽0.1
18:2 Linoleic	20.0 - 30.0	20.0 - 30.0	20.0 - 30.0	20.0 - 30.0
18:3 Alpha Linolenic	ND - 0.5	⩽0.4	⩽0.4	⩽0.4
Phytosterols	**% of Total Sterols**			
Cholesterol	ND - 1.0	⩽0.7	⩽0.7	⩽0.7
Brassicasterol	ND - 0.3	⩽0.3	⩽0.3	⩽0.3
Campesterol	2.0 - 5.0	⩽5.0	⩽5.0	⩽4.0
β-Sitosterol	73.0 - 86.0	73.0 - 87.0	73.0 - 87.0	73.0 - 87.0
Stigmasterol	0.4 - 4.0	⩽4.0	⩽4.0	⩽3.0
δ-5-Avenasterol	5.0 - 14.0	⩾5.0	⩾5.0	⩾10.0
δ-7-Avenasterol	ND - 6.0	⩽3.0	⩽3.0	⩽3.0
δ-7-Stigmastenol	ND - 3.0	⩽3.0	⩽3.0	⩽3.0
Others (all-7)	ND - 6.0	--	--	--
Totoal sterols (mg/100g)	159.0 - 459.0	--	--	--
Tocopherols	**mg/100g**			
α-Tocopherol	2.0 - 54.5	--	--	--
β-Tocopherol	ND - 1.0	--	--	--
δ-Tocopherol	ND - 0.5	--	--	--
γ-Tocopherol	ND - 10.4	--	--	--
Total Tocopherols	2.0 - 60.0	--	--	--
ND - Non-detectable				

- Codex, USP and EP standards focus on fatty acids and phytosterols with limits by respective percentage, and do not include oil-based limits.
- Codex standards do include oil-based limits for total sterols and tocopherols, but its lower limits for α-tocopherol and total tocopherols are quite low.
- Codex and USP composition standards: refined oil only.
- Codex use quality parameters (minerals, acid value and PV) to differentiate refined from virgin oil.
- EP composition standards: refined and virgin oil, with only difference in lower campetsterol and stigmasterol, and higher 5-δ-avenasterol for virgin oil.

Connecting the Dots 2023

Composition of Oil from California Almonds

- PROFILING OF FATTY ACIDS, PHYTOSTEROLS AND TOCOPHEROLS OFFERS A RELIABLE TOOL.
- PERCENTAGE OF INDIVIDUAL COMPONENT IN TOTAL FATTY ACIDS, TOTAL STEROLS OR TOTAL TOCOPHEROLS GOOD FOR ALMOND OIL AUTHENTICATION.
- ACTUAL MEASURED LEVELS OF INDIVIDUAL COMPONENT IN FATTY ACIDS, PHYTOSTEROLS AND TOCOPHEROLS IN 1/100G OR 1/KG OIL GOOD FOR ALMOND OIL QUALITY VERIFICATION.

California Almond Oil Composition versus Codex Standard

Analyte	Codex Limits	Reported Range	Codex Limits	Reported Range
Fatty Acids	**% of Total Fatty Acids**		**g/100g Oil**	
Saturated Fatty Acids	--	6.6 - 9.0	--	6.2 - 8.8
16:0 Palmitic	4.0 - 9.0	5.6 - 7.3	--	5.5 - 7.2
18:0 Stearic	ND - 3.0	1.0 - 2.3	--	0.9 - 2.2
20:0 Arachidic	ND - 0.5	ND - 0.1	--	ND - 0.1
22:0 Behenic	ND - 0.2	ND - 0.1	--	ND
24:0 Lignoceric	ND - 0.2	ND - 0.1	--	ND
Monounsaturated Fatty Acids	--	56.6 - 72.4	--	54.1 - 71.1
16:1 Palmitoleic	0.2 - 0.8	0.2 - 0.7	--	0.2 - 0.7
18:1 Oleic	62.0 - 76.0	57.0 - 73.4	--	54.8 - 72.3
20:1 Eicosenoic	ND - 0.3	ND - 0.2	--	ND - 0.1
Polyunsaturated Fatty Acids	--	16.6 - 30.9	--	16.3 - 30.3
18:2 Linoleic	20.0 - 30.0	17.3 - 32.4	--	17 - 31.8
18:3 Linolenic	ND - 0.5	ND - 0.3	--	ND - 0.3
Phytosterols	**% of Phytosterols**		**mg/100g Oil**	
Cholesterol	ND - 1.0	ND - 0.6	--	ND
Brassicasterol	ND - 0.3	ND - 0.3	--	ND
Campesterol	2.0 - 5.0	0.8 - 5.0	--	6.8 - 12.9
β-Sitosterol	73.0 - 86.0	69.8 - 83.2	--	197.3 - 323.8
Stigmasterol	0.4 - 4.0	0.4 - 4.5	--	2.2 - 11.4
δ-5-Avenasterol	5.0 - 14.0	5.6 - 12.2	--	--
δ-7-Avenasterol	ND - 6.0	0.6 - 2.2	--	--
δ-7-Stigmastenol	ND - 3.0	0.8 - 2.0	--	--
Others (total-7)	ND - 6.0	3.6 - 8.5	--	--
Other Sterols/Stanols (total-4)	--	12.7 - 26.0	--	33.6 - 90.3
Total Sterols	--	--	159.0 - 459.0	239.0 - 403.2
Tocopherols	**% of Total Tocopherols**		**mg/100g Oil**	
α-Tocopherol	--	94.6 - 100	2.0 - 54.5	30.1 - 73.4
β-Tocopherol	--	ND - 2.0	ND - 1.0	0 - 0.7
δ-Tocopherol	--	ND	ND - 0.5	ND
γ-Tocopherol	--	ND - 4.4	ND - 10.4	0 - 2.6
Total Tocopherols	--	--	2.0 - 60.0	31.4 - 76.2
ND - Non-dectectable				

Purdue University IRB-2023-1081

Research Participants Needed

Evaluation and Development of Food Safety Materials for Almond Stakeholders

Research Purpose:

We want to learn about your experiences in training your employees about food safety, and your suggestions for future food safety training materials for almond stakeholders.

Research Outcomes:

- Identify the gaps and needs in current food safety training for almond stakeholders
- Develop a strategic plan for developing and improving food safety training materials

Research Approach:

One-on-one virtual interview (up to 1 hour)

Who is eligible?

- Food safety managers/supervisors in the almond processing company
- Job responsibilities involve managing other employees

Interested?
Scan the QR code, or contact Han Chen at chen2401@purdue.edu to sign up:

As a token of thank you for your time and contribution, you will receive a $50 e-gift card after completing the interview.

All your information will be kept confidential!

If you have any questions, please feel free to contact Han Chen at chen2401@purdue.edu, or the project principal investigator, Dr. Betty Feng at yfengchi@purdue.edu.


california almonds
Almond Board of California
Thank you