Tortilla Mold Spoilage: Causes &Prevention

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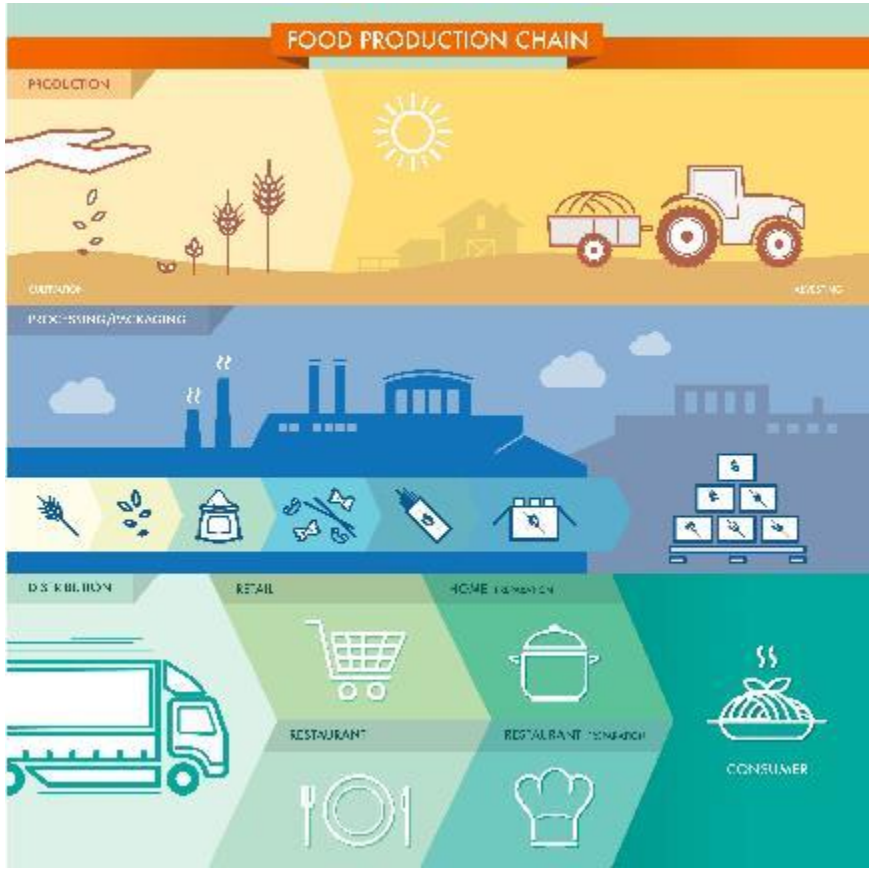
Food Spoilage

- Food spoilage is a major global concern
- According to the FAO, 1/3rd of food is spoiled/wasted every day
  - Spoilage incurs huge economic losses and affects the entire food product chain
  - Microbial spoilage is most common cause of food spoilage
- Estimated bakery product loss is 5% in US & 1-5% in Europe



http://www.fao.org/sustainable-development-goals/overview/en/
Garcia et al., 2021

Tortilla Microbiology

1. Microbial Community
2. Factors of Microbial Contamination
3. Preventive Measures
    a) Plant/GMP
    b) Formulation
4. Preservatives/Mode of action
    a) Selection of preservatives
    b) Application of preservatives

TYPES OF MICROBIAL SPOILAGE

Mold
Most Common

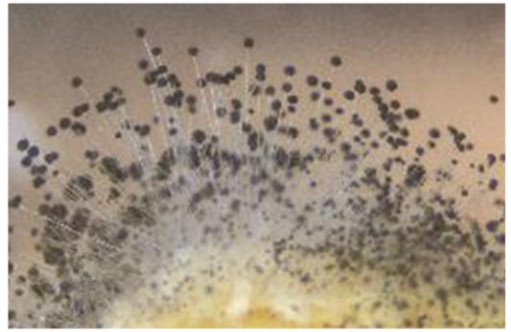
Yeast
Creamy colonies

Bacteria
Precedes Mold Growth (A_w above 0.86)

Microbial Community of Tortillas

Aspergillus- Black,yellow, green

Rhizopus – “Black bread mold”, rapid decay



Mucor – Rapid growth, cottony colonies

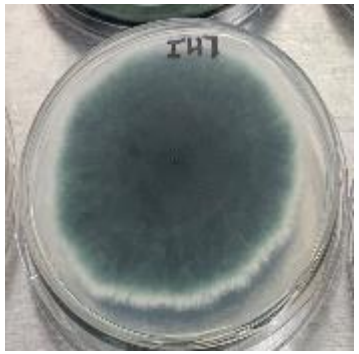
Neurospora – “Red bread mold”

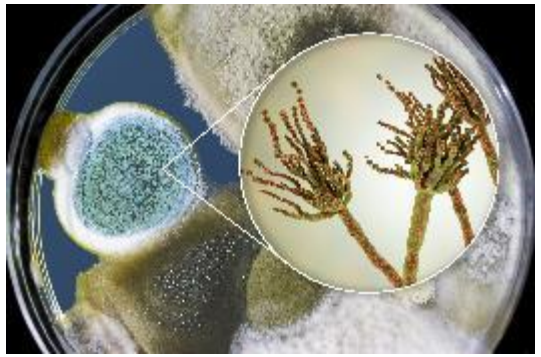
Yeast – Geotrichum Creamy colonies

Bacterial- Bacillus subtilis: Rope formers

Microbial Community of Tortillas

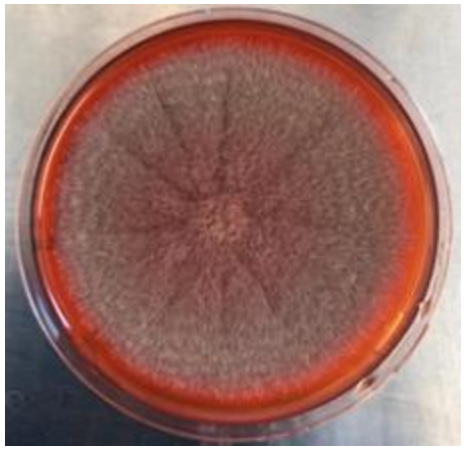
- *Penicillium* –
  - Various colors, typically green
  - A few species are preservative resistant (PRM-Preservative Resistant Mold)
    - e.g., *Penicillium roqueforti, P. paneum, P. carneum.*
    - *Penicillium roqueforti a* sorbate resistant mold, produces a 1,3 pentadiene - a kerosene smelling compound
    - *Penicillium roqueforti* can grow under refrigerated temperature, also called “Cold Weather Mold”





Microbial Community of Tortillas

- Resistant Mold Variants
  - Heat Resistant Mold (HRM)
    - *Monascus spp*: e.g., *Monascus ruber, M. pilosus*
    - They can survive kill steps e.g, pasteurization, baking
    - Also called “Summer Month Mold” or Ascospores



Factors of Microbial Contamination

Raw Materials

Quality/Storage

Plant Environment

Processing parameters

Equipment

Food Build-Up

Plant Environment

Water Quality

Air Quality

Plant Environment

Sanitation

Personnel Hygiene

Plant Environment

Packaging

Condensation

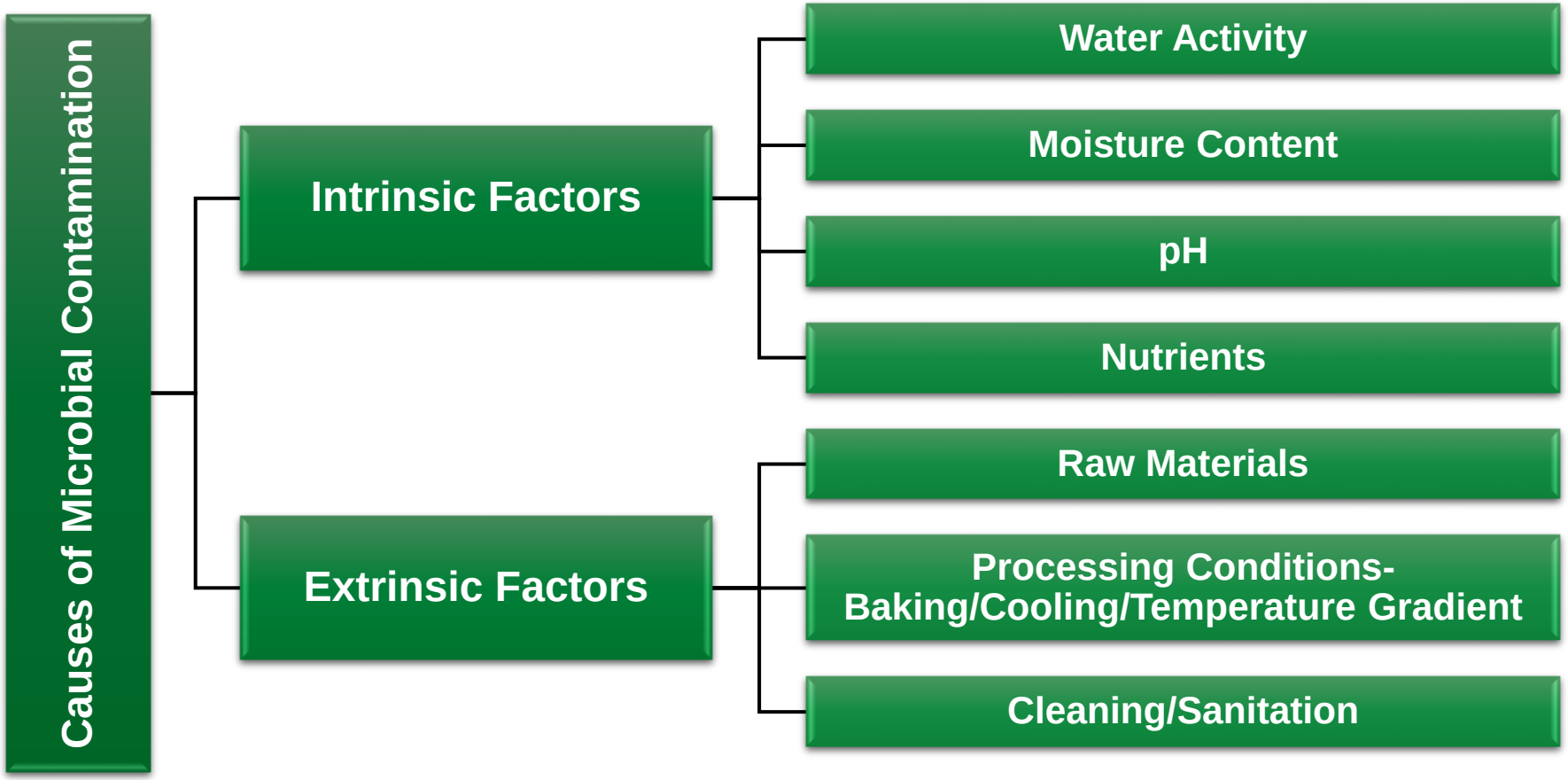
Formulation

Preservative

Acidulant

pH, Aw

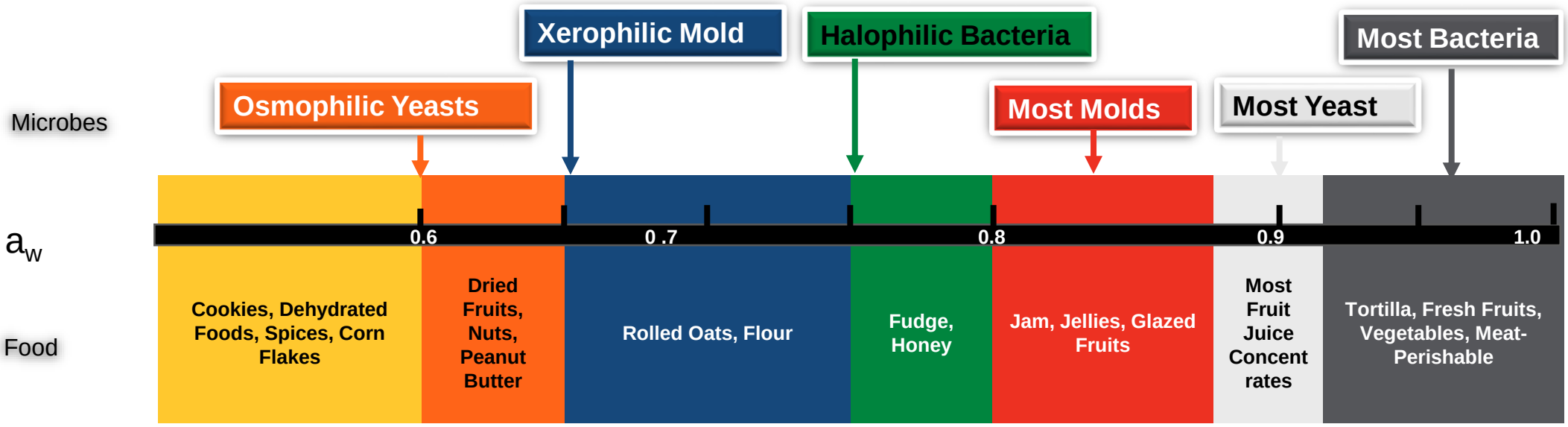
Factors of Microbial Contamination



Factors of Microbial Contamination

Water Activity (a_w) for Foods and Microbes

Minimum a_w for Growth



Note: a_w = Free water available to microorganism; Moisture Content: Water content of food

Daifas et al., 2004

Factors of Microbial Contamination: Water Activity (a_w)

Tortillas are the Perfect Home for Microbial Communities

- Excellent Nutrition Source
- Moisture = 35 – 50%
- Aw = 0.8 to 0.97
- pH = 4.8 – 12
- Typical Storage = 70 – 90 ^{o}F
- Oxygen in package
- Storage Time

Factors of Microbial Contamination

Raw Materials – Raw agricultural commodity

- Potential source of mold, yeast and bacteria
  - Spores of HRM and PRM (*P. roqueforti, P. paneum, P. polonicum*)
- Flour dust can be a carrier for spores on equipment surface/processing area

Packaging Materials –

- Wooden pallets and cardboard boxes can bring a lot of PRM spores to the packaging area

Factors of Microbial Contamination

Plant Environment

- Processing Conditions
  - Baking
    - HRM spores (ascospores) can survive baking temperatures
    - Ascospores contaminate food equipment surfaces
    - Grow better in warmer months
  - Cooling/Temperature Gradient
    - Water condensation
    - Surfaces, walls, ceiling, overhead piping
    - *Penicillium roqueforti* can grow in colder months
  - Cleaning and Sanitation

Munioz et. Al. 2019

Preventive Measures: Segregation

Post - Processing contamination

Receiving/Mixing

Baking (Kill Step)

Cooling

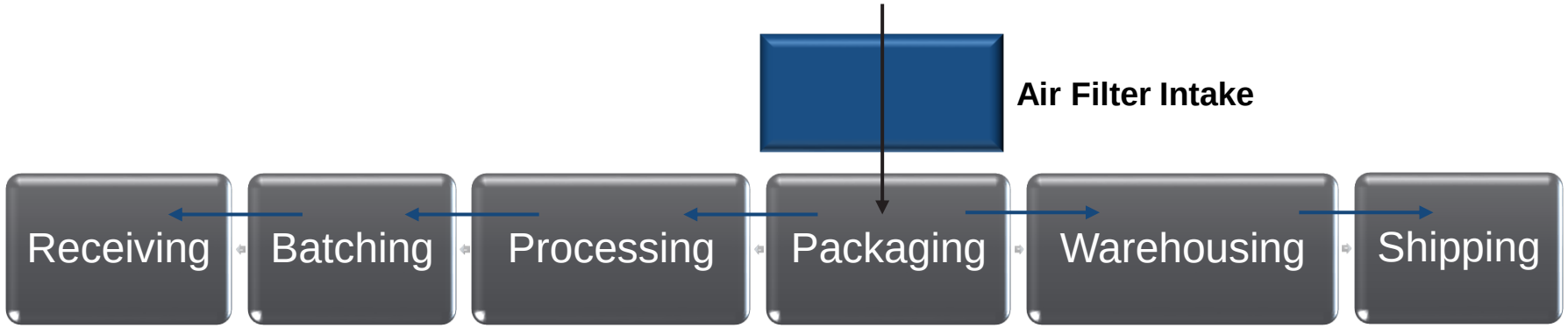
Packaging/Storage

Shipping

Conveyor air, Equipment Surface, Condensate

Preventive Measures: Air Quality

- Create positive air pressure in plant
- Air condition the plant and keep doors & windows closed
- Micro filter on incoming air
- Limit maintenance activity to down days



https://www.food-safety.com/articles/3832-in-plant-air-handling-and-food-safety-there-is-a-connection

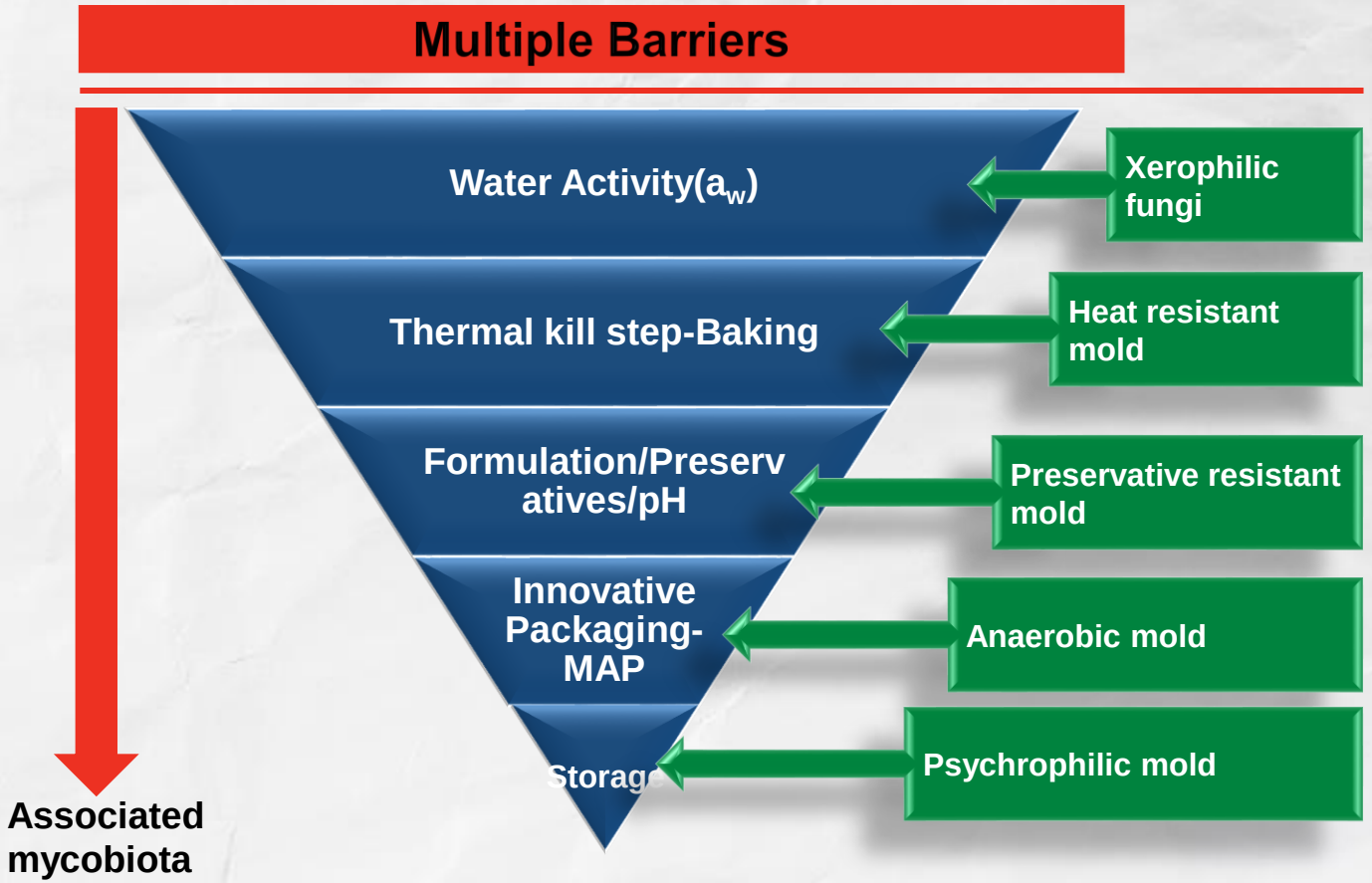
Preventive Measures: Cleaning & Sanitation

- Adoption of hygienic-sanitary practices are very effective
  - Cleaning schedules – daily, weekly, monthly
- Sanitization process using appropriate sanitizing agents at adequate concentration
- Clean air
  - Compressed air should be used to clean & remove the flour
  - Vacuum cleaner with HEPA filter
  - Maintain temperature and humidity of primary packaging area

Preventive Measures: Antimicrobials

Hurdle Technology : Multiple Barriers

- a_w
- Thermal kill step-Baking
- Formulation-Preservatives/pH
- Innovative Packaging/MAP, Vacuum,O_2 Scavengers
- Storage temperature (Refrigerated/Frozen)



Adapted from Rico-Munoz, et al, 2018

Preventive Measures: Antimicrobials

- Antimicrobials (AM) are extensively used to inhibit microbial spoilage in tortillas
- Propionic acid is the most commonly used mold inhibitor
- Sorbic acid and benzoic acid are used as helper molecules

	Spoilage Organism		
Effective Agent	**Mold**	**Yeast**	**Bacteria**
Propionic acid	X		X
Sorbic Acid	X	X	X
Acetic Acid	X		X
Benzoic Acid	X	X	X
Parabens	X		X

Preventive Measures: Antimicrobials

Undissociated Acid (%)	pH
99	2.87
95	**3.59**
90	3.92
80	4.27
70	4.50
60	4.69
50 (pKa)	**4.87**
40	5.05
30	5.24
20	5.47
10	5.82
1	**6.87**
0.5	7.17

$HA \rightleftharpoons H^+ + A^-$

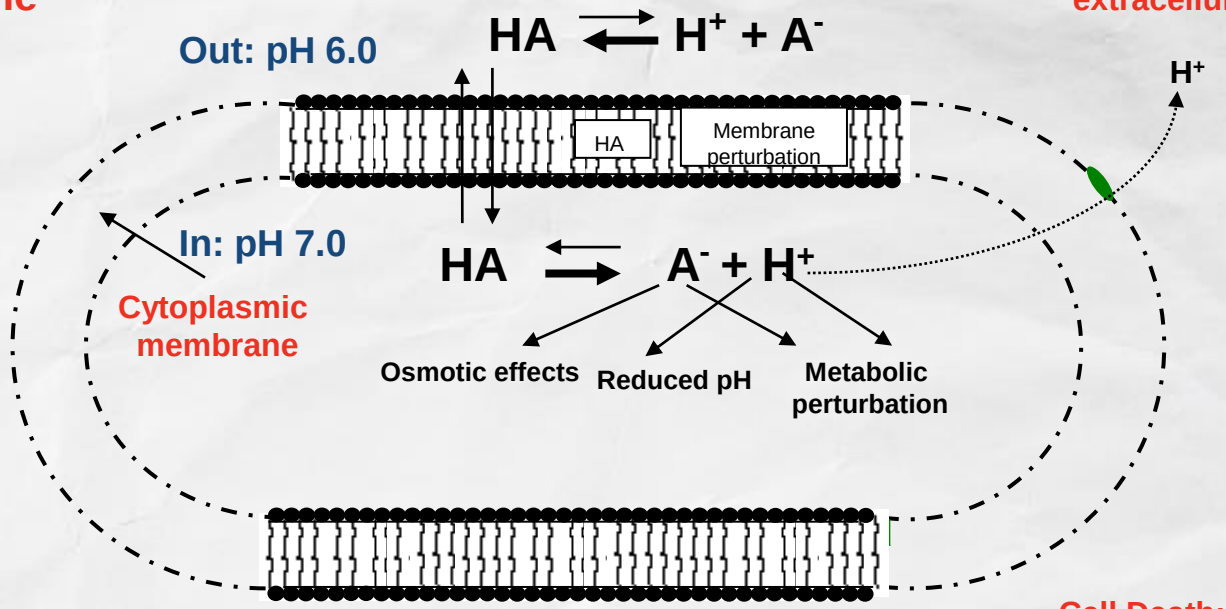
pKa = pH when concentration of acid is equal to its conjugate base i.e., acid is 50% dissociated

Preventive Measures: Antimicrobials

- Propionic Acid
  - Undissociated acid theory/acid stress
- Sorbic Acid
  - Partly due to the undissociated acid
  - Loss of lipid membrane integrity
  - Inhibition of enzymes required for cell division
- Benzoic Acid
  - Alter membrane fluidity leading to disruption of membrane trafficking and dynamics

Undissociated acid can penetrate the cell membrane

Presence of organic acids in undissociated form at lower extracellular pH



Cell Death:
Dissociation of organic acids into protons and anion

Adapted from Hirshfield et. al, 2003
Busta et. Al., 1986

Preventive Measures: Antimicrobials

pH	Undissociated	Active* (lbs)
5.6	15	0.15
5.4	**20**	**0.20**
5.2	30	0.30
5.0	40	0.4
4.8	50	0.5

- pH range = shelf life obtained at the high end is the standard
- Acceptable pH range = 4.8 to 5.2 then the shelf life at 5.2 is the standard

** Based on 1 pound added to the dough*

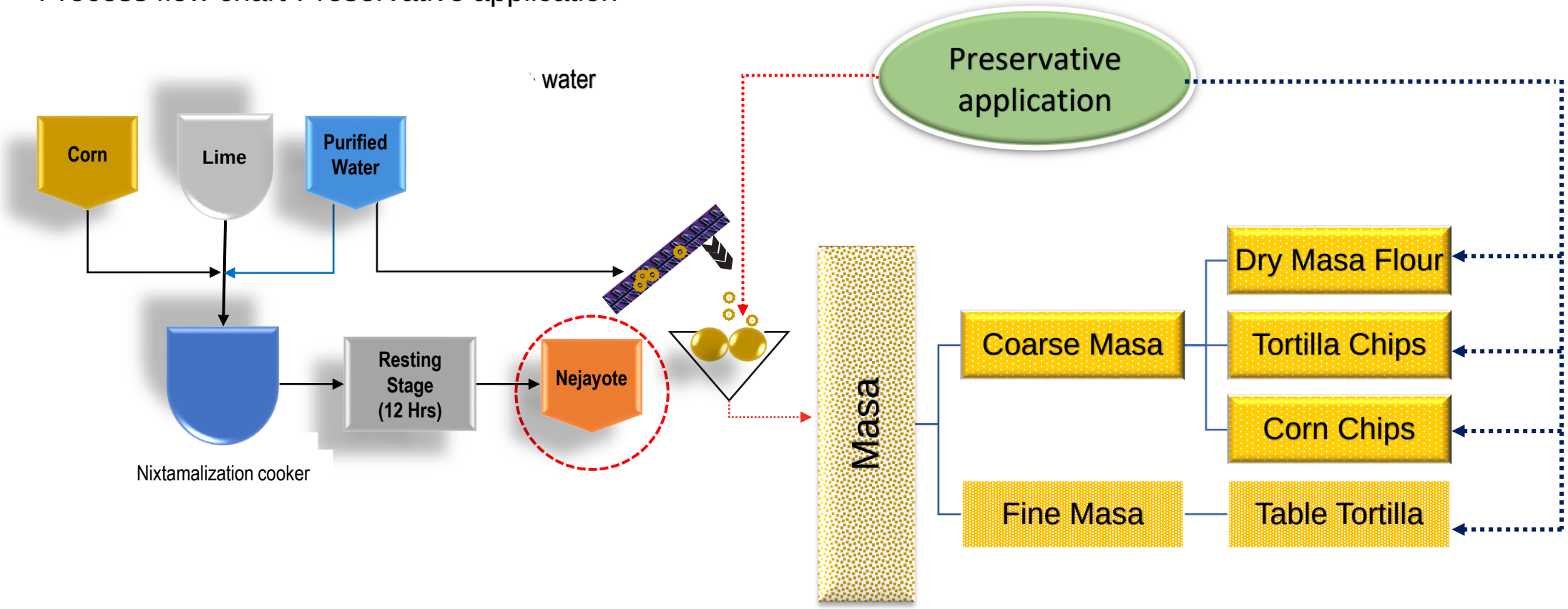
Preventive Measures: Antimicrobials

- Acidulants
  - Lower the pH of finished product
  - Improve the efficiency of preservatives
  - Commonly used acids are:
    - Phosphoric acid- liquid, corrosive
    - Fumaric acid - dry, slow acting
    - Malic acid/Citric Acid: dry, fast acting
    - Encapsulated acids: to prevent interaction with leavening system adding “before baking stage”
  - Disadvantage: affect the after taste of product

Selection of acidulant based on finished product requirement

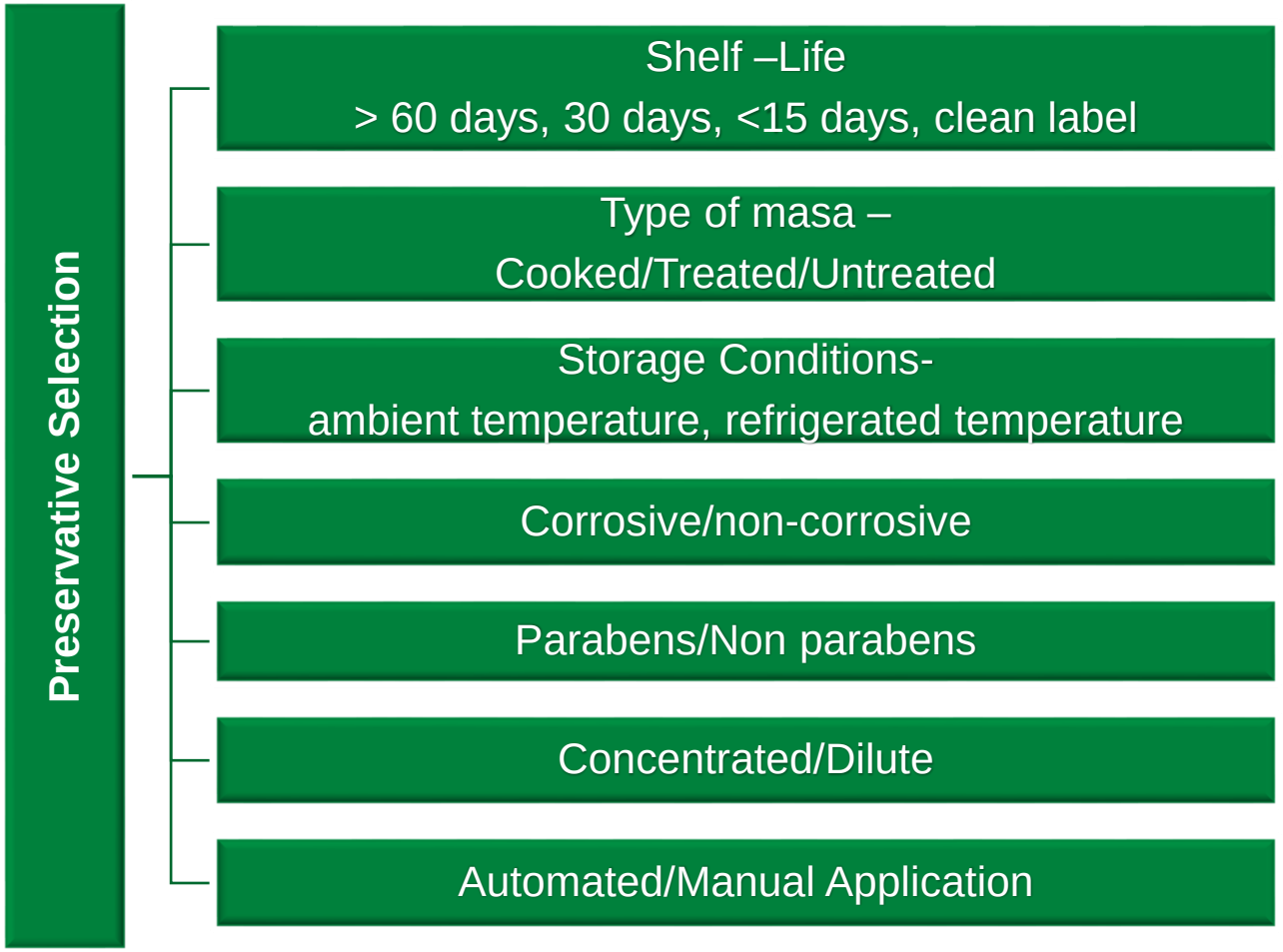
Application of Preservatives: Corn Tortillas

Process flow chart-Preservative application



Adapted from Rosentrater, K.A. 2006

Application of Preservatives: Corn Tortillas



Application of Preservatives: Corn Tortillas

- Preservative selection
  - Microbial spectrum control
  - Non-corrosive/Buffered
  - Concentrated
  - Automated application

Application of Preservatives: Corn Tortillas

SHIELD® Liquid Antimicrobials

SHIELD® Variants	Actives
SHIELD® CT	Propionic acid, Parabens
SHIELD® NCD	Propionic acid
SHIELD® CTB	Propionic acid, Benzoic acid
SHIELD® FL4	Propionic acid, Sorbic acid
SHIELD® FL	Propionic acid, Sorbic acid
SHIELD® NXT	Propionic acid, Parabens
SHIELD® T	Propionic acid

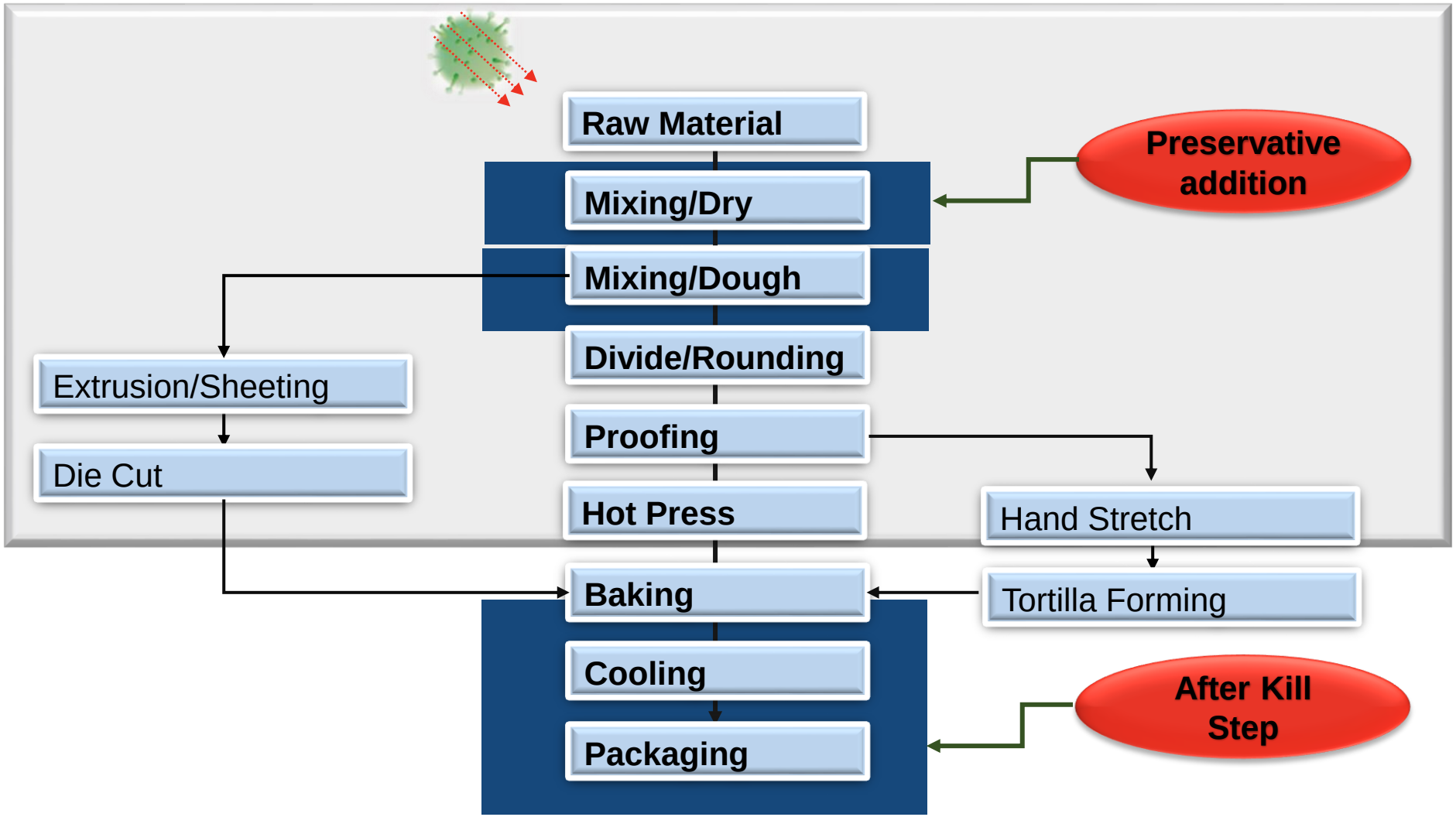
Applications: Cooked corn/Masa, Corn flour, Table corn tortillas, Tortilla chips, Corn chips

Application of Preservatives: Flour Tortillas

Preservative selection

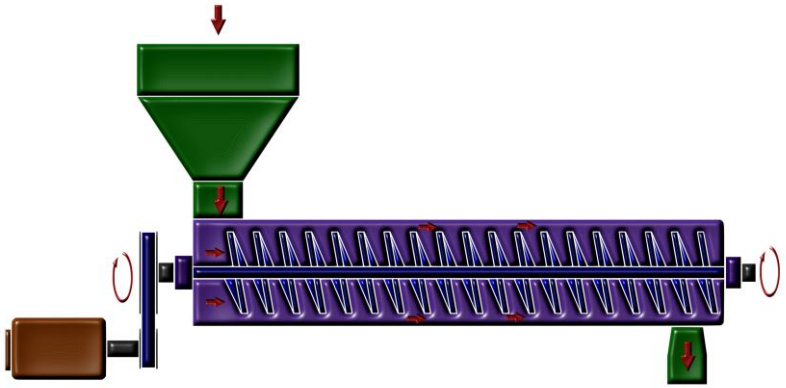
- Dry preservatives are preferred
- Liquid preservatives interact with leavening system
- Commonly used preservatives are
  - Calcium Propionate: Salt of propionic acid
  - Potassium Sorbate: Salt of sorbic acid
  - Sodium Benzoate: Salt of benzoic acid

Application of Preservatives: Flour Tortillas



Process flow chart-Preservative application

Product Application: Uniform Distribution



- Uniform distribution of preservatives is very critical
  - Dry Preservatives
    - Validation/process qualification
    - Dosage in batch system or continuous system
  - Liquid Preservatives
    - Validation/process qualification
    - Active analysis
    - Dough pH, finished product pH
    - Automation-dosing system/pump system
    - Addition to water system

Application Systems 101 – The Basics

Objective:

Apply a liquid product to a dry material or matrix and touch as many particles as possible.

The Basics:

- Make it Flow – Mechanical Pump, Pneumatic Pressure
- Measure Flow – Flow Meter, Scale, Catch & Weigh
- Regulate Flow – Variable Speed Drive, Metering Valve
- Optimized Distribution – Spray Nozzle, Disc Atomizing
- Secondary Distribution – Mixing, Blending

Application Systems: The Basics

- Proper pump sizing is imperative for correct application rate
- Liquid dispersion by either spray nozzle or injection is important to specify for proper liquid dispersion
  - Spray pattern
  - Material coverage
  - Droplet size
- When properly engineered, specified, and installed, most can achieve consistent and accurate flow rates.

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