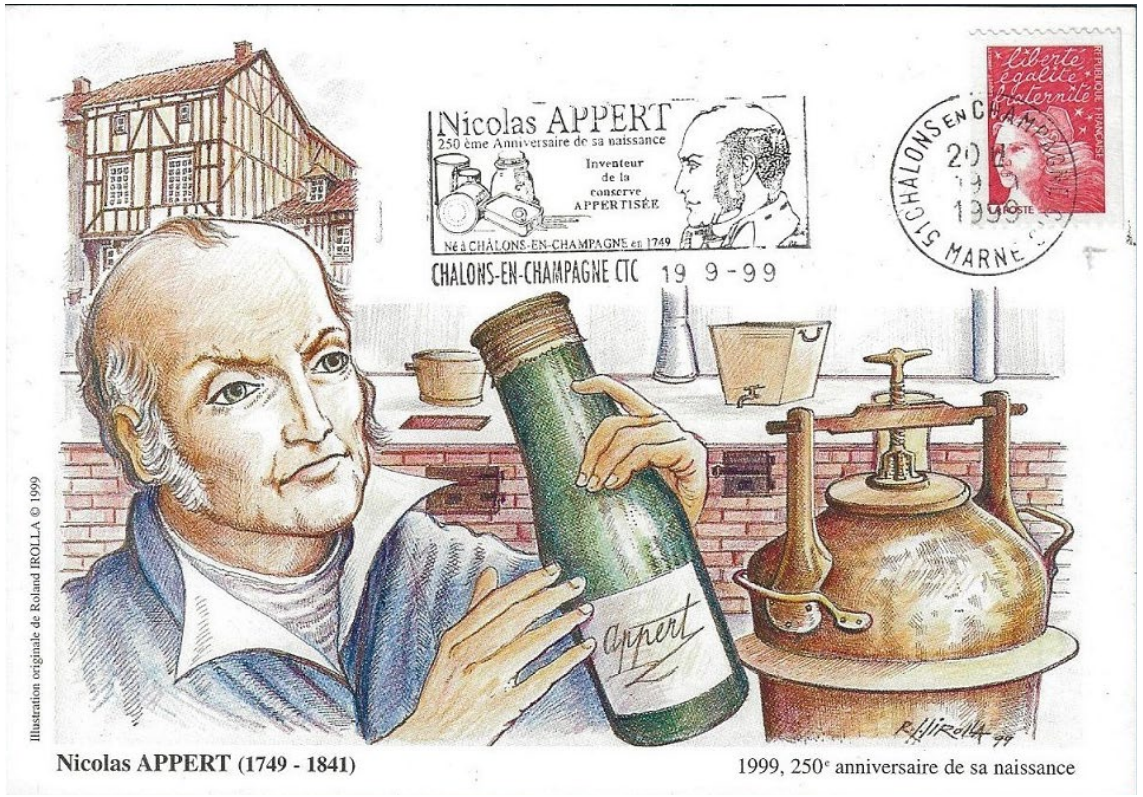
The Role and Purpose of Processing in Food Production

JIFSAN-CFS3 Advisory Council Annual Symposium
College Park, Maryland
October 29-30, 2024

Nicolas Appert (1749 – 1841)

- Known as Father of Canning
- French confectioner and inventor
- Invented airtight food preservation
- Food in glass jars, sealed with cork and sealing wax, wrapped in leather and placed in boiling water
- Help French Army sustain long periods and further distance during war



Food Processing

- **Food Processing** = defined as the use of methods and techniques involving equipment, energy, and tools to transform agricultural products such as grains, meats, vegetables, fruits, and milk into food ingredients or finished food products.

- **Processed Food** = defined as a food material has been changed in some way through a combination of ingredients together with processing steps to make the food safe to eat, shelf-stable for future use, convenient to use (e.g. microwaveable dinners), tasty/palatable, (e.g. milk chocolate bar) and/or more nutritious (e.g breakfast cereals fortified with vitamins).

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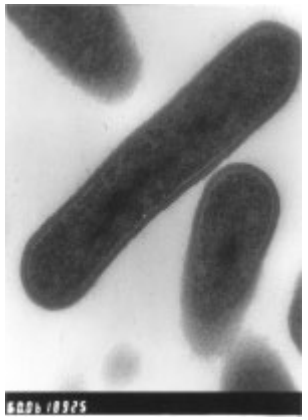
Food Processing and Processed Foods

All processed foods use food processing, but not all food processing leads to processed foods.

Food Processing  **Processed Food**

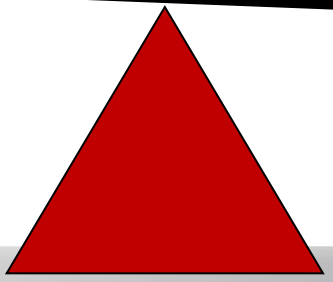
Food Processing Balance



Need to destroy
Pathogens
Spoilage Organisms
Enzymes

VS

Optimize
Flavor
Texture
Color
Nutritional quality



Food Preservation Techniques

1. Traditional Techniques
   - Desiccation
     - Drying
     - Salting/sugaring
   - Fermentation
   - Heating
   - Freezing

2. Modern Techniques
   - Drying / Freeze drying
   - Cooling
   - Heating
   - Vacuum packing/MAP
   - Food additives

3. *Novel Techniques*
   - *Irradiation*
     - *High Pressure*
     - *Pulse Electric Field*
     - *Ultrasound*

Food Processing through the use of Antimicrobials

Table 13–1 Summary of Some GRAS Chemical Food Preservatives

Preservatives	*Maximum Tolerance*	*Organisms Affected*	*Foods*
Propionic acid/ propionates	0.32%	Molds	Bread, cakes, some cheeses, rope inhibitor in bread dough
Sorbic acid/sorbates	0.2%	Molds	Hard cheeses, figs, syrups, salad dressings, jellies, cakes
Benzoic acid/ benzoates	0.1%	Yeasts and molds	Margarine, pickle relishes, apple cider, soft drinks, tomato catsup, salad dressings
Parabens*	0.1%†	Yeasts and molds	Bakery products, soft drinks, pickles, salad dressings
SO_2/sulfites	200–300 ppm	Insects, microorganisms	Molasses, dried fruits, wine making, lemon juice (not to be used in meats or other foods recognized as sources
Ethylene/propylene oxides‡	700 ppm	Yeasts, molds, vermin	Fumigant for spices, nuts
Sodium diacetate	0.32%	Molds	Bread
Nisin	1%	Lactics, clostridia	Certain pasteurized cheese spreads
Dehydroacetic acid	65 ppm	Insects	Pesticide on strawberries, squash
Sodium nitrite‡	120 ppm	Clostridia	Meat-curing preparations
Caprylic acid	–	Molds	Cheese wraps
Sodium lactate	Up to 4.8%	Bacteria	Pre-cooked meats
Ethyl formate	15–220 ppm§	Yeasts and molds	Dried fruits, nuts

Note: GRAS (generally recognized as safe) per Section 201[32] (s) of the U.S. Food, Drug, and Cosmetic Act as amended.

*Methyl-, propyl-, and heptyl-esters of *p*-hydroxybenzoic acid.
†Heptyl-ester—12 ppm in beers; 20 ppm in noncarbonated and fruit-based beverages.
‡May be involved in mutagenesis and/or carcinogenesis.
§As formic acid.

GRAS Food Preservatives

Propionic Acid/Propionates
Sorbic Acid/Sorbates
Benzoic Acid/Benzoates
Parabens
SO2/Sulfites
Ethylene/Propylene Oxides
Sodium Diacetate
Nisin
Dehydroacetic Acid
Sodium Nitrate
Caprylic Acid
Sodium Lactate
Ethyl Formate

Control of *Clostridium botulinum* in Low Acid Foods

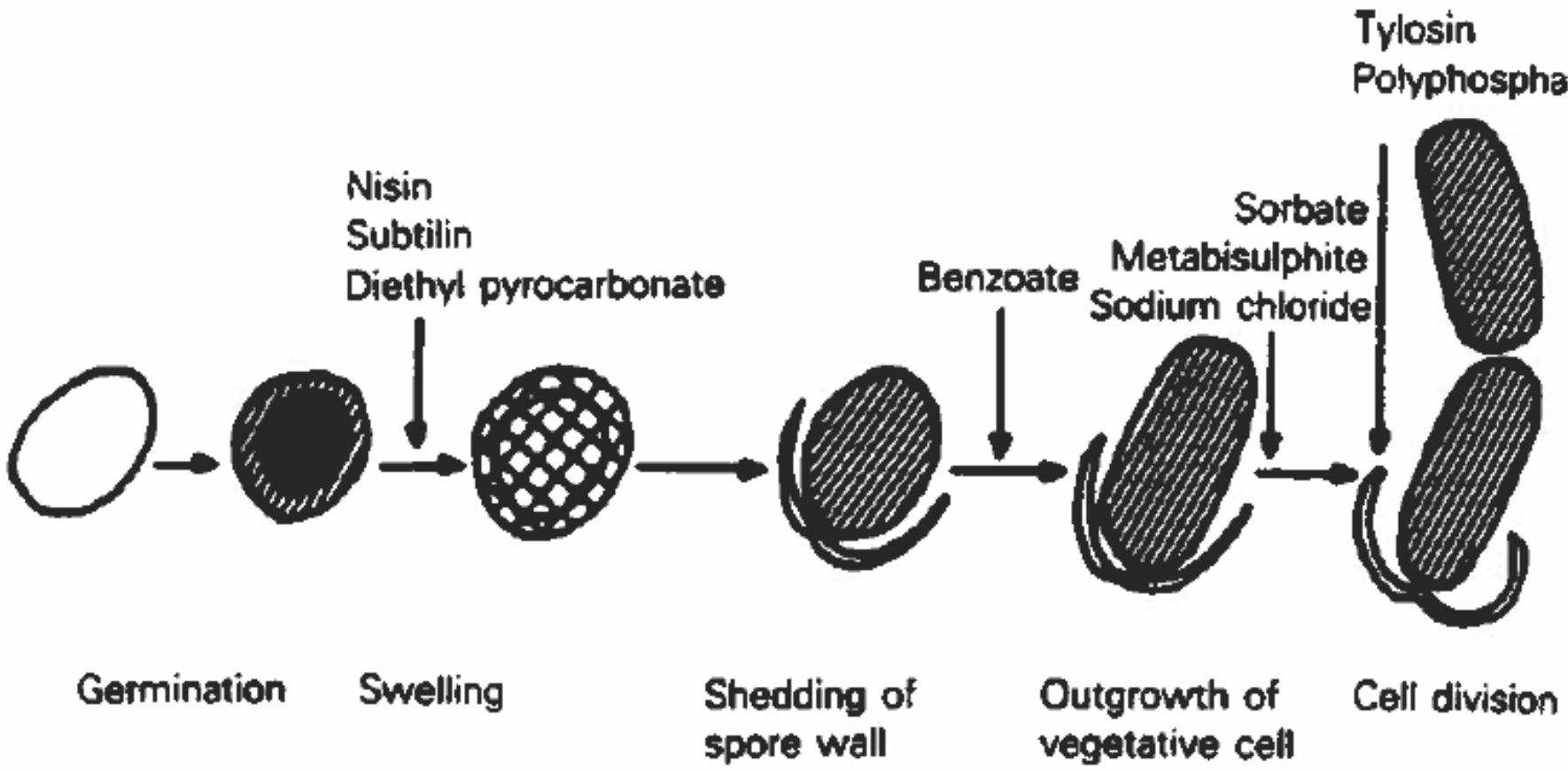


Figure 13–1 Diagrammatic representation of growth of an endospore into vegetable cells showing stages arrested by minimum inhibitory concentrations of some food preservatives. *Source*: From Gould.[72]

Salt and Sugars

- Namely NaCl and sucrose
- Salt reduces a_w levels and increases osmotic pressure
  - Water moves away from cell resulting in plasmolysis
- Sugar – relies on relative concentrations
  - Generally 6x more sugar to achieve the same effect as NaCl

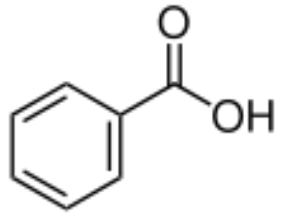
Nitrites and Nitrates

- Sodium nitrite ($NaNO_2$) or sodium nitrate ($NaNO_3$)
- Mostly used in the meat curing industry
  - Stabilizes colour, inhibit spoilage and pathogens, enhance flavour
- Dissociates or eliminated on heating and storage

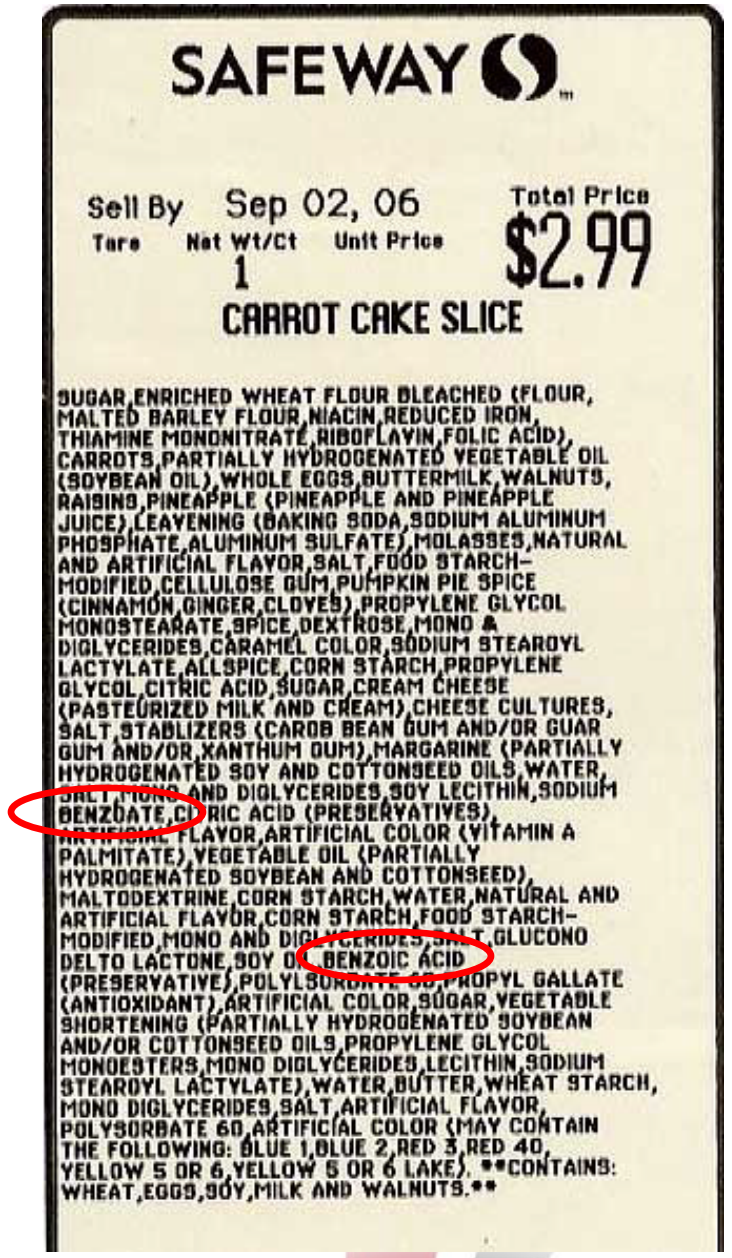
- Can both be reducing or oxidizing agent
  - In acid – nitrous acid is formed and decomposes to nitric oxide
- Inhibits *C. botulinum* and other *Clostridium* species
- Interfers with iron-sulfur enzymes to form iron-nitrosyl complexes, synthesis of ATP from pyruvate, electron transport

Benzoic Acid and the Parabens

- Benzoic acid (C_6H_5COOH)
- Na salt ($C_7H_5NaO_2$)
- esters of *p*-hydroxybenzoic acid (parabens)



Benzoate's includes any of the following permitted preservatives (*E* numbers 210-219):
E210 or Benzoic acid
E211 or Sodium benzoate
E212 or Potassium benzoate
E213 or Calcium benzoate
E214 or Ethyl 4-hydroxybenzoate or Ethyl para-hydroxybenzoate
E215 or Ethyl 4-hydroxybenzoate, sodium salt or sodium ethyl para-hydroxy-benzoate
E216 or Propyl 4-hydroxybenzoate or Propyl para-hydroxybenzoate
E217 or Propyl 4-hydroxybenzoate, sodium salt or sodium propyl parahydroxybenzoate
E218 or Methyl 4-hydroxybenzoate or Methyl para-hydroxybenzoate
E219 or Methyl 4-hydroxybenzoate, sodium salt or Sodium methyl parahydroxybenzoate.

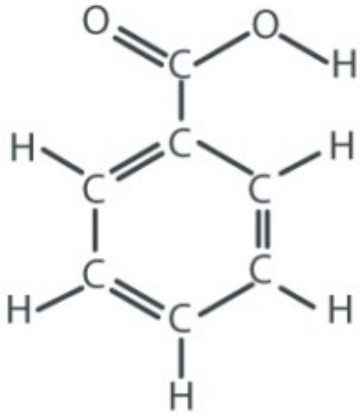

SAFEWAY

Sell By Sep 02, 06
Tare Net Wt/Ct 1 Unit Price
Total Price $2.99

CARROT CAKE SLICE

SUGAR,ENRICHED WHEAT FLOUR BLEACHED (FLOUR, MALTED BARLEY FLOUR,NIACIN,REDUCED IRON, THIAMINE MONONITRATE,RIBOFLAVIN,FOLIC ACID), CARROTS,PARTIALLY HYDROGENATED VEGETABLE OIL (SOYBEAN OIL),WHOLE EGGS,BUTTERMILK,WALNUTS, RAISINS,PINEAPPLE (PINEAPPLE AND PINEAPPLE JUICE),LEAVENING (BAKING SODA,SODIUM ALUMINUM PHOSPHATE,ALUMINUM SULFATE),MOLASSES,NATURAL AND ARTIFICIAL FLAVOR,SALT,FOOD STARCH-MODIFIED,CELLULOSE GUM,PUMPKIN PIE SPICE (CINNAMON,GINGER,CLOVES),PROPYLENE GLYCOL MONOSTEARATE,SPICE,DEXTROSE,MONO & DIGLYCERIDES,CARAMEL COLOR,SODIUM STEAROYL LACTYLATE,ALLSPICE,CORN STARCH,PROPYLENE GLYCOL,CITRIC ACID,SUGAR,CREAM CHEESE (PASTEURIZED MILK AND CREAM),CHEESE CULTURES, SALT,STABLIZERS (CAROB BEAN GUM AND/OR GUAR GUM AND/OR,XANTHUM GUM),MARGARINE (PARTIALLY HYDROGENATED SOY AND COTTONSEED OILS,WATER, SALT,MONO AND DIGLYCERIDES,SOY LECITHIN,SODIUM BENZOATE,CITRIC ACID (PRESERVATIVES), ARTIFICIAL FLAVOR,ARTIFICIAL COLOR (VITAMIN A PALMITATE),VEGETABLE OIL (PARTIALLY HYDROGENATED SOYBEAN AND COTTONSEED), MALTODEXTRINE,CORN STARCH,WATER,NATURAL AND ARTIFICIAL FLAVOR,CORN STARCH,FOOD STARCH-MODIFIED,MONO AND DIGLYCERIDES,SALT,GLUCONO DELTO LACTONE,SOY OIL, BENZOIC ACID (PRESERVATIVE),POLYSORBATE 60,PROPYL GALLATE (ANTIOXIDANT),ARTIFICIAL COLOR,SUGAR,VEGETABLE SHORTENING (PARTIALLY HYDROGENATED SOYBEAN AND/OR COTTONSEED OILS,PROPYLENE GLYCOL MONOESTERS,MONO DIGLYCERIDES,LECITHIN,SODIUM STEAROYL LACTYLATE),WATER,BUTTER,WHEAT STARCH, MONO DIGLYCERIDES,SALT,ARTIFICIAL FLAVOR, POLYSORBATE 60,ARTIFICIAL COLOR (MAY CONTAIN THE FOLLOWING: BLUE 1,BLUE 2,RED 3,RED 40, YELLOW 5 OR 6,YELLOW 5 OR 6 LAKE). **CONTAINS: WHEAT,EGGS,SOY,MILK AND WALNUTS.**

Benzoic Acid



- First additive permitted by FDA
- Activity is pH related – low pH
  - pH 4, 60% undissociated (active)
  - pH 6, 1.5% undissociated (active)
- Controls yeast and molds (100-500 ppm)
- Mode of action:
  - Inhibits cellular uptake of substances
  - Soluble in cell membrane and act as proton ionophores
  - Cells leaks protons → ↑energy output to maintain internal pH
  - Disruption of membrane and affects amino acid transport
- Applications: Commonly found in high acid products – apple cider, soft drinks, salad dressing, baked goods

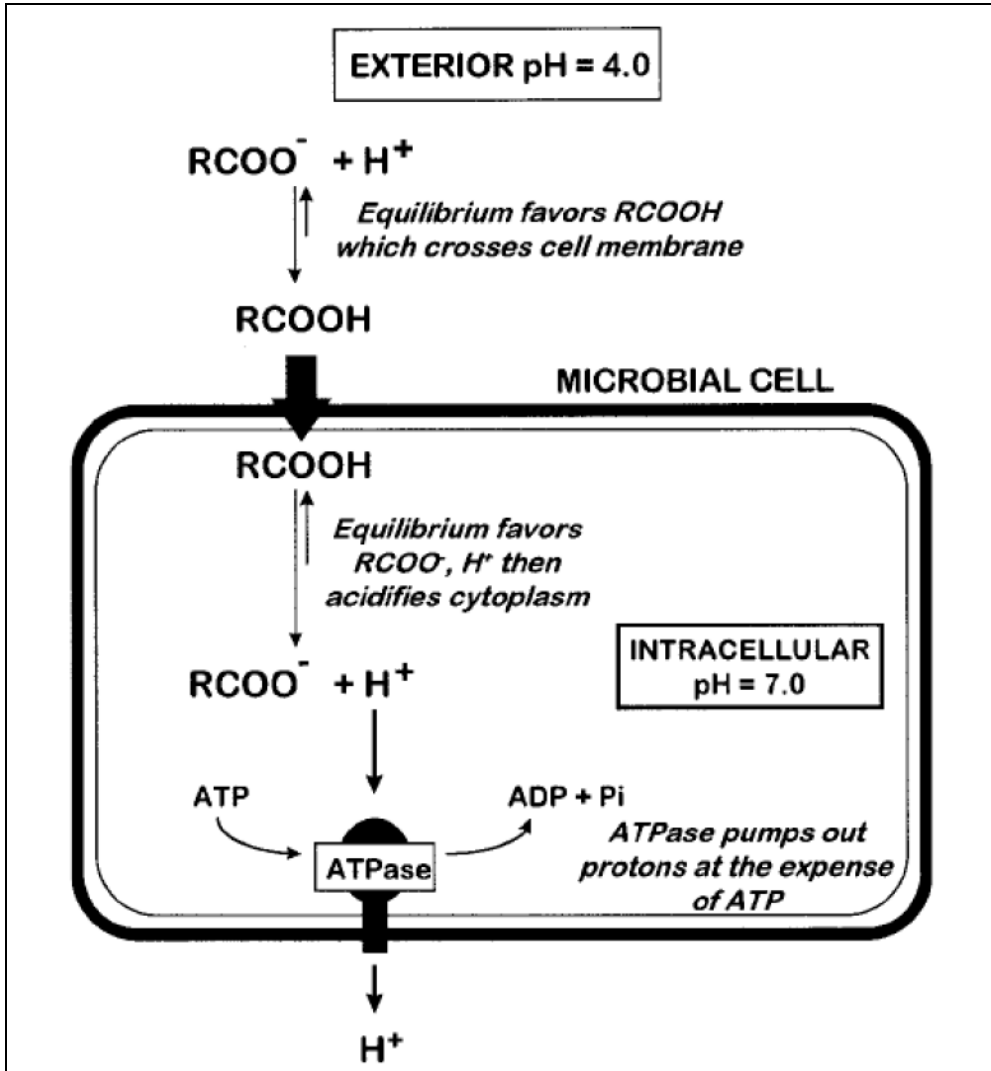


Figure 33.1 Fate of an organic acid (RCOOH) in a low pH environment in the presence of a microbial cell.

Davidson and Taylor, 2007

Benzoic Acid

- Controls yeast and molds (100-500 ppm)
- Mode of action:
  - Inhibits cellular uptake of substances
  - Soluble in cell membrane and act as proton ionophores
  - Cells leaks protons → ↑energy output to maintain internal pH
  - Disruption of membrane and affects amino acid transport
- Health impacts
  - Irritation of the eyes, skin, nose, throat and lungs
  - Coughing, wheezing and shortness of breath
  - May be bad for those with liver problems or with sensitivity to aspirin
  - Sodium benzoate – increase risk of inflammation, oxidative stress, obesity, ADHD

Food Processing through the use of Technologies

Boiling vs Sous-vide Cooking

	Traditional cooking	Sous-vide treatment
Cooking temperature	Product brought to the boil	65°C Test1–74°C Test2
Cooking time	1 hr	10 hr Test1 4 hr Test 2

Peas

Minerals	Traditional cooking mean ± *SD*	Sous-vide mean ± *SD*	Δ Change
Magnesium (mg)	31.52 ± 0.84	39.00 ± 0.91	7.48
Potassium (mg)	71.42 ± 0.71	182.10 ± 2.64	110.68
Iron (mg)	1.37 ± 0.03	7.22 ± 0.14	5.85
Zinc (mg)	–	–	–
Copper (mg)	78.45 ± 1.67	69.17 ± 1.58	−9.28

Pearl Barley

	Traditional cooking mean ± *SD*	Sous-vide mean ± *SD*	Δ Change
	49.07 ± 0.88	37.12 ± 0.97	−11.95
	39.82 ± 0.86	71.47 ± 1.82	31.65
	2.10 ± 0.04	3.60 ± 0.12	1.50
	–		–
	43.07 ± 0.97	59.20 ± 1.26	16.13

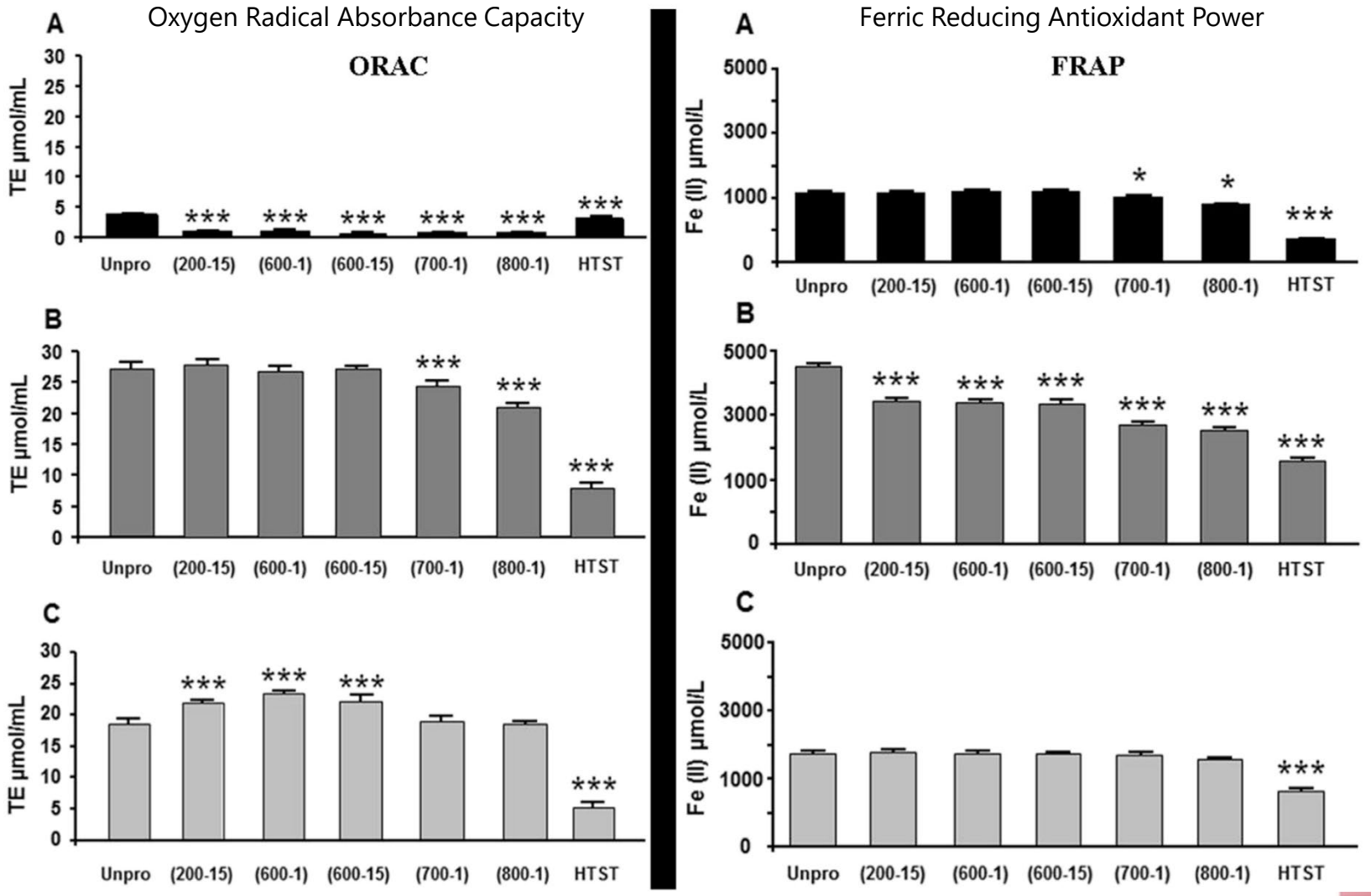
Rondanelli et al. (2017) Food Science & Nutrition, 5:827-833

HPP and HTST on Antioxidant Values in Strawberry

Dairy with no freeze-dried strawberry powder

Freeze-dried strawberry powder + Distilled Water

Dairy with freeze-dried strawberry powder



Tadapaneni et al. (2012) Journal of Agricultural and Food Chemistry, 60, 5795-5802

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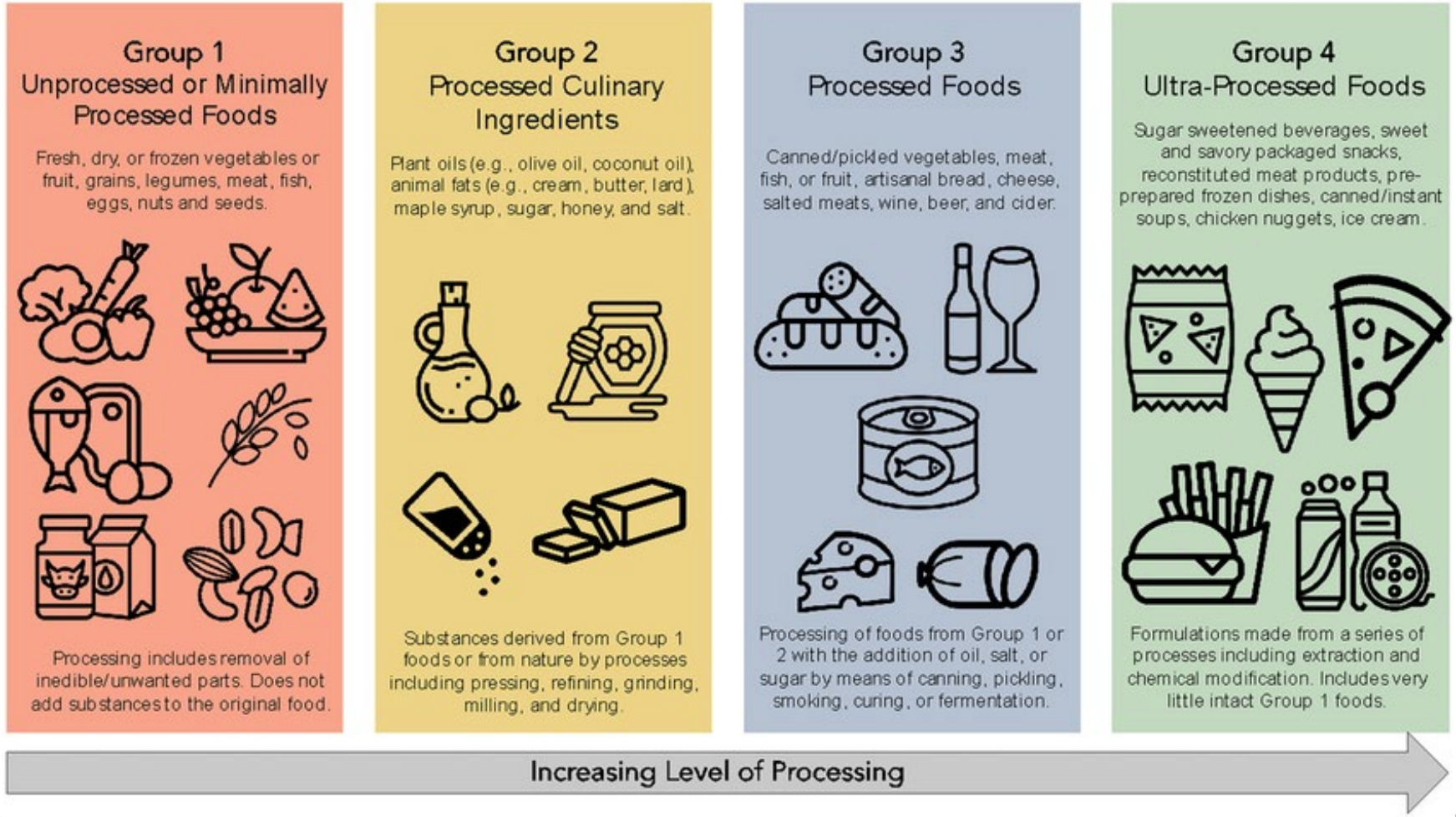
NOVA Classification



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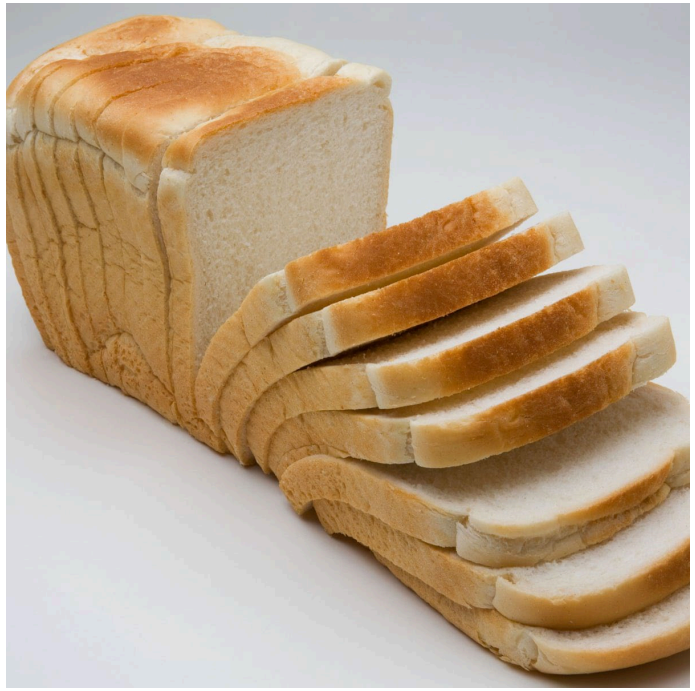
1 2 3 4

Formulations of industrial ingredients and substances derived from foods or else created in laboratories, and typically contain little or even no whole foods.

Bread vs Bread



Enriched Wheat Flour, Water, Sugar, Yeast, Vegetable Oil, Wheat Gluten, Sea Salt, Cultured Wheat Flour, Soy Lecithin, Citric Acid, Grain Vinegar

Wheat Gluten = chewiness

Cultured Wheat Flour = natural preservative and flavor enhancer, prevents mold and bacterial growth

Soy Lecithin = natural emulsifying agent from soybeans for flavor, texture and extend shelf-life

Citric Acid = weak organic acid as antimicrobial

Grain Vinegar – vinegar made from grains for flavor and antimicrobial

All Purpose Flour or Bread Flour, Water, Sugar, Yeast, Vegetable Oil, Sea Salt

HPP Deli Meats

Water, Honey, Salt, Contains 2% or Less of Turbinado Sugar, Cultured Celery Powder, Sea Salt, Cherry Powder

Key Benefits of **Food Processing**

Food Safety

Food processing systems in the 21st century and the associated safety and quality management tools enable continued delivery of more nutritious and safe food than any time in human history.

Food Preservation and Long Shelf-Life

The use of technologies, such as aseptic and ultra-high temperature food processing allows some food products to be stored unrefrigerated for a longer period of time, for example, high-protein nutrition shak with a shelf-life of 12 months, for older adults.

Year-Round Food Supply

Availability

Another example of advances in food processing is the increasing availability of many regionally grown food products, such as pineapple grown in Hawaii, the Philippines, or Thailand in convenient single-serve plastic packages.

Convenience

Advances in food processing have resulted in the development and widespread availability of convenient food products that require minimal preparation/cooking and ready-to-eat (RTE) food products, some of which are also healthful. For example, whole grain pasta made by cooking, extruding, and drying grain flour, is a shelf-stable product that requires minimal preparation time.

Affordability

Advances in food processing to deliver benefits such as food safety, preservation, shelf-life extension, and/or convenience is often associated with increased costs. However, large-scale processing technologies enable production of cost-effective products for consumers to purchase at grocery stores rather than make it at home from raw ingredients.

Healthy Options

Food processing has helped deliver healthy food options (e.g., plant-based foods, plant-based protein, low-fat meat and dairy products) to assist consumers in following a healthy dietary pattern(s).

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Benefits and Impacts of Food Operations

Technique	Examples	Outcomes & benefits	Impact
Preservation	• Pasteurization of milk or juice • Fermenting dairy into cheese or yogurt • Pickling or canning produce • Salting meats	• Distributors can ship products over greater distances • Retailers can stock products longer • Consumers can keep foods longer	• A range of local and non-local foods remain available over a longer time frame
Processing for food safety (cleaning, sterilization)	• Washing, pasteurizing, cooking, salting, drying, refrigerating, freezing	• Food-borne pathogens and contaminants are removed or minimized, meaning that consumers are at a lower risk of foodborne illness	• A greater proportion of the population has access to safe food
Processing to change flavour, texture, aroma, color or form	• Milling grains • Mixing ingredients • Adding flavors and colors • Molding foods and ingredients into shapes	• Manufacturers may gain higher profits and a foothold in a competitive market • Consumers have access to a wider variety of products	• Adds value to food products
Processing to reduce preparation times and make food more portable	• Ready-to-serve meals • Fast foods • Convenience foods: Bottled drinks, meat jerky, cakes, cookies, breakfast cereal bars, frozen pizzas, baby food	• Manufacturers may gain higher sales by responding to consumer demand for convenience food • Consumers can eat virtually anywhere, at any time, with minimal effort	• Access to safe (and preferably nutritious) foods for time-poor consumers
Processing to restore and/or raise nutrient levels in food	• Fortifying milk with vitamin D, salt with iodine, and grains with B vitamins, iron and folic acid	• Manufacturers can use fortification as a selling point, potentially generating greater sales • Consumers are at lower risks for chronic nutrient deficiencies	• Adds value and nutrition density to food, can improve bioavailability and population health implemented as public health policies

Augustin et al. Trends in Food Science & Technology 56 (2016) 115-125

Future of Food Processing

- Food formulation remains a priority for food manufacturers
  - Focus now on reduction of salt, sugar, fat and energy density
  - Supporting reduction in energy intake and BMI initiatives
  - Revisit use of food additives

- Refinement of food processes or process innovation
  - E.g. thermal processing under vacuum (sous-vide) reduces temperature-related vitamin and nutrient losses
  - Use of novel and non-thermal technologies e.g. High Pressure Processing

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Thank You!

Alvin Lee
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Balance Diet + Regular Exercise