Considerations for Limiting and Preventing Microbial Contamination in Whole Grain Cereal Based Products

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Why Worry About Safety?

- ✓ Foodborne diseases/outbreaks
  - ❖ Worldwide over 1 billion cases occur per year
  - ❖ Over 5 million children die each year from foodborne diseases
  - ❖ In the US 9.4 million cases are estimated to occur annually
- ✓ Economic losses associated with contaminated product:
  - ❖ Production Losses
  - ❖ Product Recall
  - ❖ Product Liability
  - ❖ Loss of Business
- ✓ **It is the right thing to do!**

Wheat Flour: A Food Safety Risk Factor?

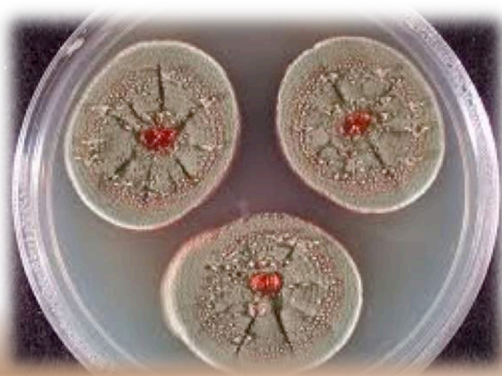
Historically: Flour and grain based products have always been considered a safe product, regarding pathogens!

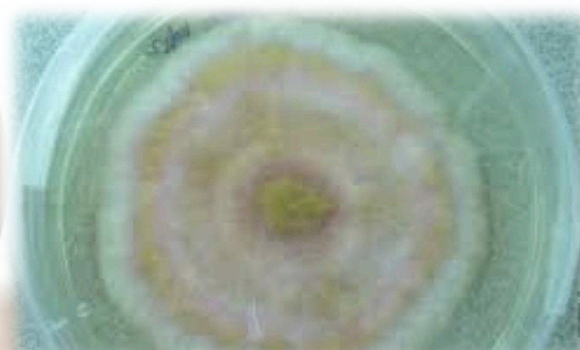
More recently, however…

- ✓ Foodborne outbreaks associated with flour:
  - ❖ 2005 - United States (***Salmonella***)
  - ❖ 2008 - South Island of New Zealand (***Salmonella***)
  - ❖ 2009 - United States (***Escherichia coli* O157:H7**)

Mycotoxins of Greatest Concern in Grains

Mycotoxins	Molds
Aflatoxins	*Aspergillus flavus, A. parasiticus, A. nomius*
Ochratoxin	*Aspergillus ochraceus, A. niger* *Penicillium verrucosum*
Fumonisins	*Fusarium verticillioides (moniliforme)* *F. proliferatum, F. subglutinans*
Deoxynivalenol (DON, Vomitoxin)	*Fusarium graminearum, F. culmorum* *F. pseudograminearum*
Zearalenone	*Fusarium graminearum, F. culmorum* *F. crookwellense*

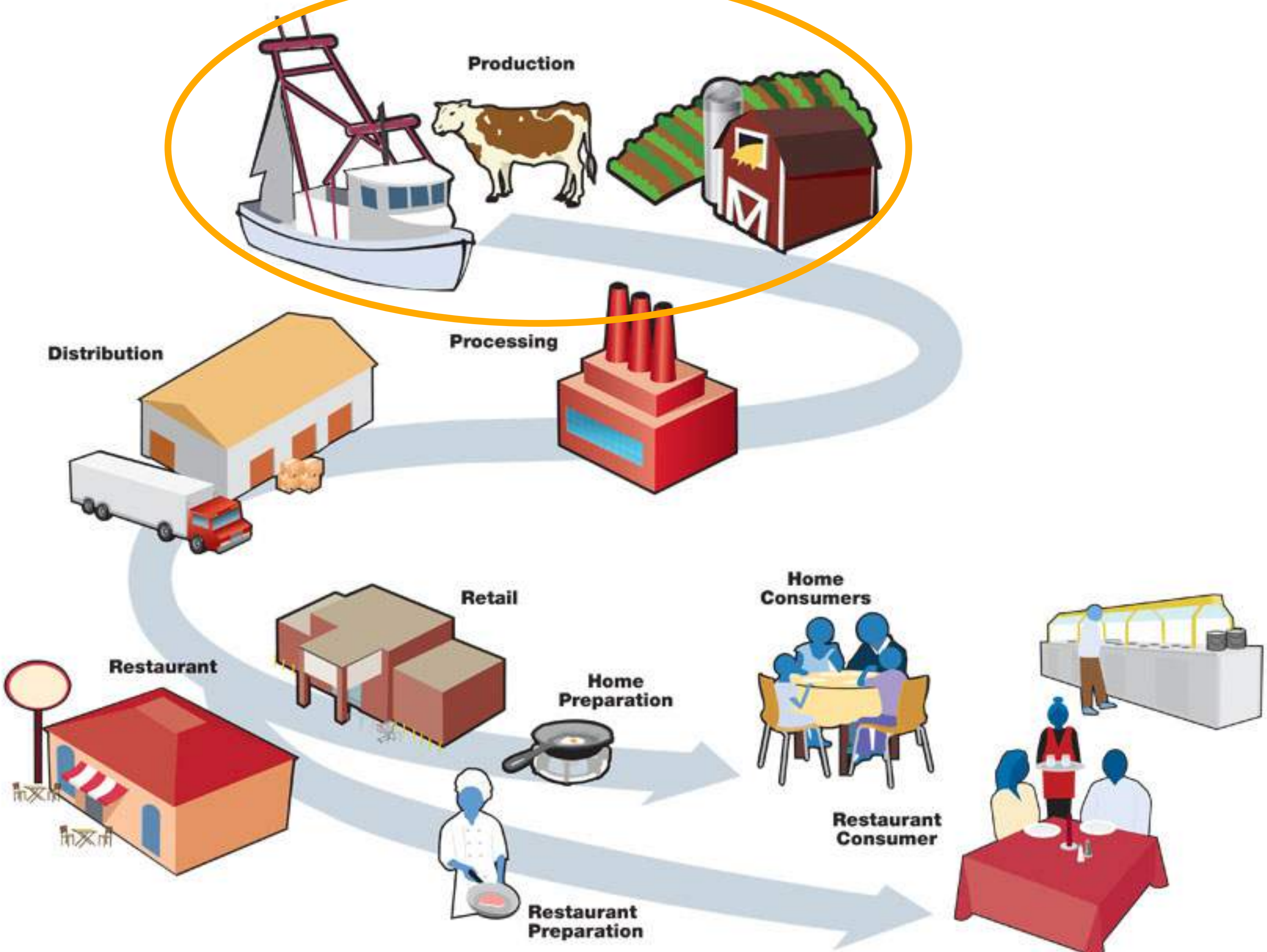




Challenges for the Grain Industry

- Microbiological quality of wheat grains
- Microbiological quality of milling-end products
- Trends in grain based foods
- Trends in grain processing
- Consumer eating habits

The Food Production Chain



Microbiological Quality and Safety of Grains

Raw agricultural commodities:

- ✓ Subject to contamination from the environment
- ✓ **Broad diversity of microbial contaminants**

Microbial Test	Standard*	Flour**
Aerobic plate count	$<10^5$	1.1×10^5
Enterobacteriaceae/ Coliforms	<100	150
E. coli (total)	<100	12.8% positive
Salmonella	Not detected in 25g	1.3% positive

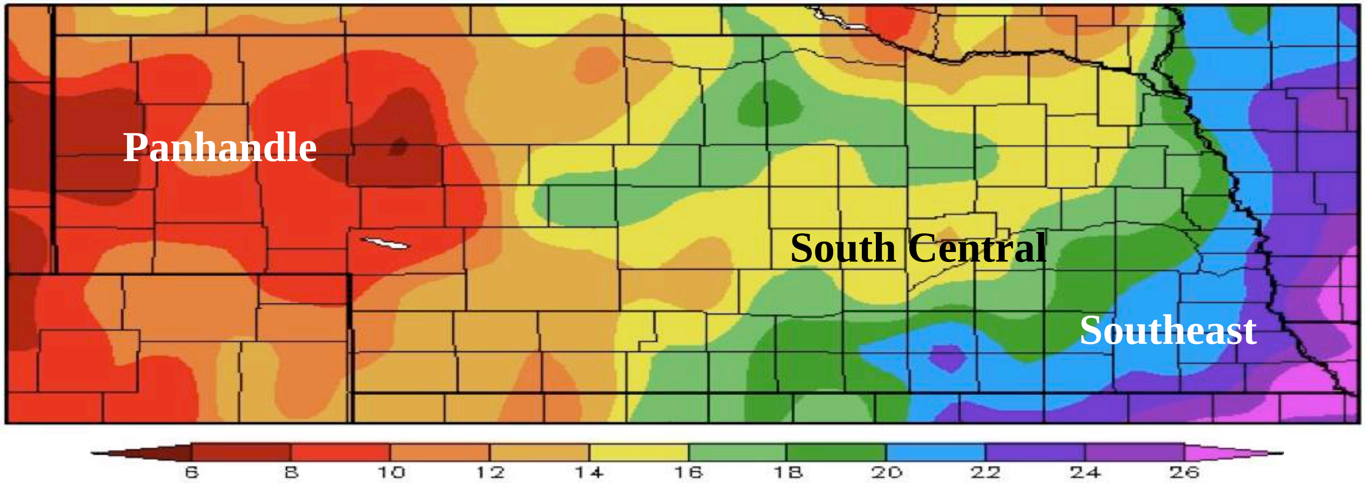
*Ready-to-eat standards for pasta, pizza, meals, tarts, pies, cakes & pastries without dairy cream at the point of sale in UK

**Data from 4,000 wheat flour samples from the US in 1993

Microbiological Quality and Safety of Grains

Fluctuation in microbial populations

- ✓ Production practices, **meteorological conditions** and method of harvesting



2011- 2012 growing season precipitation for Nebraska
Source: USDA NASS Nebraska Field Office

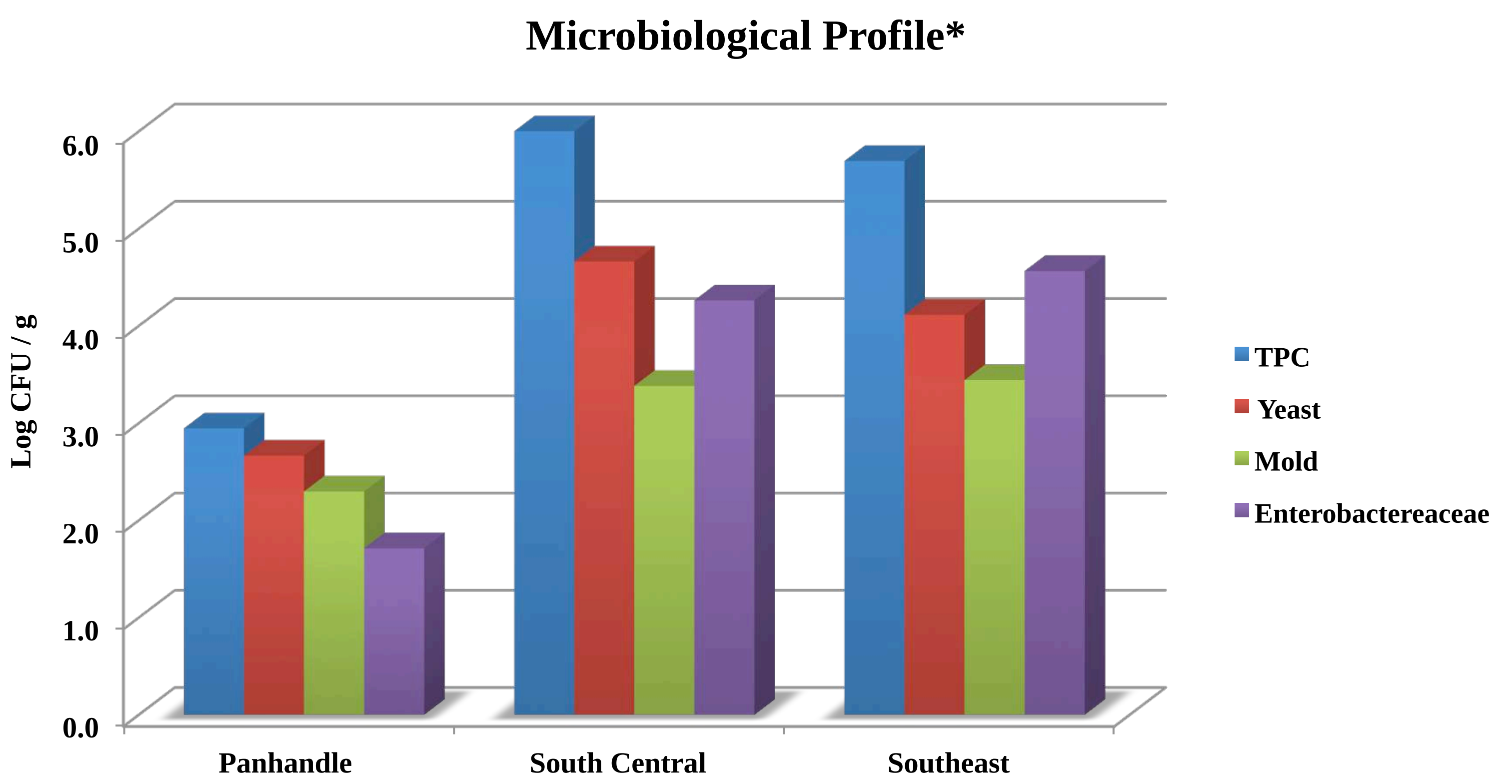
	Districts		
Weather Related Data	**Panhandle**	**South Central**	**Southeast**
Precipitation*	8.96''	15.90''	18.96''
Temperature*	70.2 °F	70.5 °F	65.7 °F

*Average precipitation and temperature during the growing season

Microbiological Quality and Safety of Grains

Fluctuation in microbial populations

- ✓ Production practices, **meteorological conditions** and method of harvesting



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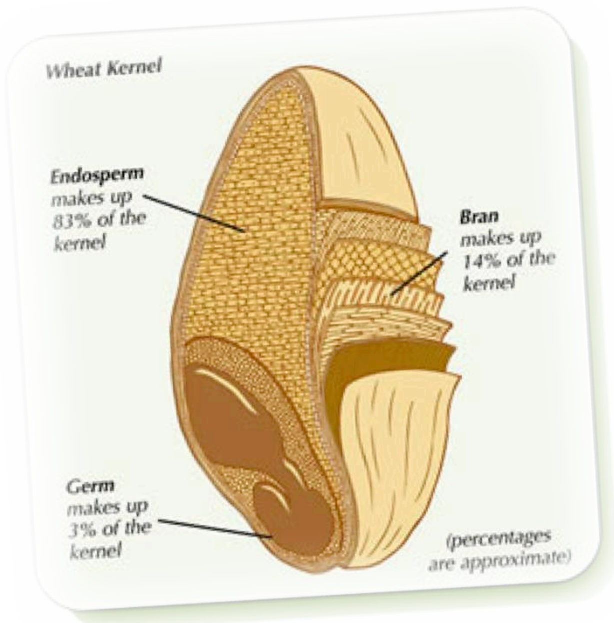
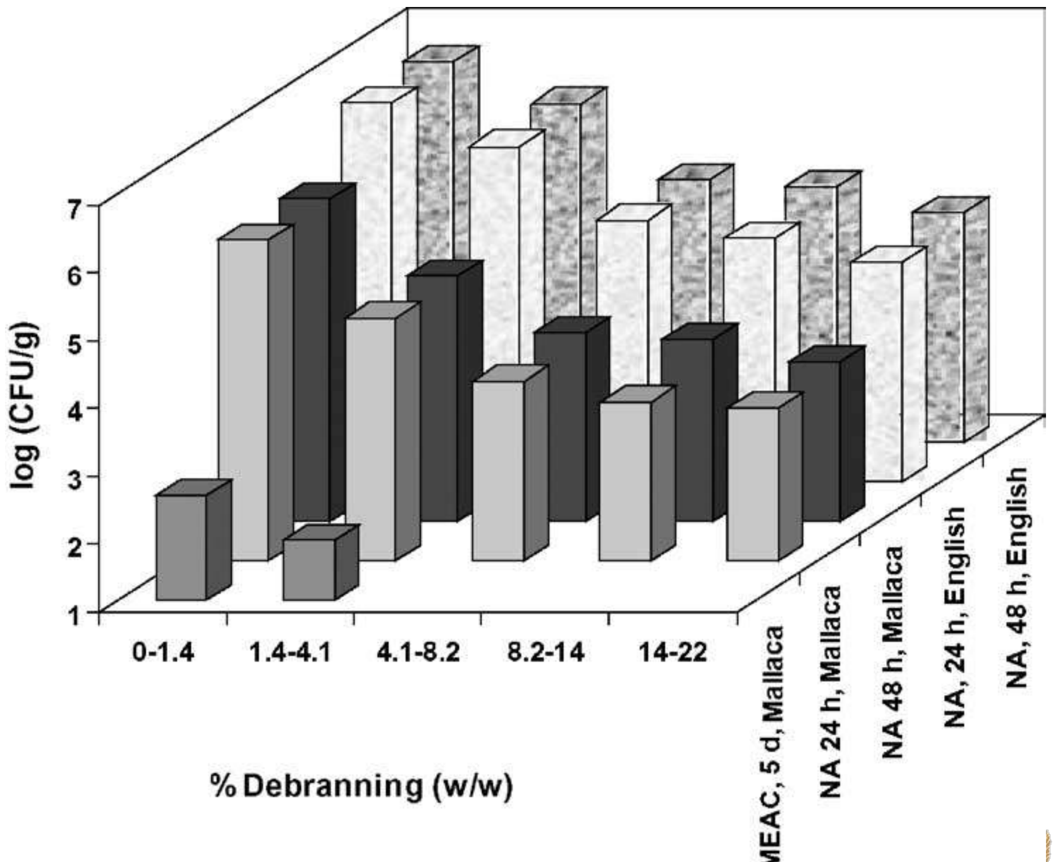
Microbiological Quality and Safety of Grains

The majority of the microorganisms are **concentrated** towards the surface of the kernel

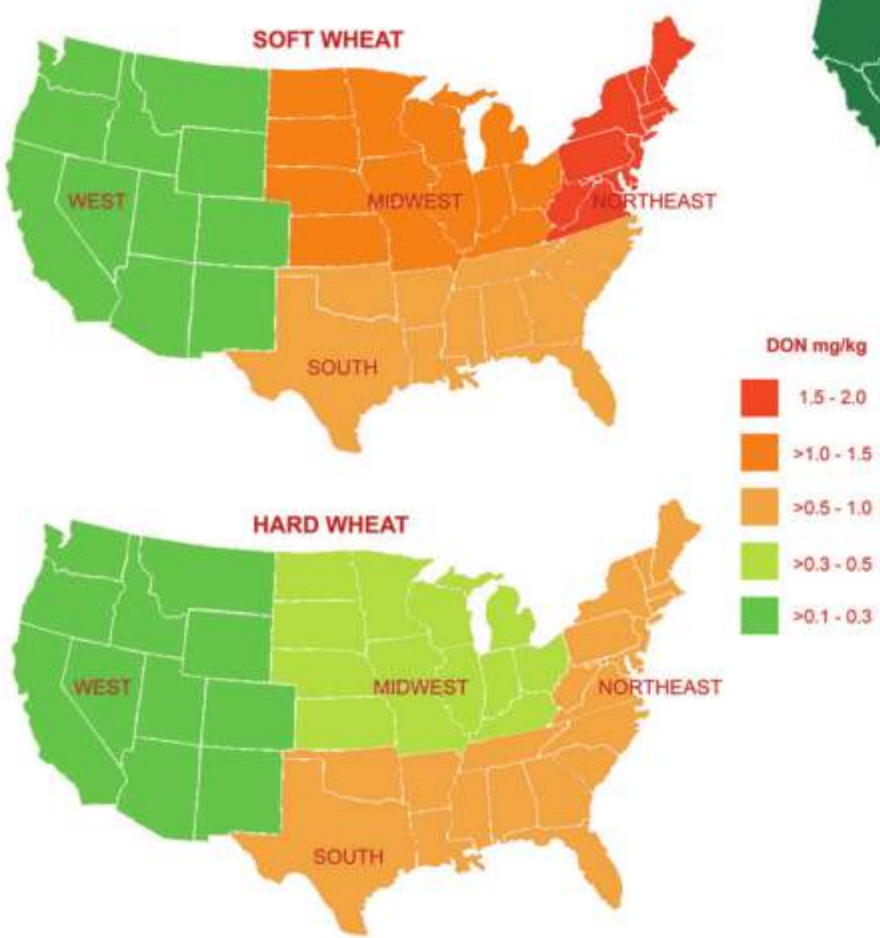
- ✓ Some species can occupy the inner part of the kernel





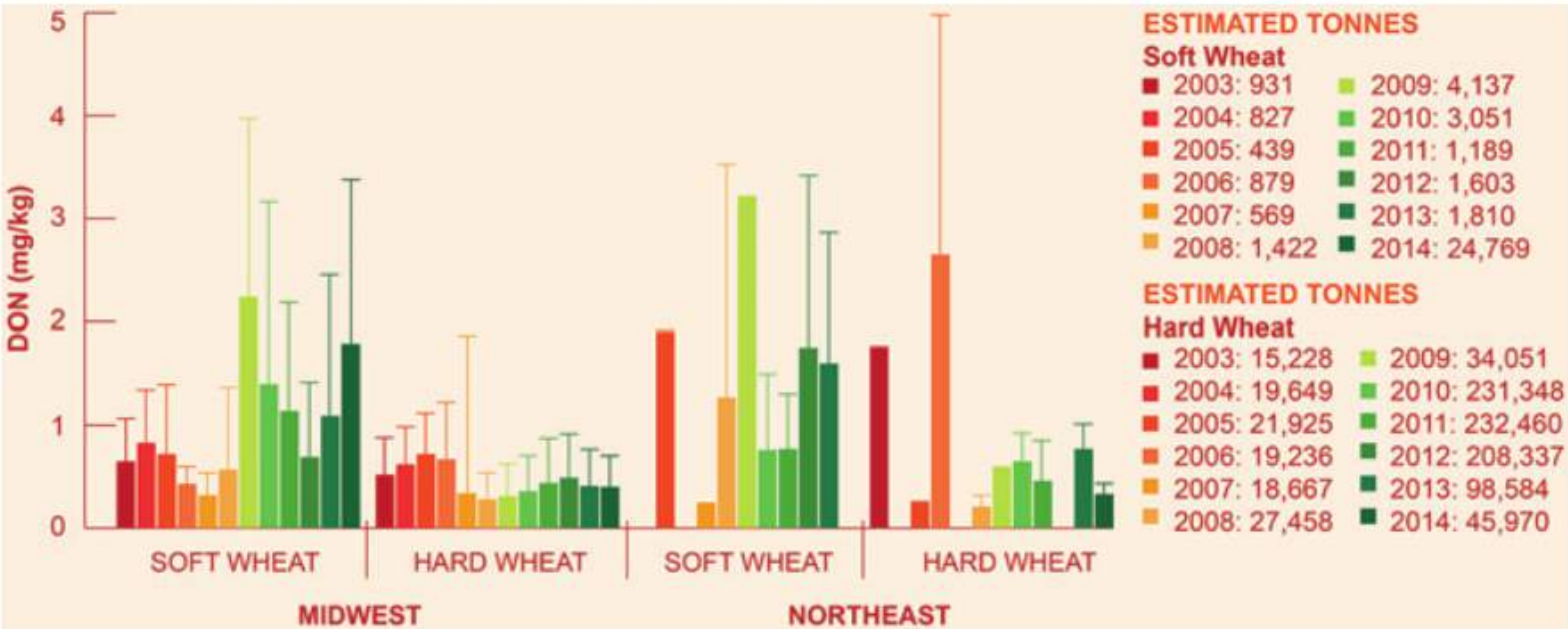
Laca et al., 2006 – Distribution of microbial contamination within cereal grains.

Microbiological Quality and Safety of Grains



Bianchini et al., 2015.
DON Occurrence in Grains:
A North American Perspective.

Microbiological Quality and Safety of Grains



Bianchini et al., 2015. DON Occurrence in Grains:
A North American Perspective.

Control Measures

- ✓ Trend/Surveillance data
- ✓ Analysis of incoming grain or "Supplier Approval Program"
- ✓ Awareness of the current weather issues ***locally*** and ***globally***

Informed decision about where to source grain in a global market.

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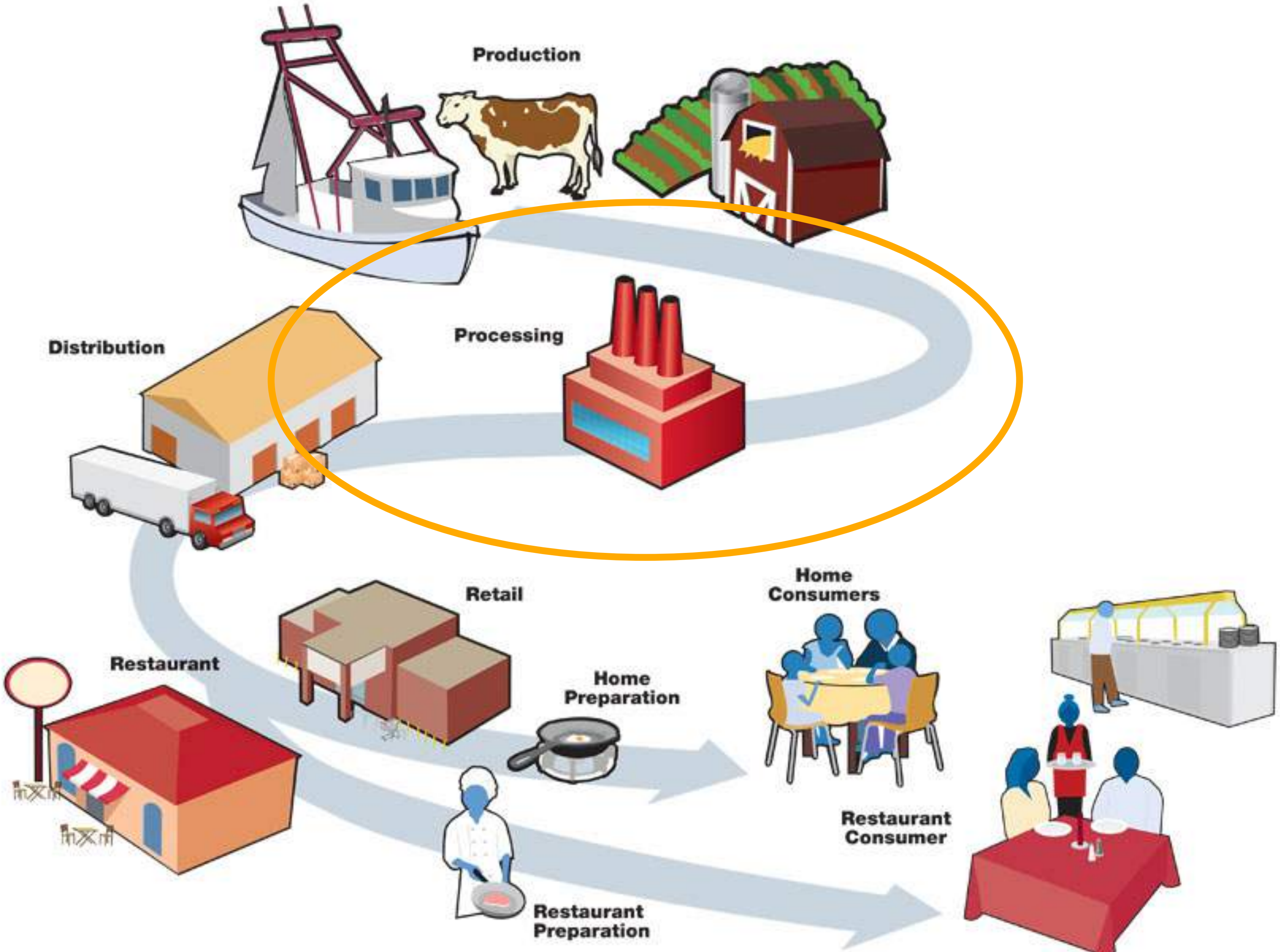


Cleaning

Cleaning

APCs (log CFU/g) in durum wheat samples (2001 crop season):

District	Dirty [a]	Clean [b]
Montana	7.2	6.1
NW North Dakota	8.4	8.6
NC North Dakota	8.5	8.2
NE North Dakota	8.4	8.3
SW North Dakota	8.2	5.3
SE North Dakota	8.4	6.9
Region [c]	8.2 ± 1.3	7.2 ± 0.5

[a] Sample as collected.

[b] Seived grain.

[c] Average of 6 district values ± standard deviation.

Manthey et al., 2004.

Cleaning

Effect on mycotoxins:

- ✓ Remove moldy kernels, broken kernels, and fine materials
- ✓ Remove scab infested wheat and barley: ↓ DON 5.5 – 19%
- ✓ In corn: ↓ Fumonisin by 26-69%
- ✓ Moldy kernel, seed or nut:
  ↓ Aflatoxin (40-80%)

Cleaning

COUNTRY	COMMODITY	INITIAL DON CONCENTRATION (mg/kg)	REDUCTION AFTER CLEANING (%)	CLEANING	REFERENCE
ITALY	Durum wheat	0.4 -13.1	1 - 31%	Rationel Kornser vice Mod. M220V sifter (equipped with an aspiration system and two sieves)	Visconti *et al* 2004 (138)
USA	Soft red winter wheat	0.6 - 20	average 51%	Carter Day dockage tester	Delwiche *et al* 2005 (139)
CZECH REPUBLIC	Wheat	0.09 - 3.0	45 - 59%	Sieving, scouring and polishing (the laboratory aspirator of dust particles Labofix Brabender)	Lancova *et al* 2008 (140)
UNITED KINGDOM	Wheat	0.01 - 0.32	- 8* - 78% (average 48%)	Separator/ classifier (sieving) with aspiration	Scudamore and Patel 2008 (141)

* Represents an increase

Bianchini et al., 2015. DON Occurrence in Grains: A North American Perspective.

Washing

Microbial load in durum wheat after different washing treatments:

Treatment	Bacteria (log CFU/g)	Fungi (log CFU/g)
Dry Grain (Control)	4.3a	4.9a
Distilled Water Wash	4.2a	4.9a
Ozonated Water Wash (16.5 mg ozone/L)	3.8b	4.7a
Chlorinated Water Wash (700 mg/L)	2.4c	4.5a
Acetic acid (1%) Wash	0.5d	1.9b
Acetic Acid (1%) and Ozonated Water (20.5 mg/L) Wash	0.2e	1.7b

Dhillon, et al., 2009.

Tempering

Tempering

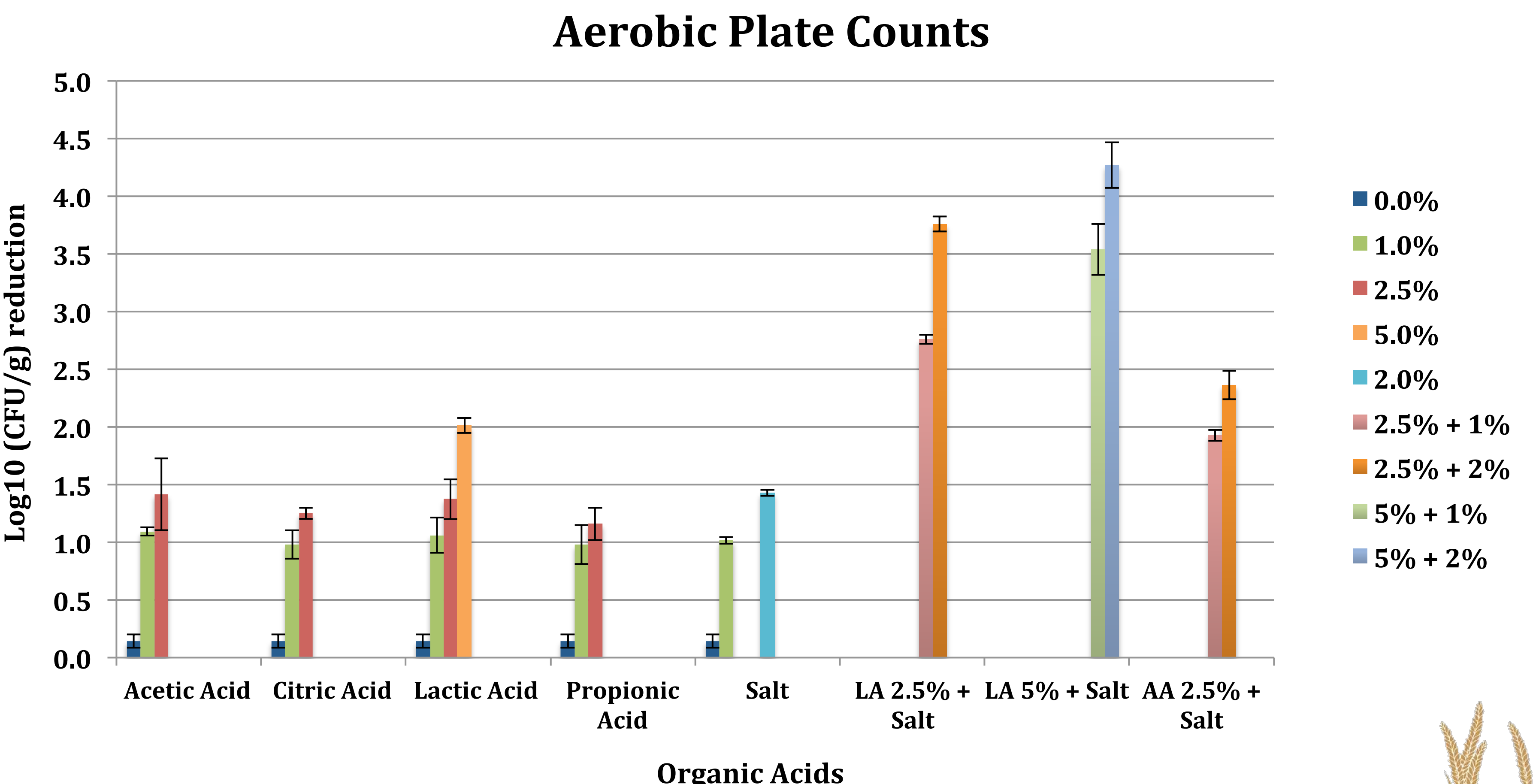
Effect of ozone during wheat tempering:

	Flour obtained from soft wheat (Adiyaman Beyaz)		Flour obtained from hard wheat (Arjantin)	
	Bacteria (log CFU/g)	Fungi (log CFU/g)	Bacteria (log CFU/g)	Fungi (log CFU/g)
No Treatment	4.6	3.5	5.5	4.1
Water	4.0	3.5	5.1	4.0
Ozonated Water 1.5 mg ozone/L	3.4	3.0	4.7	3.7
Ozonated Water 11.5 mg ozone/L	2.5	2.4	4.0	3.1

Ibanoglu, 2001.

Tempering

Effect of organic acids and salt solutions during hard wheat tempering:



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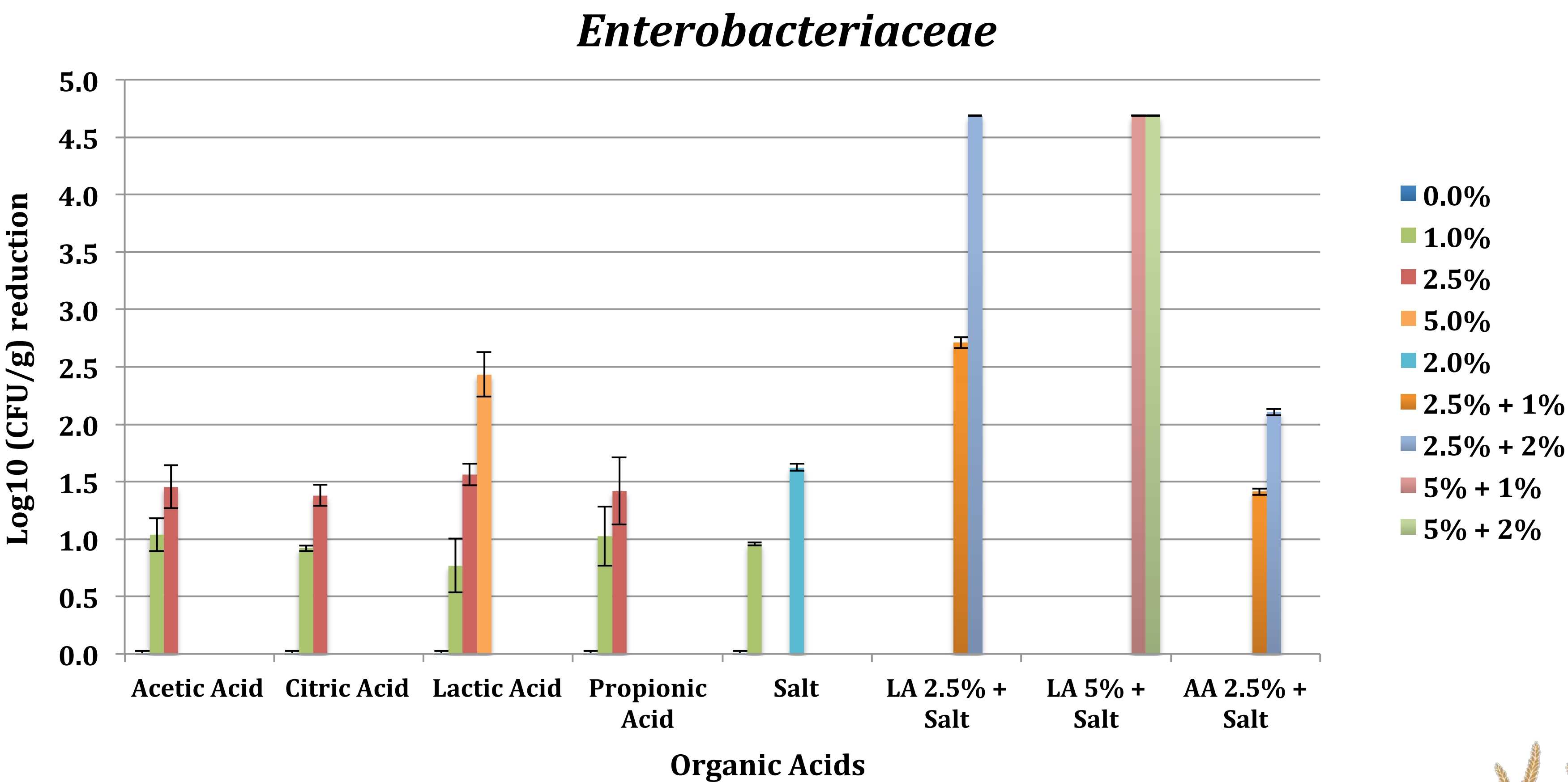
Tempering

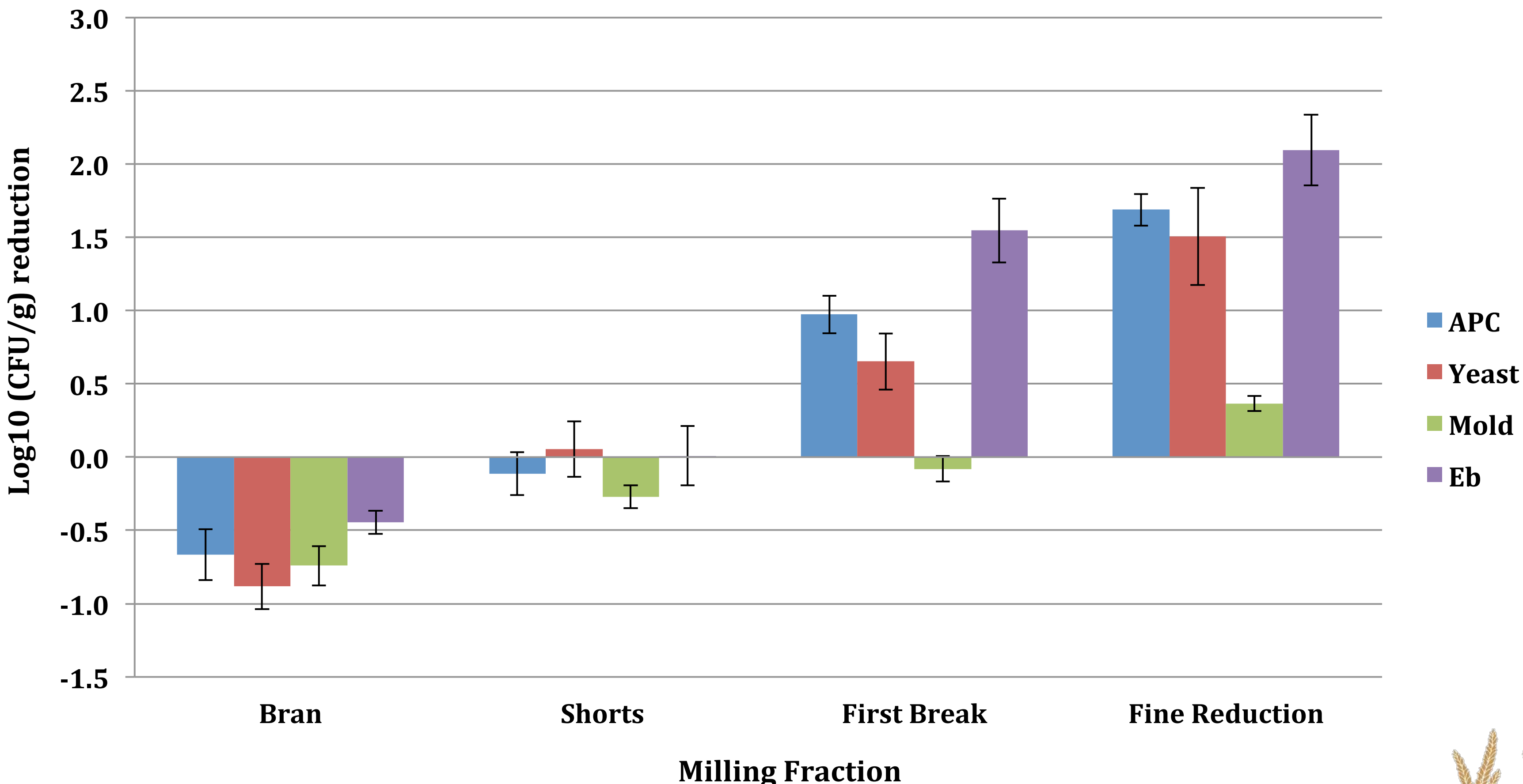
Effect of organic acids and salt solutions during hard wheat tempering:



Milling

Dry Milling

Microbial distribution during milling of hard wheat:



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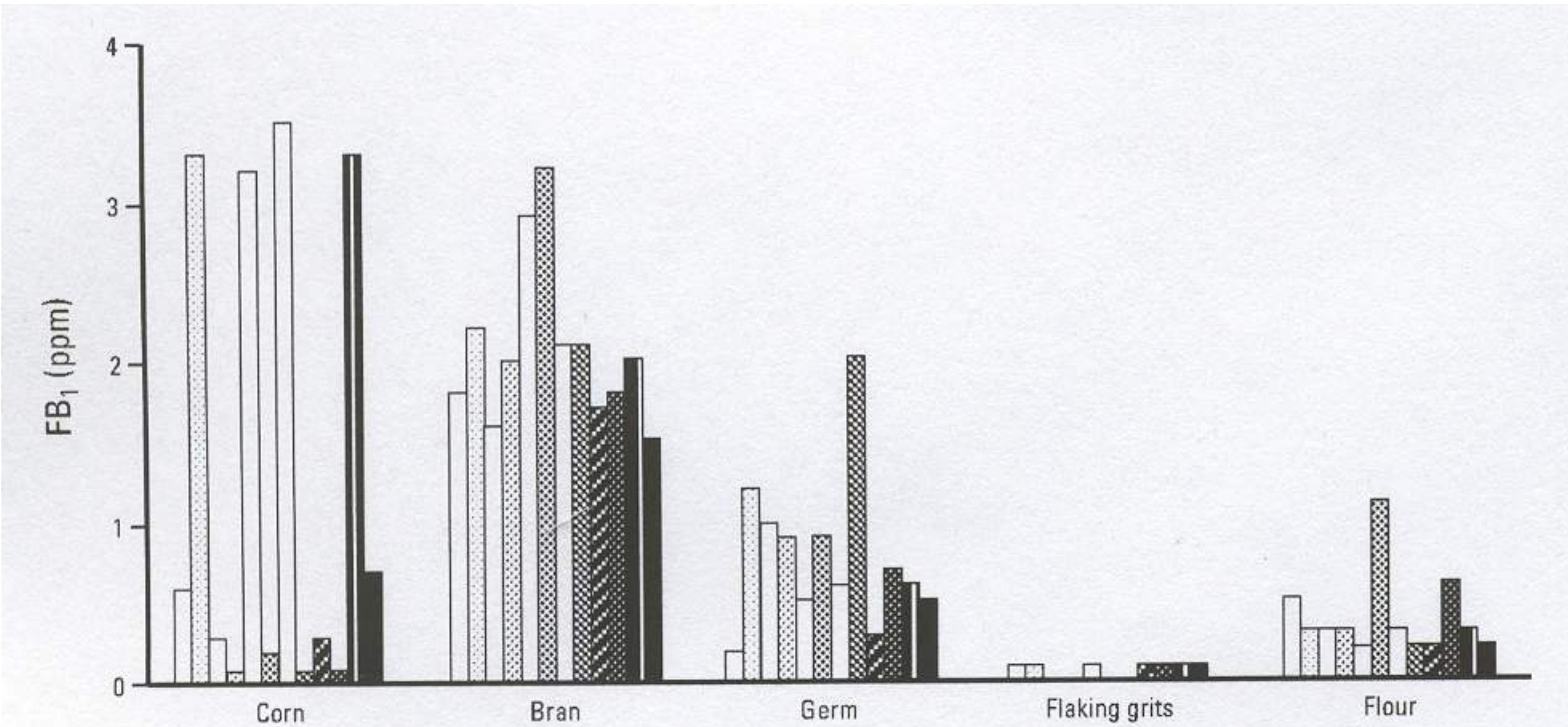
Dry Milling



FB_1 content in corn and milled fractions. Each bar represents a sample of corn and various fractions from consecutive weeks
(Katta *et al.*, 1997)

Dry Milling

Wheat, barley, rice and other cereals:

DON

Zearalenone

Aflatoxin

Ochratoxin A

Bran fraction

Germ

Wet Milling

Distribution of Fumonisins in Different Fractions of Wet Milled Yellow Corn

Fraction	FB_1 (ppm)	FB_2 (ppm)
Fiber	4.2	2.6
Germ	2.2	1.1
Gluten	5.4	4.8
Starch	<0.1	<0.1
Steep Water	1.2	2.5
Process Water	<0.1	<0.1

Modified from Bennett *et al.* 1996

Wet Milling

Aflatoxins	→	Steep water
Zearalenone		Gluten fiber
Fumonisins		Germ

Starch: Relatively free of mycotoxins

After Milling

After Milling

Reduction of microbial load in wheat flour by heating:

#	Sample	Standard Plate Count (CFU/gm)	Coliform Count (CFU/gm)	Yeast Count (CFU/gm)	Mold Count (CFU/gm)
		Microbiological analysis of flour			
1	Control flour	2700	30	200	150
2	Heat-treated flour	120	<10	<10	10

	Crust (% moisture)	Crumb (% moisture)
Bread made from treated flour	18.8%	42.6%
Bread made from untreated flour	16.5%	39.7%

Upreti et al., 2010 – Patent Application – Heat-treated flour.
US 2010/0092639 A1.

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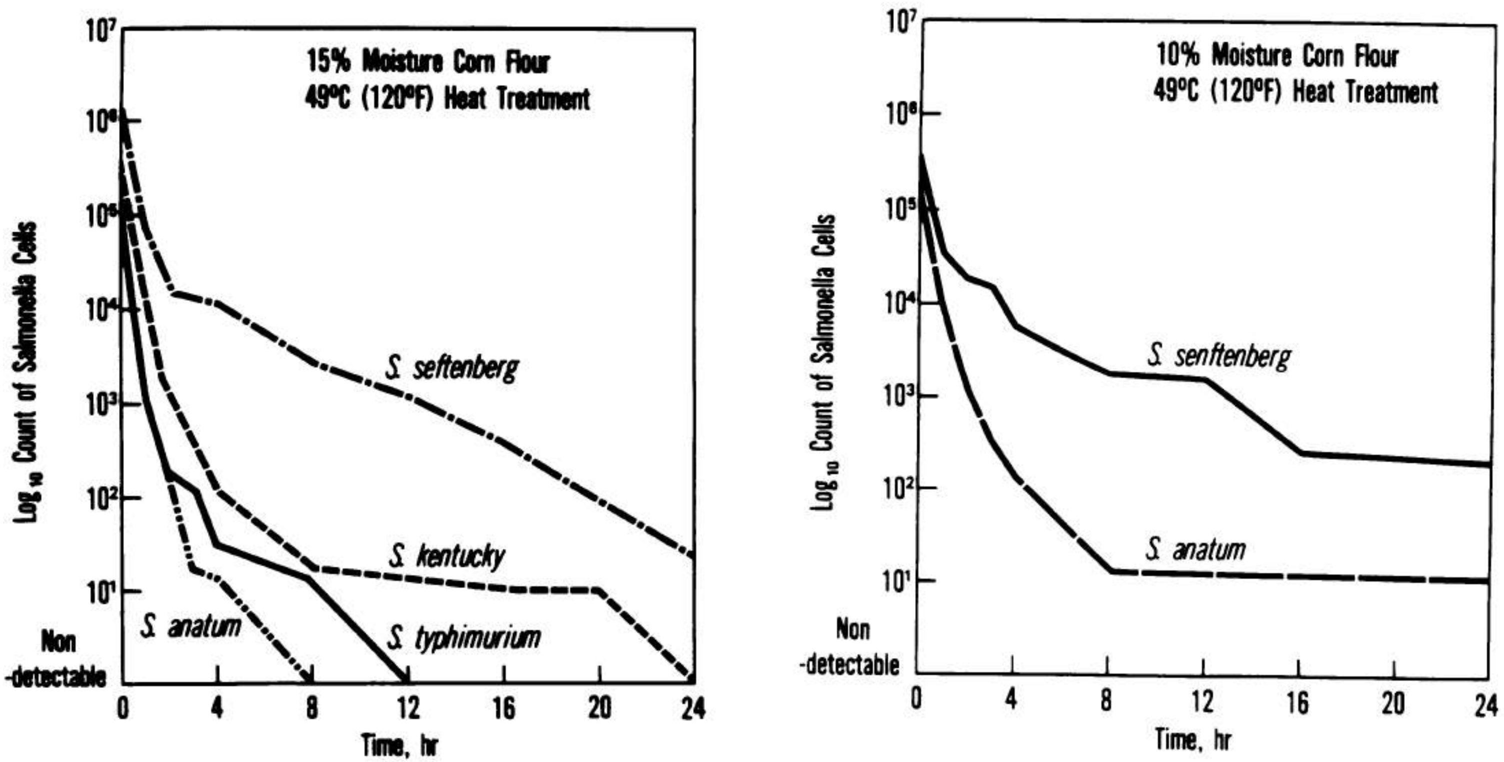
After Milling

Reduction of *Salmonella* in corn meal by heating:



VanCauwenberge et al., 1981.

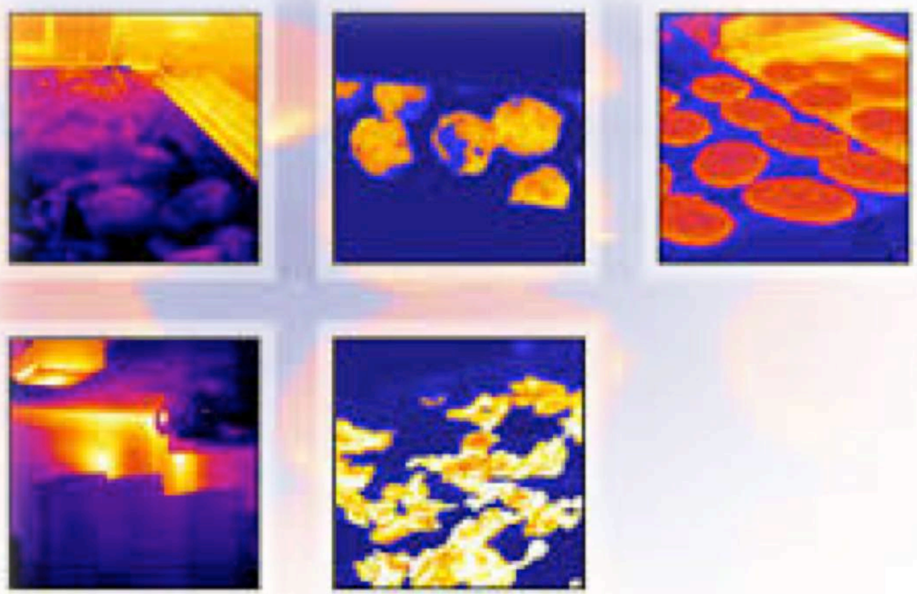
After Milling

Effect of irradiation from a ^{60}Co source on the microbial load of meals:

Contaminant	Wheat Meal				Corn Meal				Oat Meal			
Irradiation levels (Kgy)	0	1	10	25	0	1	10	25	0	1	10	25
Escherichia	---	---	---	---	+++	+++	---	---	++-	+++	---	---
Bacillus	+++	+++	---	---	+++	+++	---	---	+++	+++	---	---
Serratia	+++	++-	---	---	+++	+--	---	---	+++	++-	---	---
Enterococcus	+++	+++	---	---	++-	+--	++-	---	---	---	---	---
Clostridium	+++	+++	---	---	+++	+++	+++	---	+++	+++	---	---
Pseudomonas	---	---	---	---	---	---	---	---	++-	---	---	---
Micrococcus	---	++-	---	---	---	---	---	---	---	---	---	---
Molds	+++	+++	---	---	+++	+++	---	---	+++	+++	---	---

Hanis et al., 1988.

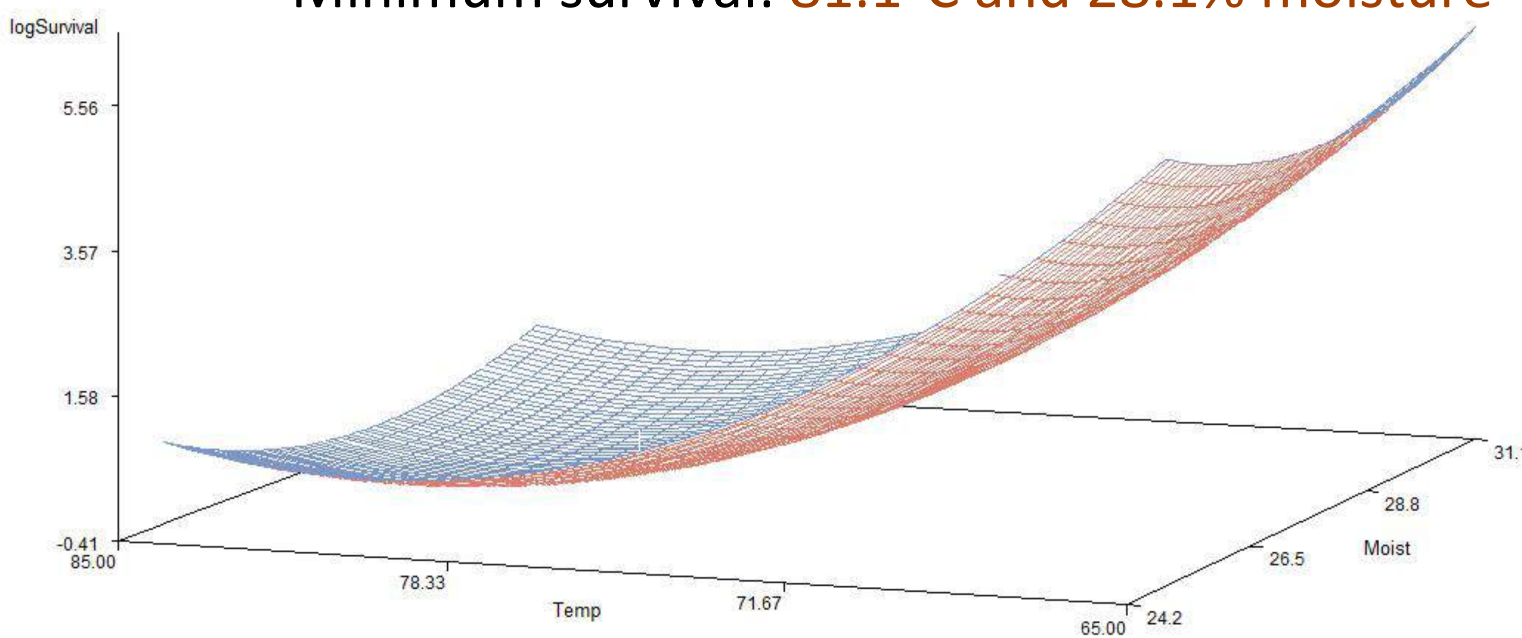
Thermal Processing



Thermal Processing

Effect of moisture and temperature on the inactivation by extrusion of *Enterococcus faecium* as a surrogate for *Salmonella*:

Minimum survival: 81.1°C and 28.1% moisture



Bianchini et al., 2012. Validation of extrusion as a killing step for *Enterococcus faecium* in a balanced carbohydrate-protein meal by using a response surface design.

Thermal Processing

Corn Flakes Processing

Corn Grits

↓

Cooking

(Steam Pressure Cookers)

↓

Hot-Air Drying

↓

Flaking

↓

Roasting

Reductions of 85% in fumonisins may be achieved.

Thermal Processing

Corn flakes processing:

- ✓ Aflatoxin:
  - ❖ Cooking and flaking with and without sugar

    64-67% ↓ Aflatoxin
  - ❖ After toasting with and without sugar

    78-85% ↓ Aflatoxin

Thermal Processing

- ✓ Corn Muffin (5 mg/Kg FB_1)

  (Jackson *et al.*, 1997)

175°C: 16% Reduction

200°C: 28% Reduction

Higher Loss at the Surface

- ✓ Corn Muffin (5 mg/Kg FB_1)

  204°C: No Reduction

  232°C: 48% Reduction

  (Castelo *et al.*, 1998)

Thermal Processing

Fried Tortilla Chips

Corn

↓

Nixtamalization
(Cooking/Steeping)

↓

Masa
(Rinsed and Ground)

↓

Sheeting/Cutting/Baking

↓

Frying

Reductions vary from 37-78%

(Voss *et al.*, 2001)

Thermal Processing

Fried Tortilla Chips:

- ✓ Aflatoxin
  - ❖ Tortilla: ↓ 52%
  - ❖ Tortilla chips: ↓ 84%
  - ❖ Corn chips: ↓ 79%
- ✓ Zearalenone
  - ❖ Tortilla: ↓ 59-100%
- ✓ Deoxynivalenol
  - ❖ Tortilla: ↓ 72-82%

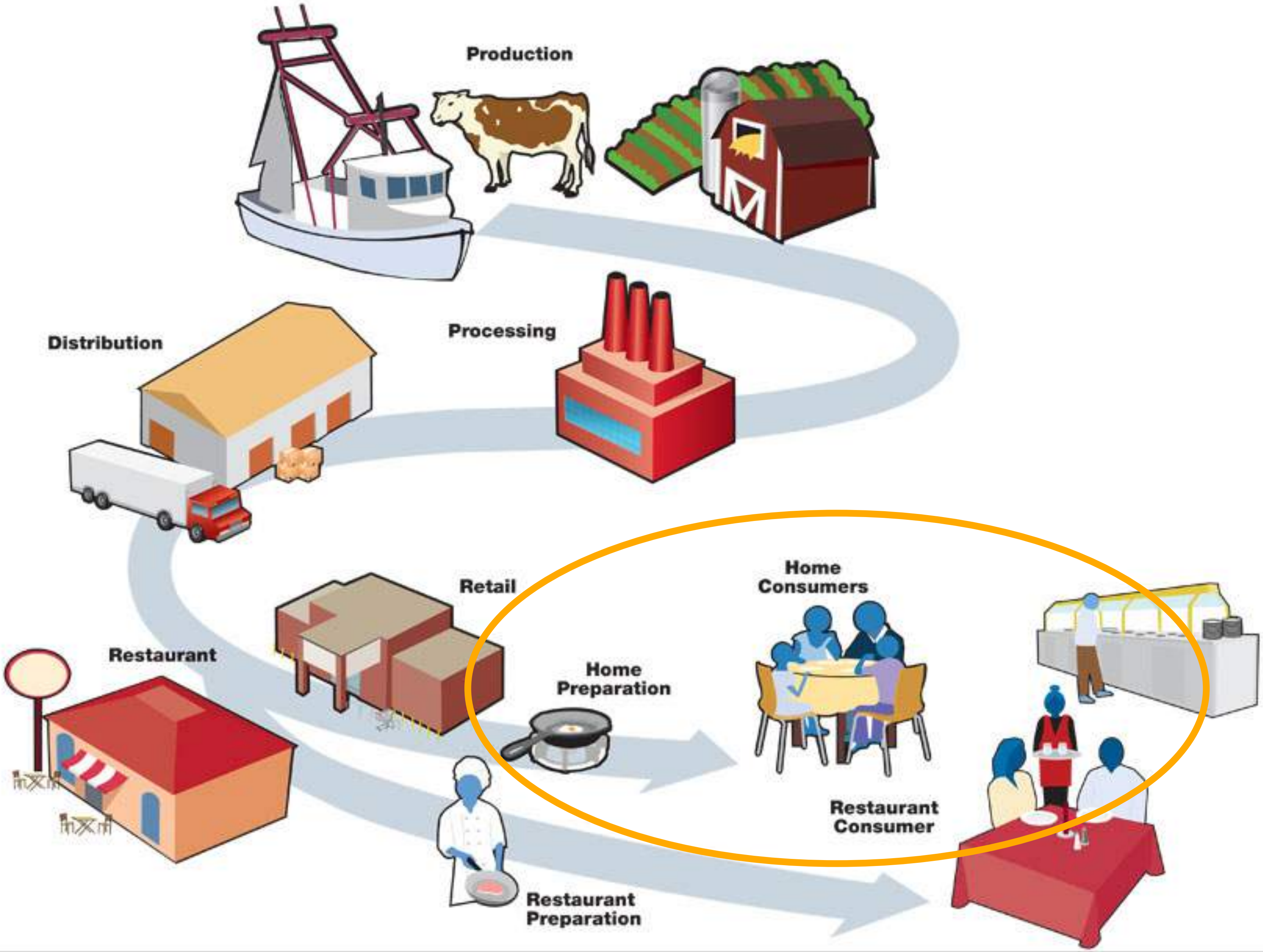
Thermal Processing

Extrusion process:

- ✓ Aflatoxin
  - 140-185°C → 33-38% Reduction
  - >185°C → 66% Reduction
- ✓ Zearalenone (120-160°C) → 70% Reduction
- ✓ Deoxynivalenol (120°C) → 11-27% Reduction
- ✓ Fumonisin (160-200°) → 46-76% Reduction
- ✓ Fumonisin (160°C, Glucose) → 93% Reduction

Temperature and screw type are important!

The Food Production Chain

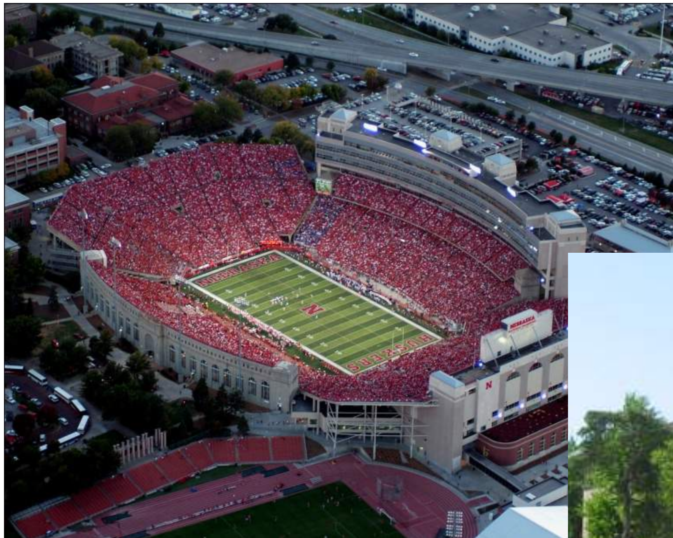


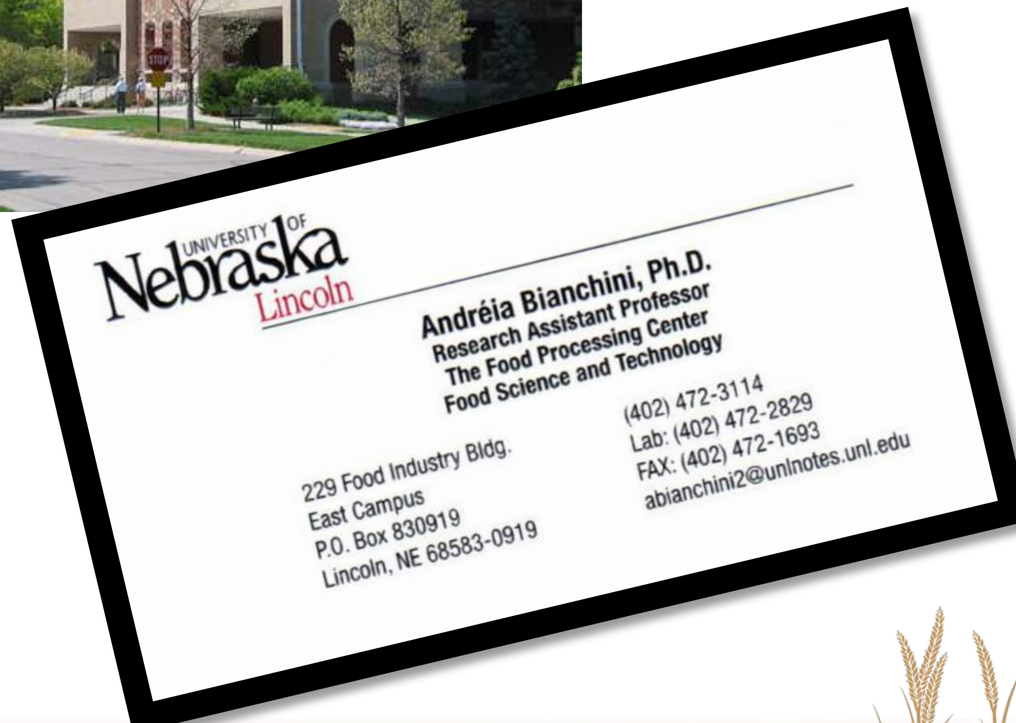
Consumer Behavior

- In the 2009 raw cookie dough outbreak in the US:
  - 94% of case patients consumed raw cookie dough
  - 11% of control consumers reported eating raw cookie dough
  - Several patients bought the dough with the intention of eating it unbaked
- A national survey in the US in 2011 revealed that consumers eat raw products occasionally:
  - 58% - Cookie dough
  - 24% - Biscuit
  - 22% - Pie crust
  - 11% - Pizza crust

Summary

- ✓ Microorganisms and mycotoxins are naturally associated with grains
  - ❖ Keeping them out from the food chain is the best approach
- ✓ Several factors influence the level of contamination and/or mycotoxin in the final grain based product
  - ❖ Ingredient storage
  - ❖ Processing choices and parameters
    - o Functionally of the flour?
    - o Mycotoxins: True reduction or chemical conversion?
- ✓ Consumer education could reduce pathogen risks associated with certain products





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