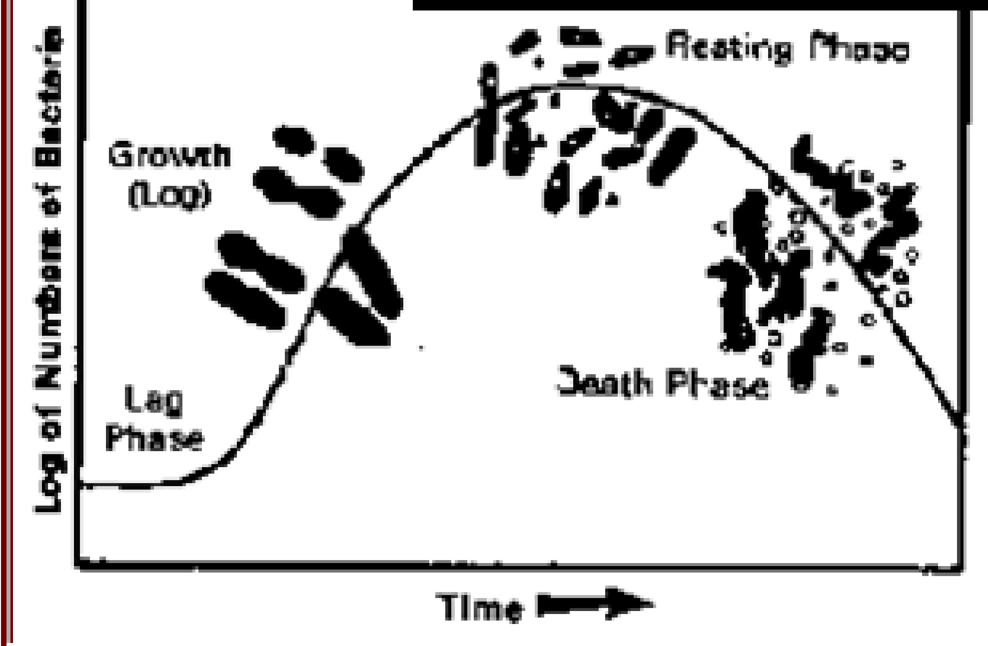
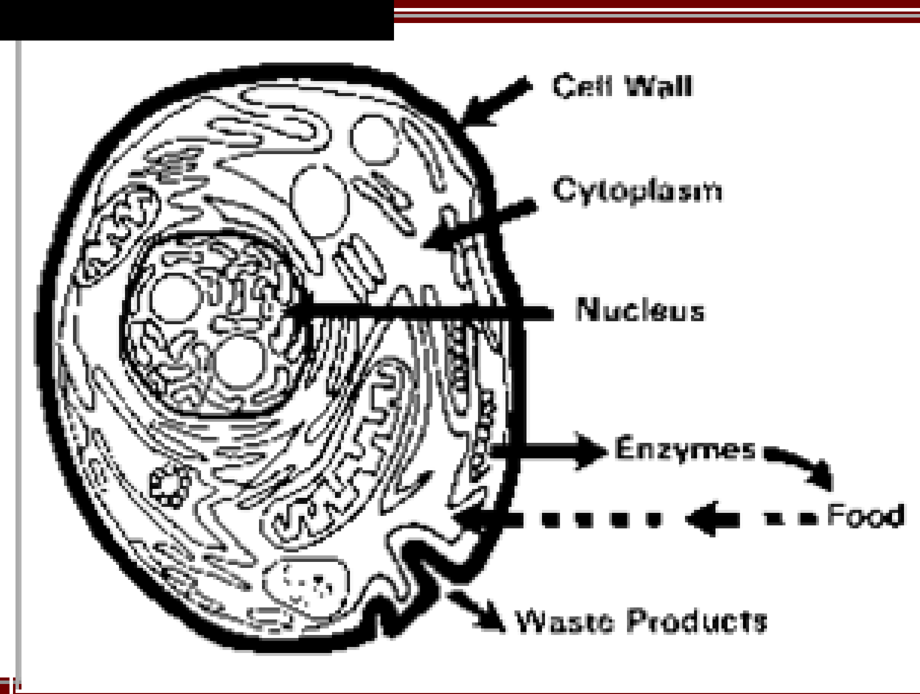
Low Thermal and Other Technologies: Principles and Applications in Food Processing

Factors Causing Deterioration

- Heat
- Cold
- Light
- Other radiation
- Oxygen Moisture
- Dryness
- Enzymes
- Microorganisms
- Macroorganisms
- Industrial contaminants
- Time





What is Ultraviolet (UV) Light?

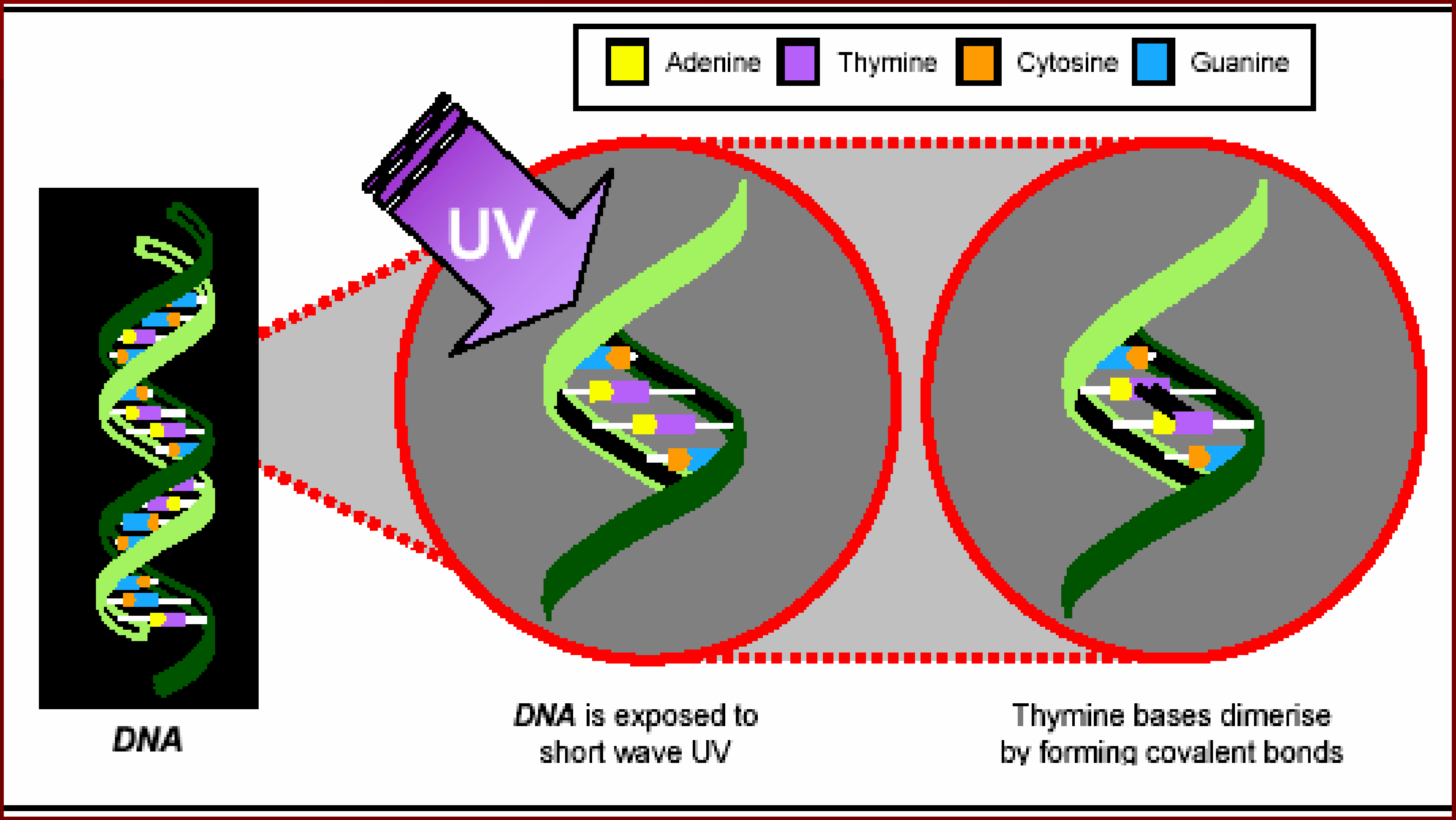
- The region of the electromagnetic spectrum between visible light and x-rays
- UV corresponds to wavelengths between 100 and 400 nm

- UVA : 320 to 400 nm
- UVB : 290 to 320 nm
- UVC: 254 nm

Applications of UV Irradiation

- Water treatment in the beverage industry
- Sanitation of packaging materials
- Food preservation
- Disinfection of equipment surfaces

Inactivation of DNA by UVC Irradiation



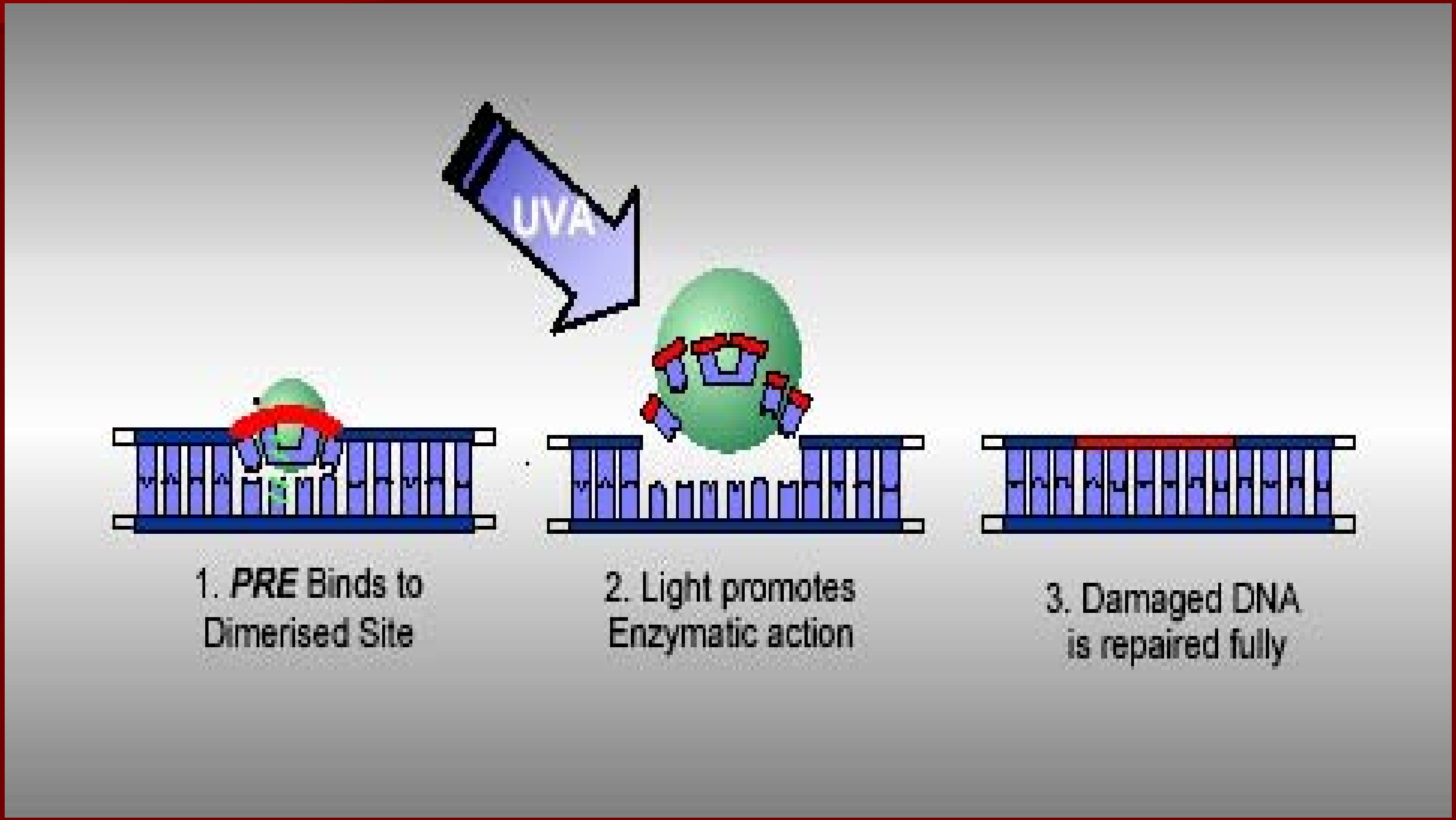
L. monocytogenes, S. *Typhimurium*, and E.coli *O157:H7 suspended in peptone water treated with UV irradiation of two intensities*

	Intensity							
	250µW/sq.cm				500µW/sq.cm			
Time (min)	Control	1	2	3	Control	1	2	3
	Log CFU/ml				Log CFU/ml			
L. monocytogenes	8.39a[1]	6.10b	2.45c	ND	8.39a	4.94b	0.75c	ND
S. Typhimurium	8.94a	6.07b	3.58c	2.28c	8.94a	5.44b	3.25c	1.93d
E.coli O157:H7	8.64a	5.42b	ND	ND	8.64a	3.76b	ND	ND

[1] Means of 3 replications within a row not followed by same letter differ ($p < 0.05$)

ND (none detected at 10^{-1} dillution)

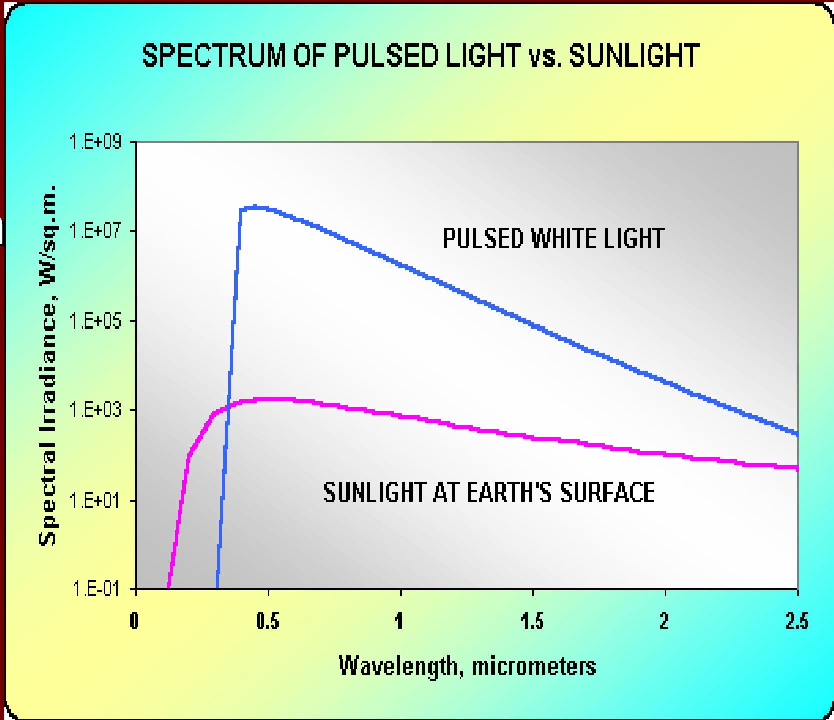
Photoreactivation of Damaged DNA



Pulsed light

- Pulsed white light, also called Pulsed Light or Pulsed UV light, involves the pulsing of a high-power xenon lamp for about 0.1-3 milliseconds per some sources (Dunn 1990, Rowan 1999, Johnson 2000), or about 100 microseconds to 10 milliseconds per other sources (Wekhof 2000).

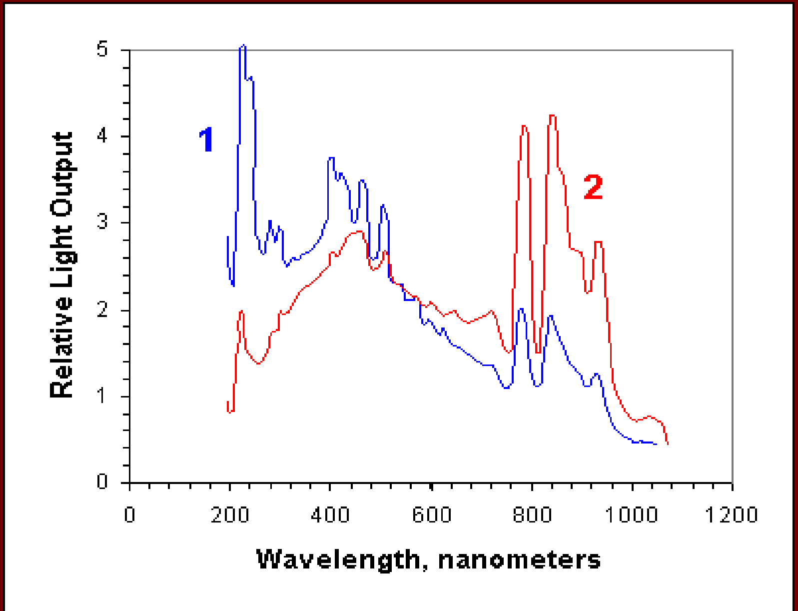
- The spectrum of light produced resembles the spectrum of sunlight but is momentarily 20,000 times as intense (Bushnell et al. 1997).



Pulsed light

- These high intensity flashes of broad spectrum white light pulsed several times a second can inactivate microbes with remarkable rapidity and effectiveness.

- The germicidal effect appears to be due to both the high ultraviolet content and the brief heating effects (Wekhoff 2000), however, these systems can be tuned to produce pulsed light with different compositions.



Pulsed light

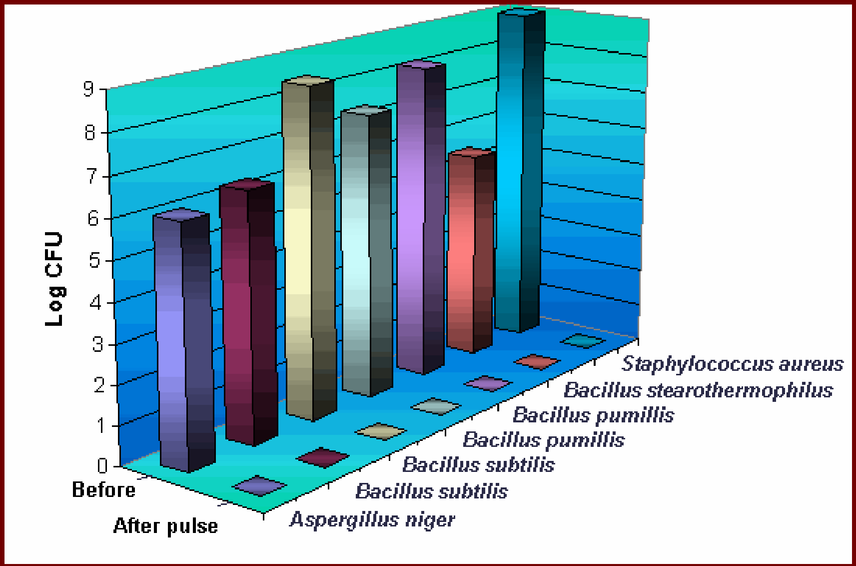
- This technology is currently being applied in the pharmaceutical packaging industry where translucent aseptically manufactured bottles and containers are sterilized in a once-through light treatment chamber.

- The chamber generates a light intensity at the surface of the exposed containers of about 1.7 J/sq.cm.,

  or 1.7 x E06 microWatt.s/sq.cm.

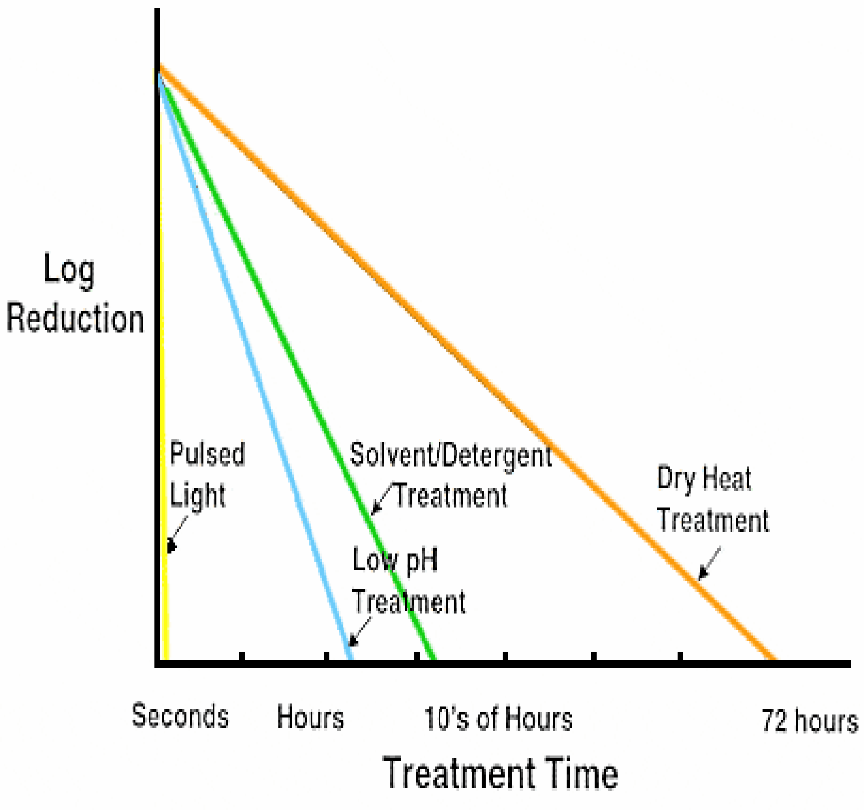
  Sunlight produces

  about 1359 Watt.s/sq.cm.

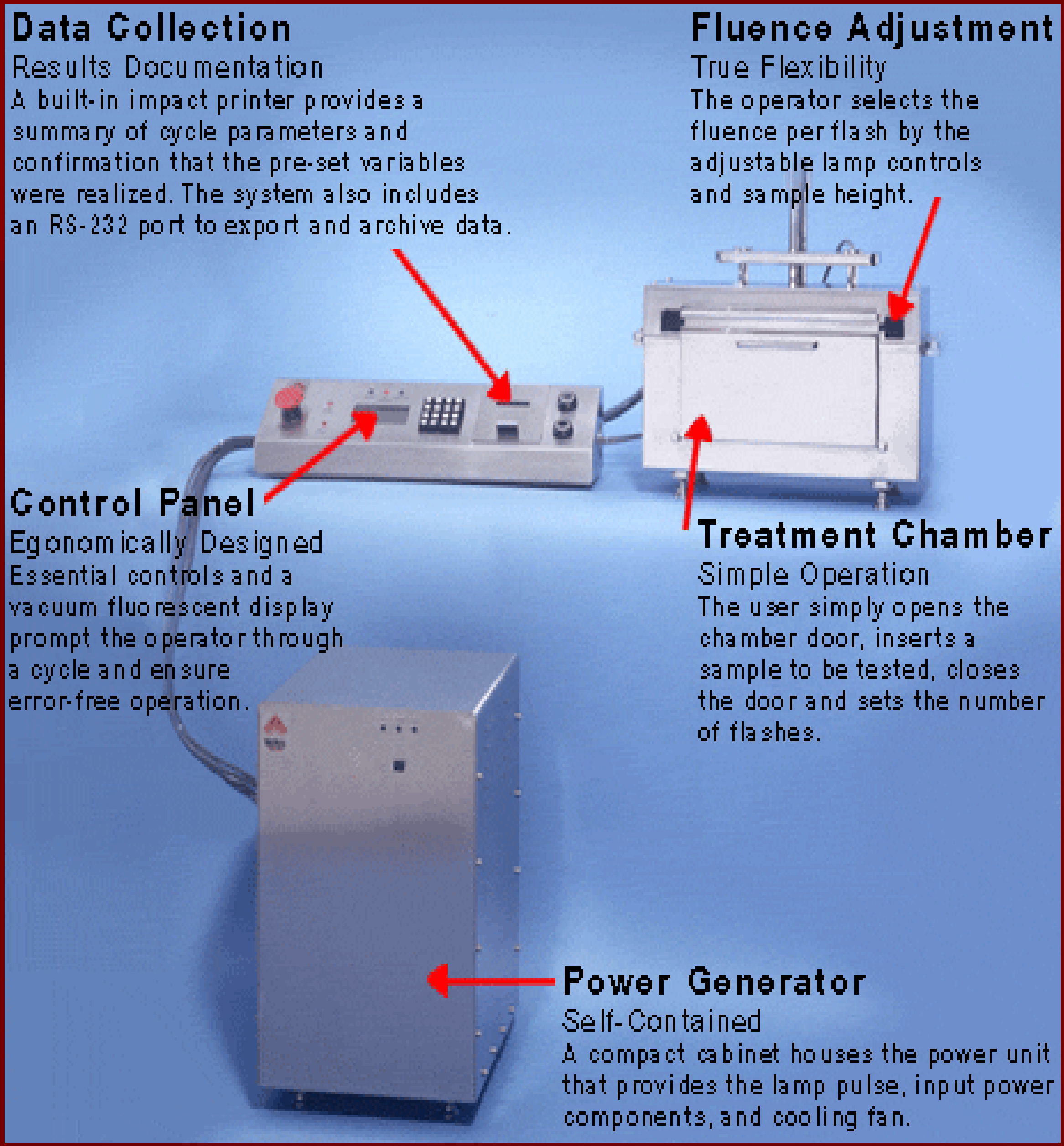


Introduction

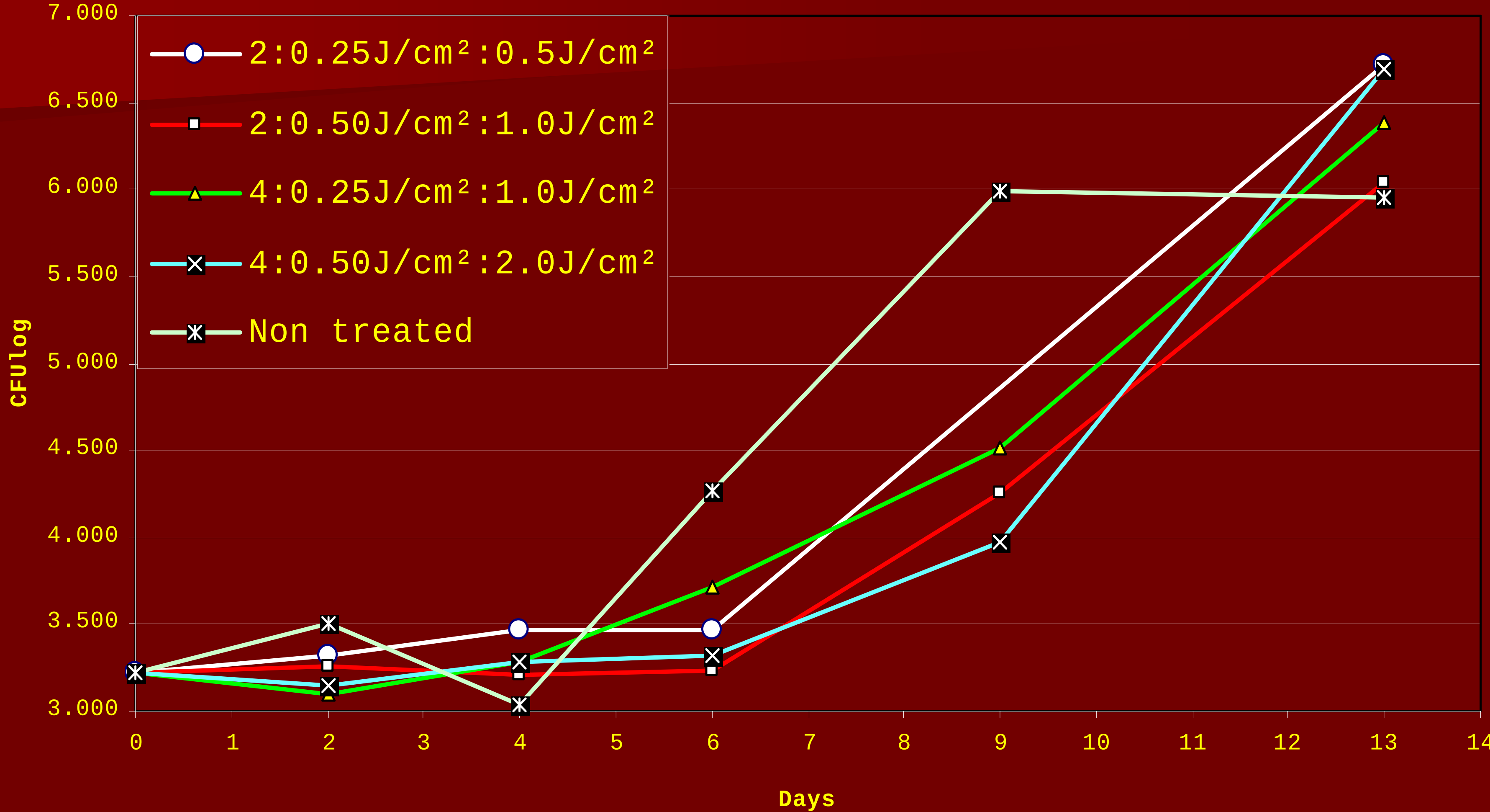
- PureBright ® Pulsed-Light



- The system

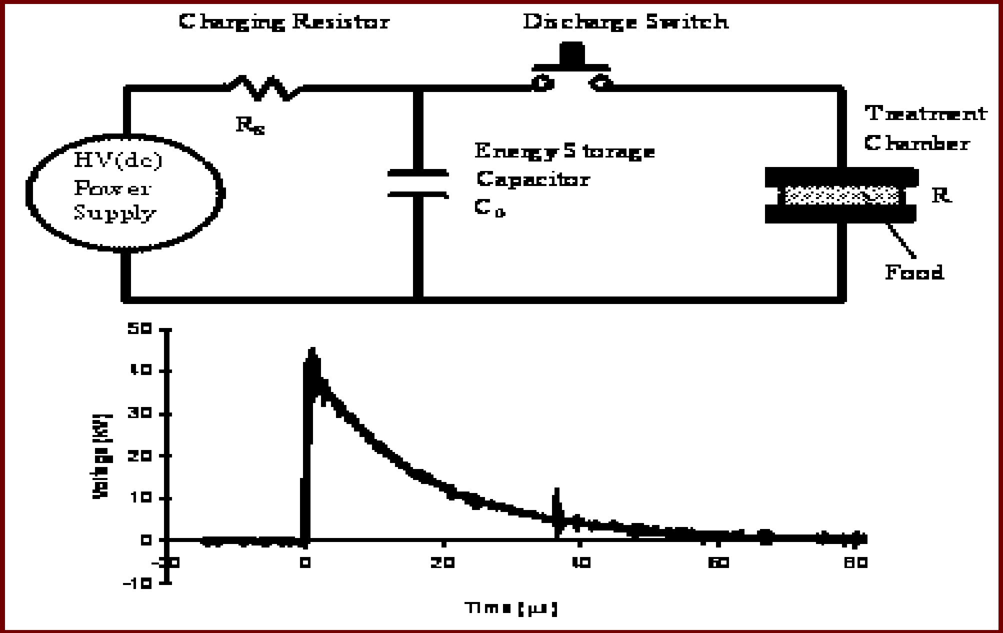

Data Collection
Results Documentation
A built-in impact printer provides a summary of cycle parameters and confirmation that the pre-set variables were realized. The system also includes an RS-232 port to export and archive data.
Fluence Adjustment
True Flexibility
The operator selects the fluence per flash by the adjustable lamp controls and sample height.
Control Panel
Egonomically Designed
Essential controls and a vacuum fluorescent display prompt the operator through a cycle and ensure error-free operation.
Treatment Chamber
Simple Operation
The user simply opens the chamber door, inserts a sample to be tested, closes the door and sets the number of flashes.
Power Generator
Self-Contained
A compact cabinet houses the power unit that provides the lamp pulse, input power components, and cooling fan.

Aerobic Plate Counts On Catfish fillets Exposed to Various Doses of Pulsed-Light



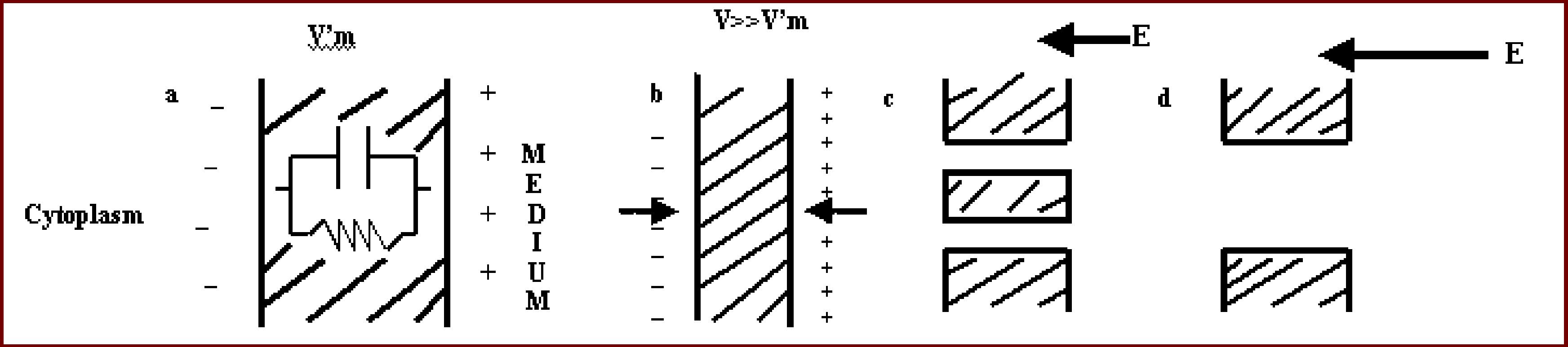
Pulsed Electric Field

- High intensity pulsed electric field (PEF) processing involves the application of pulses of high voltage (typically 20 - 80 kV/cm) to foods placed between 2 electrodes.
- PEF treatment is conducted at ambient, sub-ambient, or slightly above ambient temperature for less than 1 s, and energy loss due to heating of foods is minimized.



Pulsed Electric Field

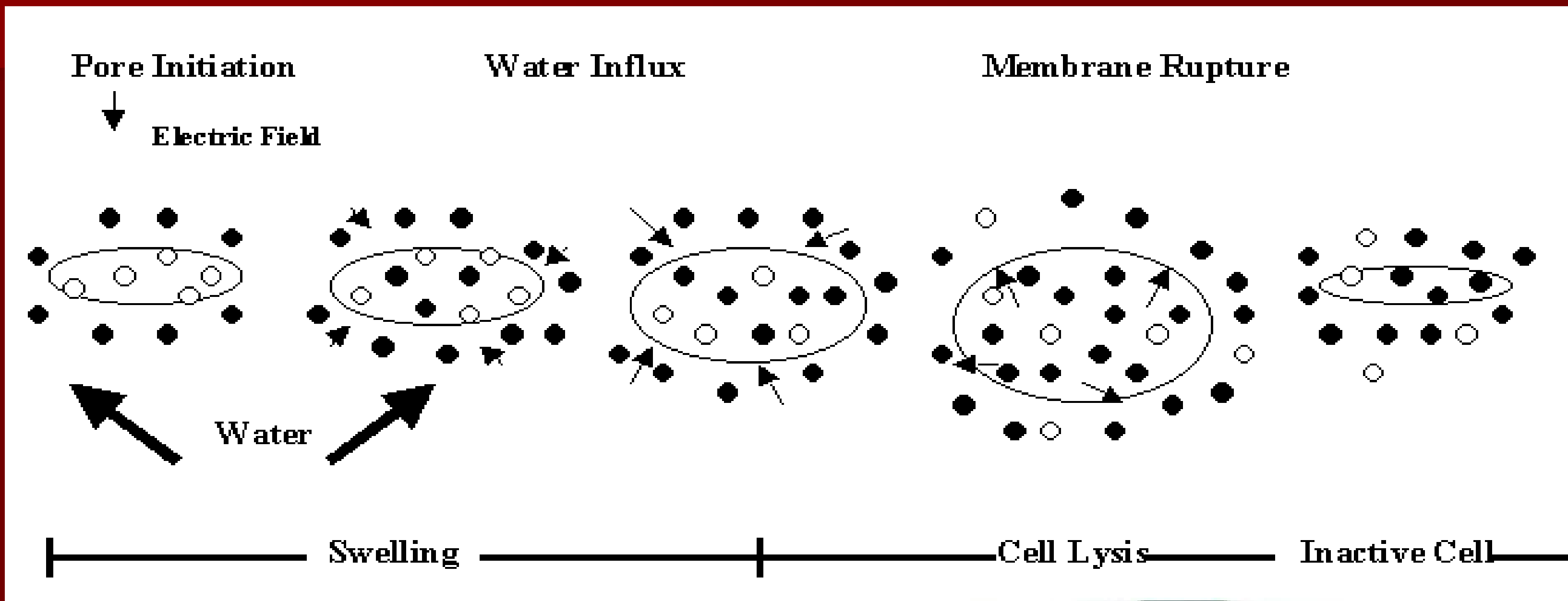
Mechanisms of Microbial Inactivation



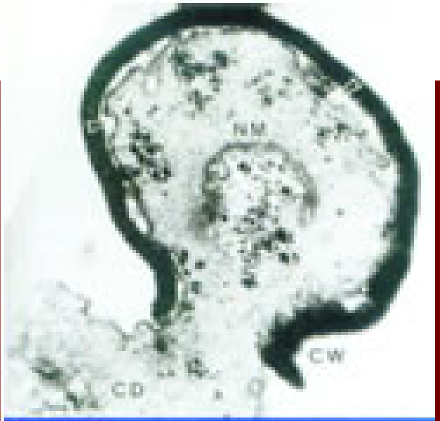
Schematic diagram of reversible and irreversible breakdown. (a) cell membrane with potential V'm, (b) membrane compression, (c) pore formation with reversible breakdown, (d) large area of the membrane subjected to irreversible breakdown with large pores (Zimmermann, 1986)

Pulsed Electric Field

Electroporation of a cell membrane



Control Cell



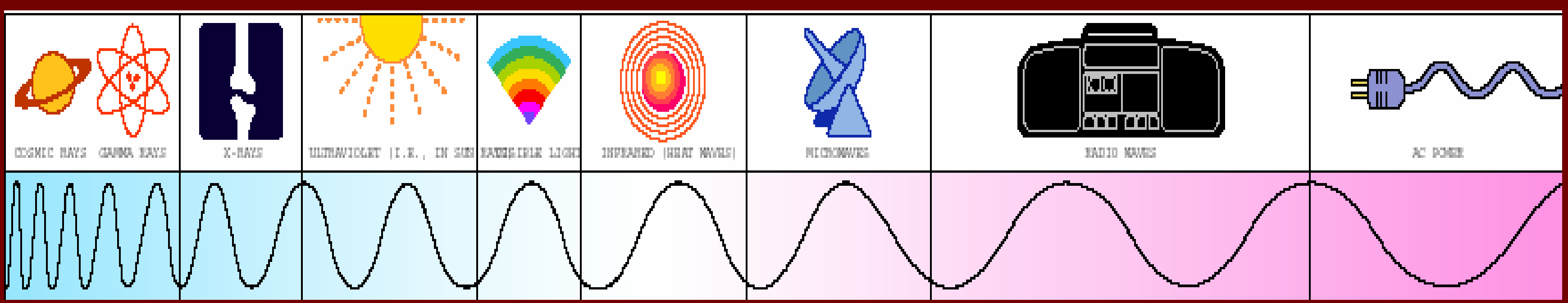
PEF Treated Cell

Pulsed Electric Field
Applications

- Processing of apple juice
- Processing of orange juice
- Processing of milk
- Processing of eggs
- Processing of green pea soup

Food Irradiation

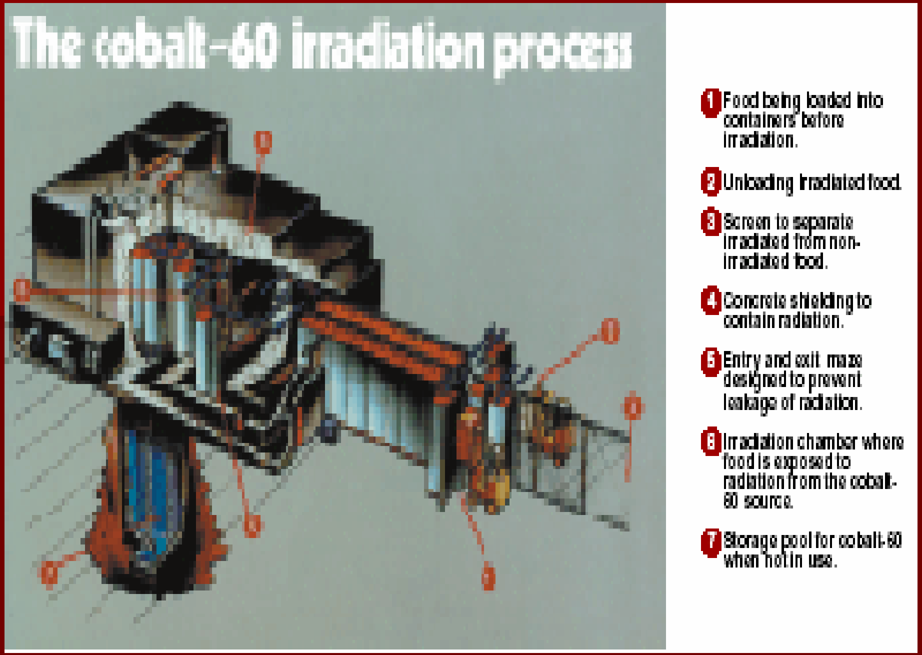
- Irradiation is a physical treatment of food with high-energy, ionizing radiation. It can be used to prolong the shelf life of food products and/or to reduce health hazards associated with certain products due to the presence of pathogenic micro-organisms.

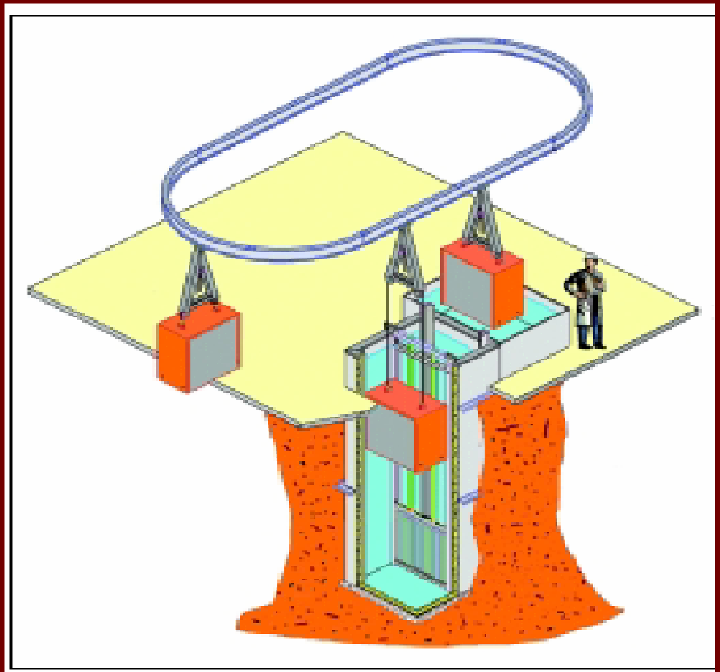


- With food irradiation, radiant energy (electrons, gamma rays, or x-rays) breaks chemical bonds, just as in cooking, but so few bonds are broken that the food is like fresh.

Food Irradiation
Applications

- The treatment may be applied for different purposes, such as:
- a) Prevention of germination and sprouting of potatoes, onions and garlic.
- b) Disinfestation by killing or sterilizing insects which infest grains, dried fruit, vegetables or nuts.
- c) Retardation of ripening and ageing of fruit and vegetables.
- d) Prolongation of the shelf life and prevention of food-borne diseases by reducing the number of viable micro-organisms in meat, poultry and seafood.
- e) Reduction of micro-organisms in spices and herbs.





Gray*Star Genesis Irradiator™ is capable of pasteurizing up to 60 million lb of fresh meat and poultry per year.

The table below lists some examples of treatment levels and the desired effect on the food item.

TYPE OF FOOD	DOSE IN kGy*	EFFECT
Meat, poultry, fish, shellfish, some vegetables, baked goods, prepared foods	20-70	Sterilization. Treated product can be stored at room temperature.
Spices and other seasonings	8-30	Reduces number of microorganisms and destroys insects. Replaces chemicals.
Meat, poultry, fish	1-10	Pasteurizes to protect against pathogens *(Salmonella, E. coli)* and delays spoilage.
Strawberries and some other fruits	1-4	Extends shelf life by reducing or eliminating molds and fungus.
Grain, fruit, vegetables	0.1-1	Kills insects or prevents them from reproducing. Could partially replace fumigants.
Bananas, avocados, mangoes, papayas, guavas and other noncitrus fruits	0.25-0.35	Delays ripening.
Pork	0.08-0.15	Inactivates trichinae.
Potatoes, onions, garlic	0.05-0.15	Inhibits sprouting

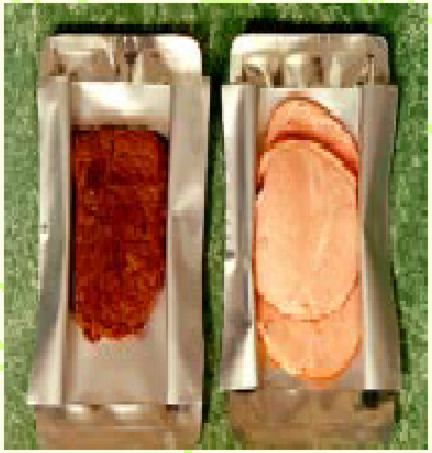
*kGy (kilogray). When a kilogram of matter absorbs the energy of one joule, this matter is said to have received a dose of one gray.

The above fresh fruits and vegetables were given a low dose (1-2 kGy) of irradiation to extend shelf life. The additional shelf life allows many products to be shipped overseas, thereby increasing the menu selection and acceptability. The bacon was given a high dose (25 kGy) to extend shelf life and significantly reduce the amount of nitrites required to cure the product.

Irradiation and its Effect on Cost
Example: Chicken, 29 oz. B Ration

	THERMOPROCESSED	IRRADIATED
COST/CAN	$4.72	$4.81
Net Weight (29 ounces)	15 oz. chicken 14 oz. liquid	27 oz. chicken 2 oz. liquid
3 oz. Portion	5 Portions	9 Portions
Cost/Serving	$0.944	$0.534

NASA has used irradiated foods since the 1970's. Currently two entrees, grilled beef steak and smoked sliced turkey, are regularly provided to NASA's space shuttle program through a joint agency Memorandum of Understanding. Additional products, such as beef teriyaki, breakfast sausage and BBQ beef brisket, are being developed for the International Space Station. Products like these could be utilized by the Meal Ready-to-Eat program in the future.

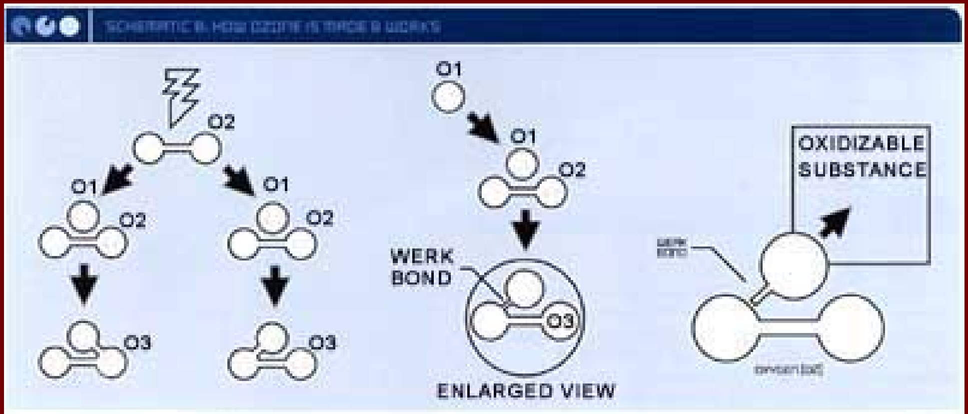


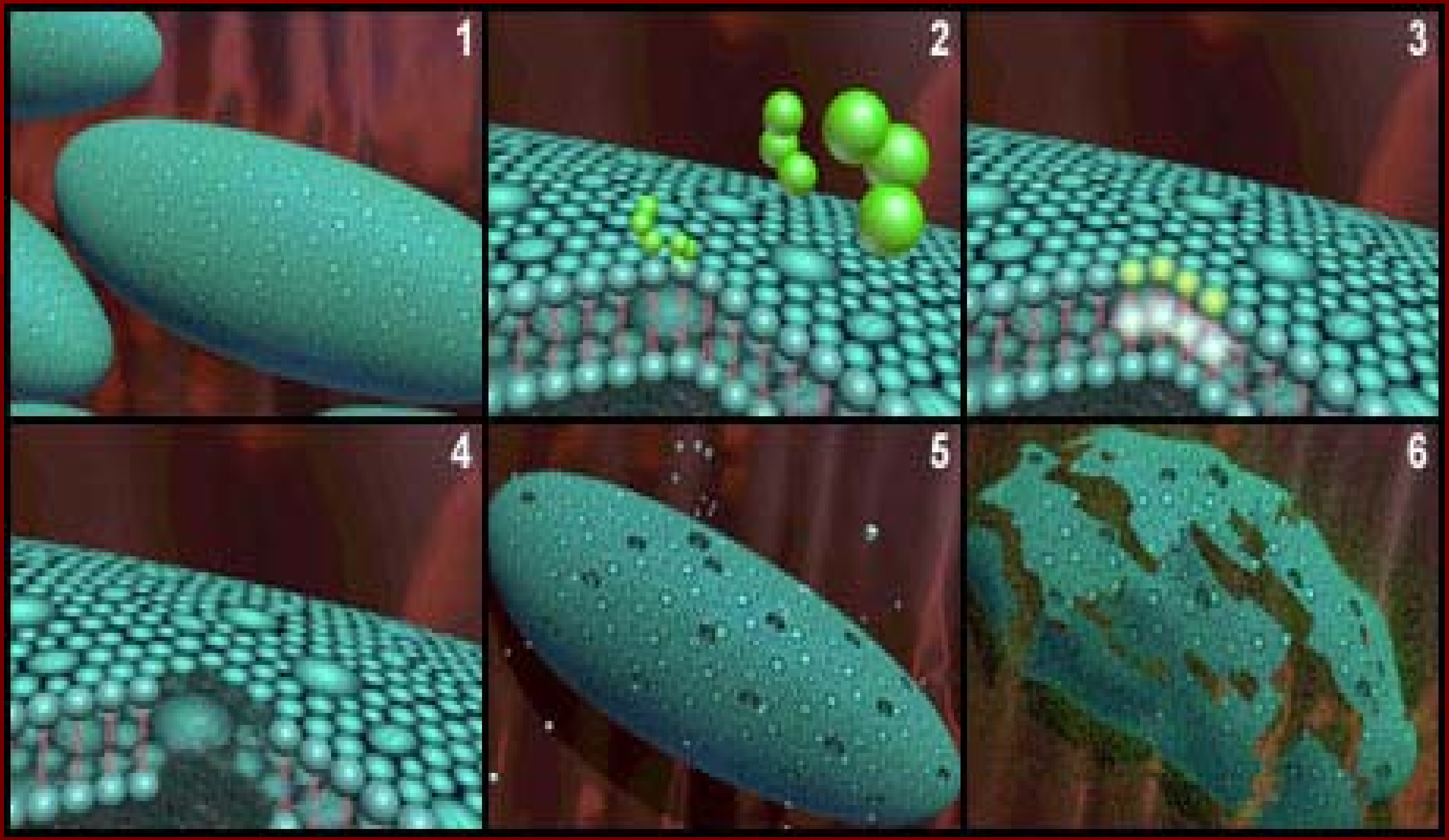
Ozone Technology

- Oxygen molecules (O_2)are split when passed through a gap formed by a high voltage electrode.

$$O_2 + \text{energy} \rightarrow 2\,O\bullet$$
$$O\bullet + O_2 \rightarrow O_3$$

- High voltage, at high frequency, is then applied to the electrodes. The plasma formed in the gap is known as a Corona Discharge, and it is here that some of the oxygen molecules split and recombine to from ozone:





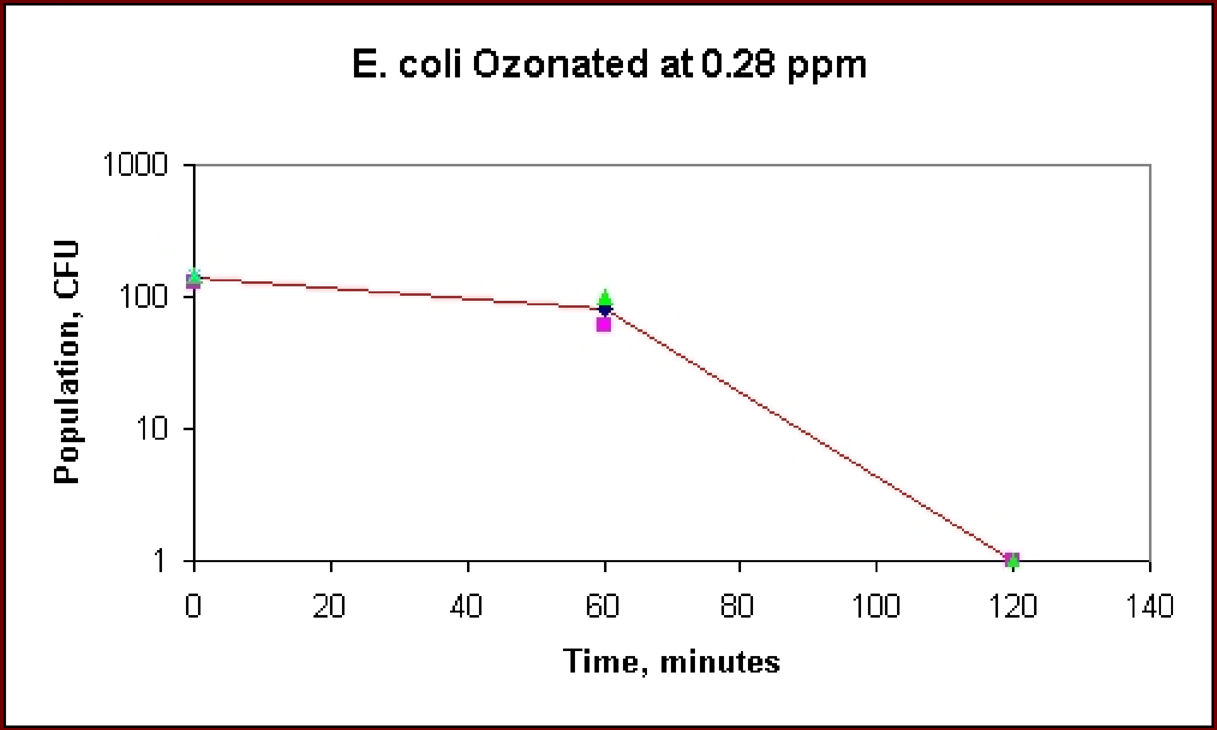
1 - Computer generated image of a bacteria cell
2 - Close-up of ozone molecule coming into contact with bacterial wall
3 - Ozone penetrating and creating hole in bacterial wall
4 - Close-up effect of ozone
5 - Bacterial cell after a few ozone molecules come into contact
6 - Destruction of cell after ozone (cell lysing)

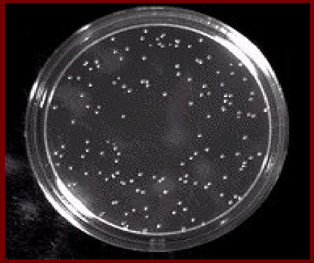
Taste and Odor Changes Caused by Ozonation

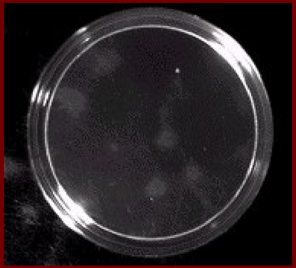
Description of Taste and Odor	Taste or Odor Intensity
Fruity	Both Increase
Musty	Both Decrease
Muddy (MIB)	Both Decrease
Earthy (Geosmin)	Both Decrease
Fishy	Both Decrease
Astringent	No Change
Plastic	No Change

Ozone Technology

Results of E coli exposed to airborne ozone







Psychrotrophic Plate and Total Colifrom Counts of Treated Catfish Fillets

Product	Treatment (Concentration)	PPC	TCC
		………….. Log CFU/g	…………..
Hydrogen Peroxide	Control	4.61	3.53
	4000 ppm	4.23	3.06
	7000 ppm	3.91	2.61
Ozone	Control	5.03	2.83
	5 ppm	4.98	2.7
	10 ppm	4.26	2.31
Salt	Control	5.23	3.56
	1% salt + 0.5% Ascorbic Acid	4.86	3.22
	10 % Brine	4.39	2.91

High Pressure Process

- Novel non-thermal food processing method that uses pressure to provide safe, minimally processed foods with superior appearance, taste, texture, and nutritional value as compared to traditional heat processed foods

  - liquid and solid foods with or without packaging

- Inactivation of microorganisms

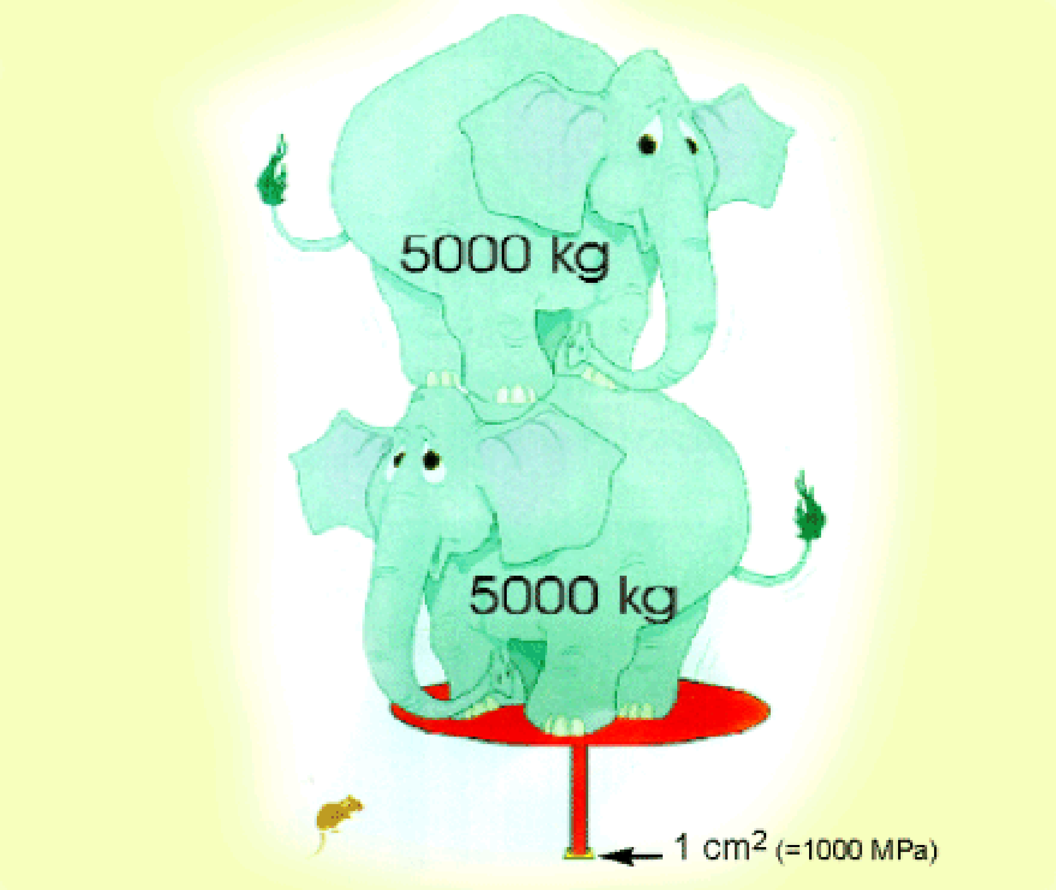
- Pressure range from 100-800 MPa

HPP mechanisms of inactivation

- The various effects of high hydrostatic pressure can be grouped into

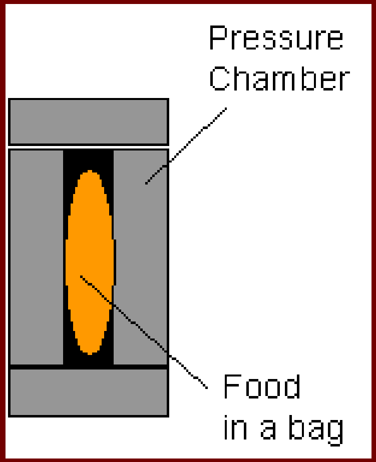
1. cell envelope-related effects,
2. pressure-induced cellular changes,
3. biochemical aspects, and
4. effects on genetic mechanisms.

High Pressure Process

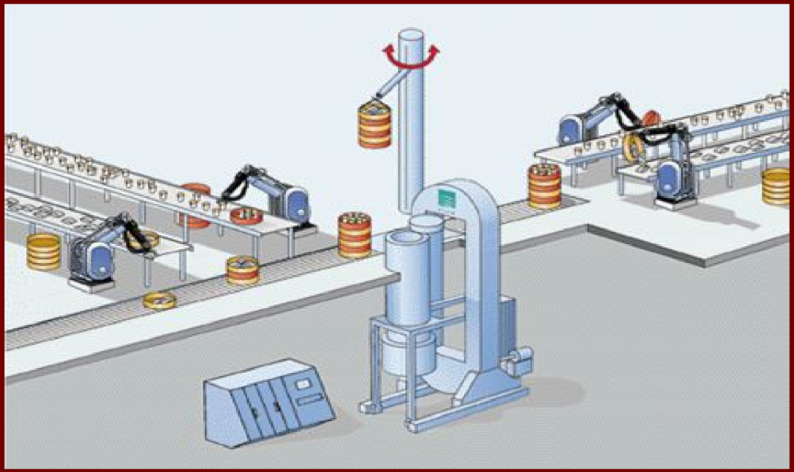


High Pressure Process

- The equipment used for hydrostatic food treatment fits in two categories — batch and continuous.
- Batch can accommodate both liquid and solid foods



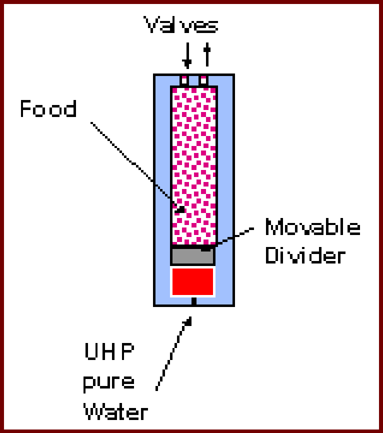
Batch schematic (left) and batch system (right) for pre-packaged production

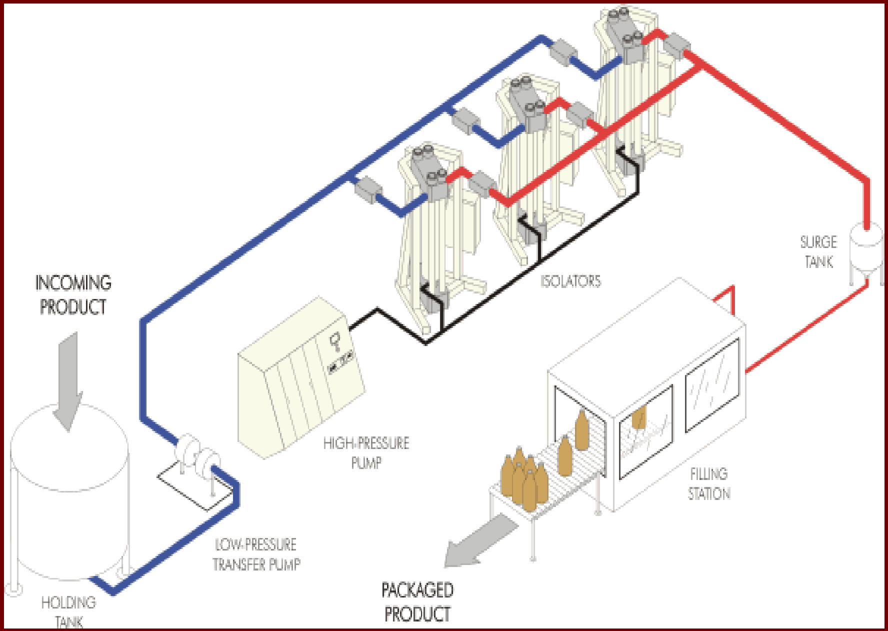


Prepackaged "batch" hydrostatic pressure production system

High Pressure Process

- Continuous for fluid products such as juice, salsas, and purees that can be pumped

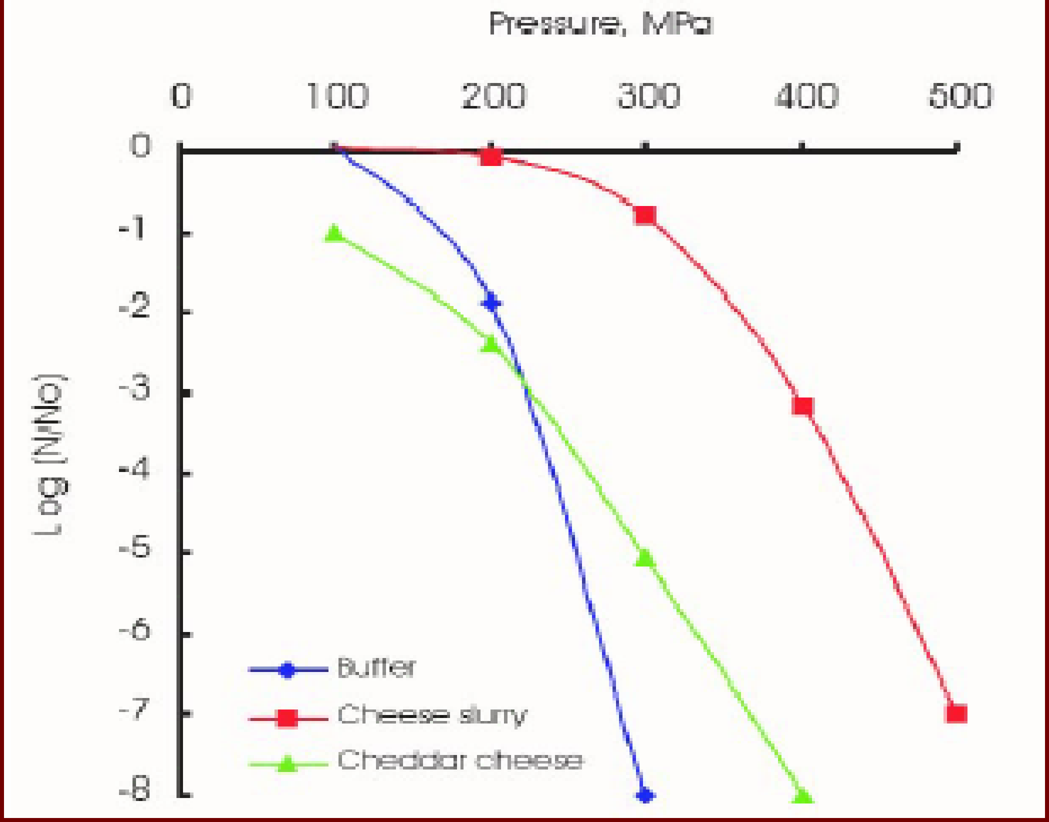




Isolator schematic (left) and isolator system (right) for in-line production

Isolator based "in-line" hydrostatic pressure production system

HPP inactivation of E.coli K12 in three different media (N0 is total number of bacteria in the control and N is the number of cells detected following pressurisation treatment)



High Frequency Ultrasound

- Ultrasound is energy generated by sound waves of 20,000 or more vibrations per second.
- Presently, most developments of ultrasonics (sonication) for food applications are nonmicrobial in nature (Hoover 1997).
- High frequencies in the range of 0.1 to 20 MHz, pulsed operation and low power levels (100 mW) are used for nondestructive testing (Gunasekaran and Chiyung1994).

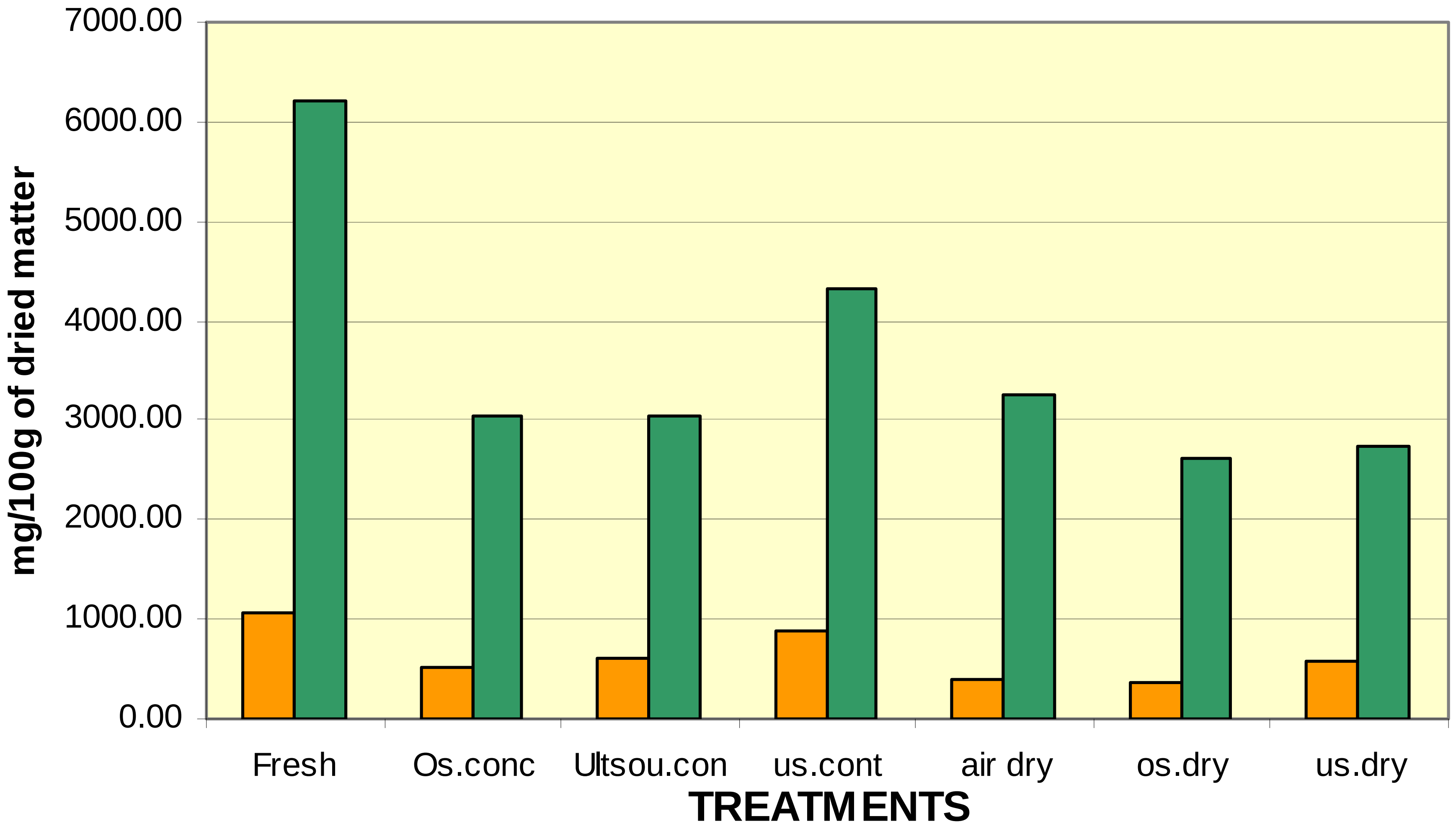
Ultrasound mechanisms of inactivation

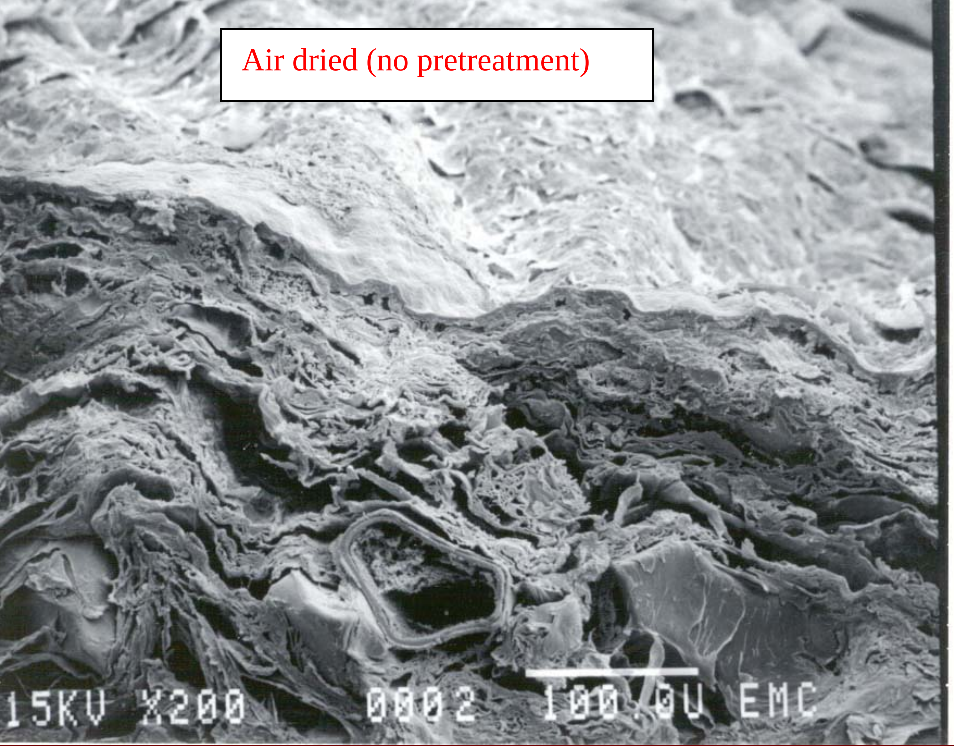
- Shear disruption
- Cavitation (creation of bubbles in liquid foods)
- Thinning of cell membranes
- Localised heating and free radical production

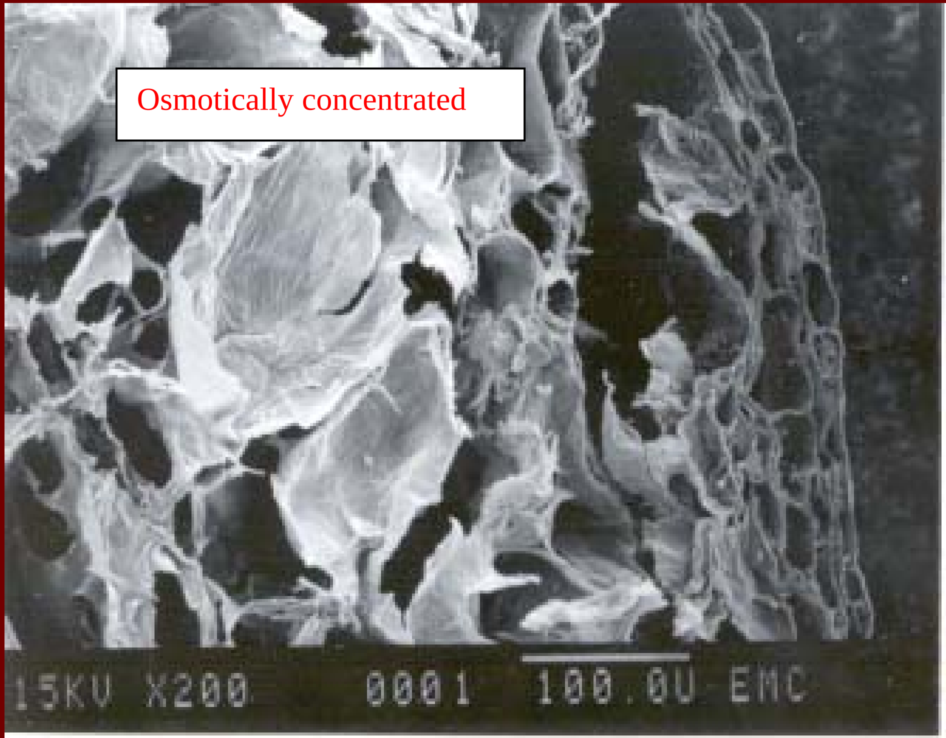
Application of processing

- Tenderisation in meat tissues (myofibrillar proteins)
- Destroying microbial cells, when combined with other treatments, including heating, pH modification, and chlorination.
- Drying

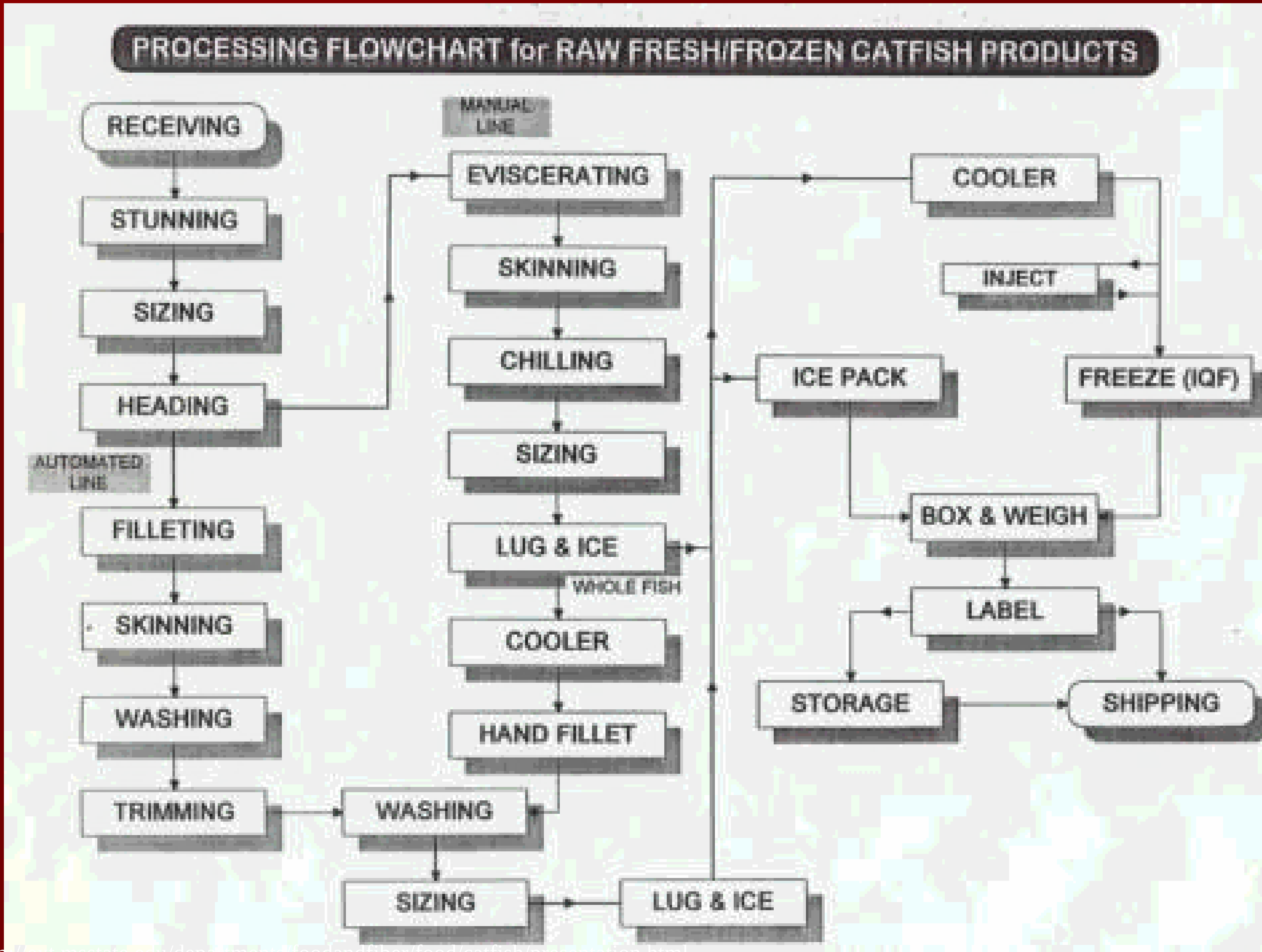
ANTHOCYANINS AND PHENOLICS IN DRY MATTER OF DIFFERENTLY TREATED BLUEBERRIES



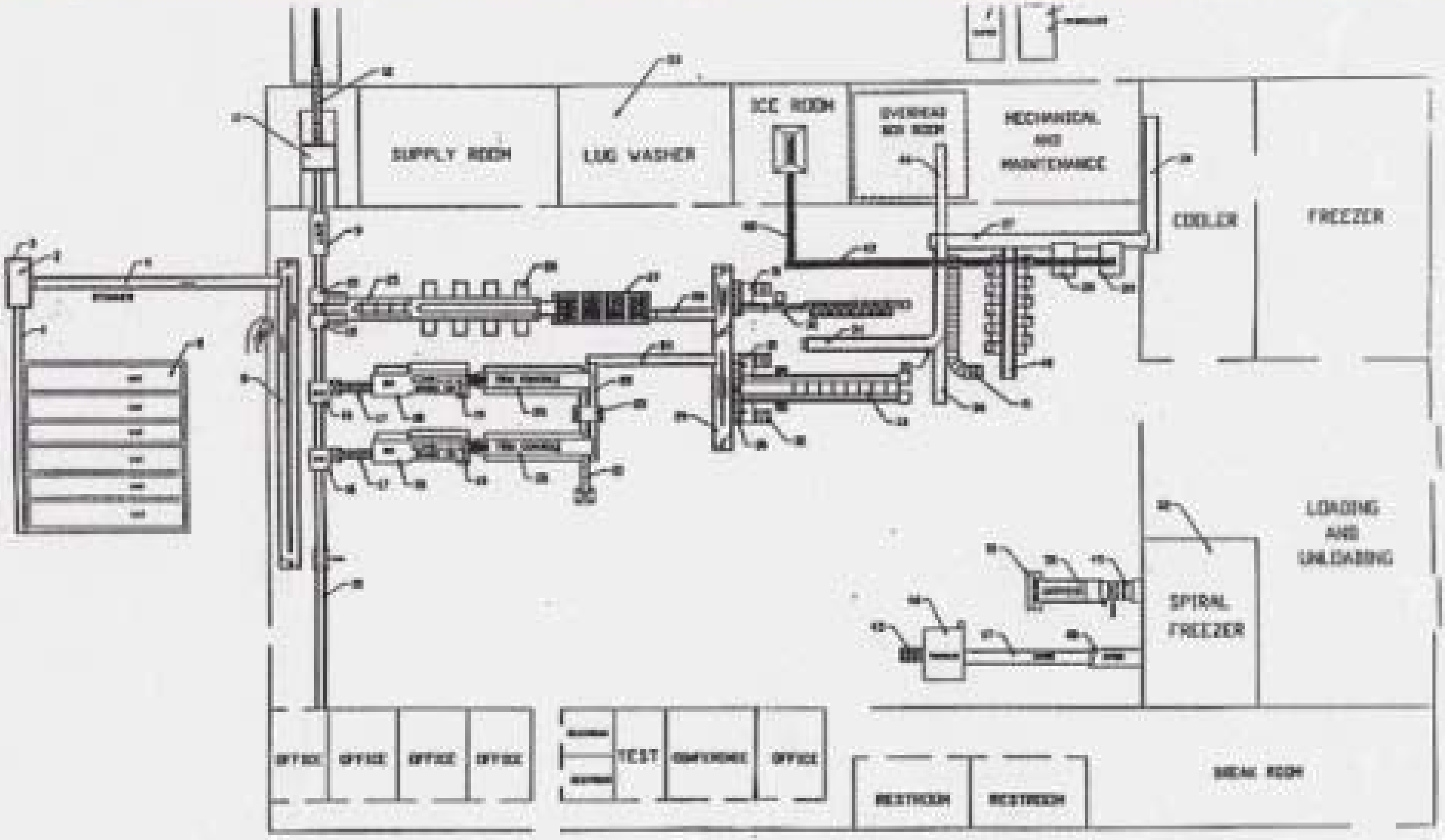

Air dried (no pretreatment)
15KV X200 0002 100.0U EMC


Osmotically concentrated
15KV X200 0001 100.0U EMC

Catfish Processing



http://ext.msstate.edu/departments/foodandfiber/food/catfish/presentation.html



SUPPLY ROOM
LUG WASHER
ICE ROOM
OVERHEAD
MECHANICAL
AND
MAINTENANCE
COOLER
FREEZER
LOADING
AND
UNLOADING
SPIRAL
FREEZER
OFFICE
OFFICE
OFFICE
OFFICE
TEST
OFFICE
RESTROOM
RESTROOM

Cryogenic Freezing

- Cryogenic freezing through direct impingement with either liquid nitrogen (N2) or carbon dioxide (CO2) has revolutionized the food industry.
- Formulations, shape, type of food, handling concerns and product safety are taken into account when attempting to achieve high product quality while reducing product temperature.
- Improvements in baseline production rates are achieved by reducing the amount of time it takes to remove heat from a product.
- Additional benefits of cryogenic freezing include a marked increase in product yield due to less dehydration.

Cryogenic Freezing

Carbon Dioxide vs. Liquid Nitrogen

Physical Properties of Nitrogen and Carbon Dioxide

Nitrogen and carbon dioxide, both consumable refrigerants, are being used in cryogenic freezing of food products. Although their similarities include using vapor in combination with either the solid or liquid form to remove heat from a product, their physical properties differ.

	Nitrogen	Carbon Dioxide
Chemical Formula	N_2	CO_2
Molecular Weight	28.01	44.01
Specific Gravity at 70°F (21°C)	0.97	1.53
Specific Volume at 70°F (21°C)	13.8 ft^3/lb	8.73 ft^3/lb
Temperature	-320°F (-195.5°C) boiling point	-109°F (-78.3°C) solid

Major Types of Cryogenic Tunnels

Flat Belt Tunnel Freezer

Multi-pass Tunnel Freezer

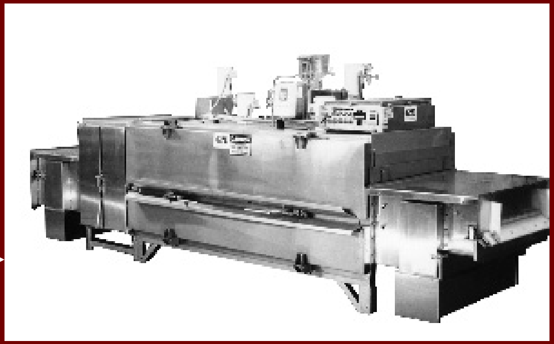
Flighted Tunnel Freezer

Immersion Freezer

Spiral Freezer

Cabinet (Batch) Freezer

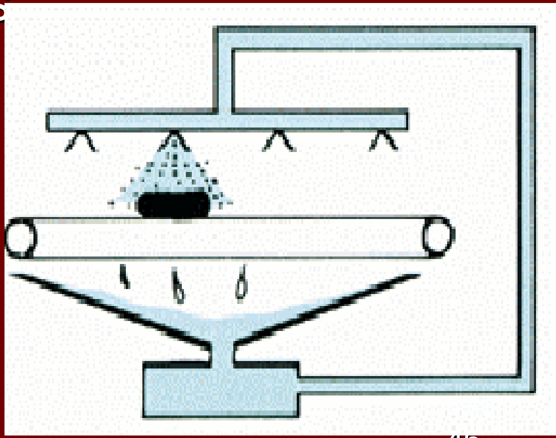
Tumbler



Cryogenic Freezing

IQF (individually quick frozen)

- A flighted system allows IQF food products to gently tumble as they freeze.
- The tumbling provides cryogen contact over all surfaces, ensuring that pieces remain separate.
- An advanced, accelerated form of blast freezing in which individual products (e.g., shrimp, fillets) are exposed to super-cold air or, more commonly, to sprays of liquid nitrogen or carbon dioxide at temperatures of minus 150° F or colder.
- Cryogenic freezing offers distinct quality benefits including a taste and texture more resembling fresh seafood.



Mechanical Freezing

- The term “mechanical refrigeration” generally refers to any system that uses electrical power to produce chilled air.
- The chilled air is continuously passed over the food product, and in doing so, it removes heat.
- Mechanical freezing systems are characterized by a large capital investment, a significant ongoing preventive maintenance cost, and a sizeable permanent commitment of plant space.
- In some cases, mechanical refrigeration systems tend to dehydrate, or strip moisture from that product.

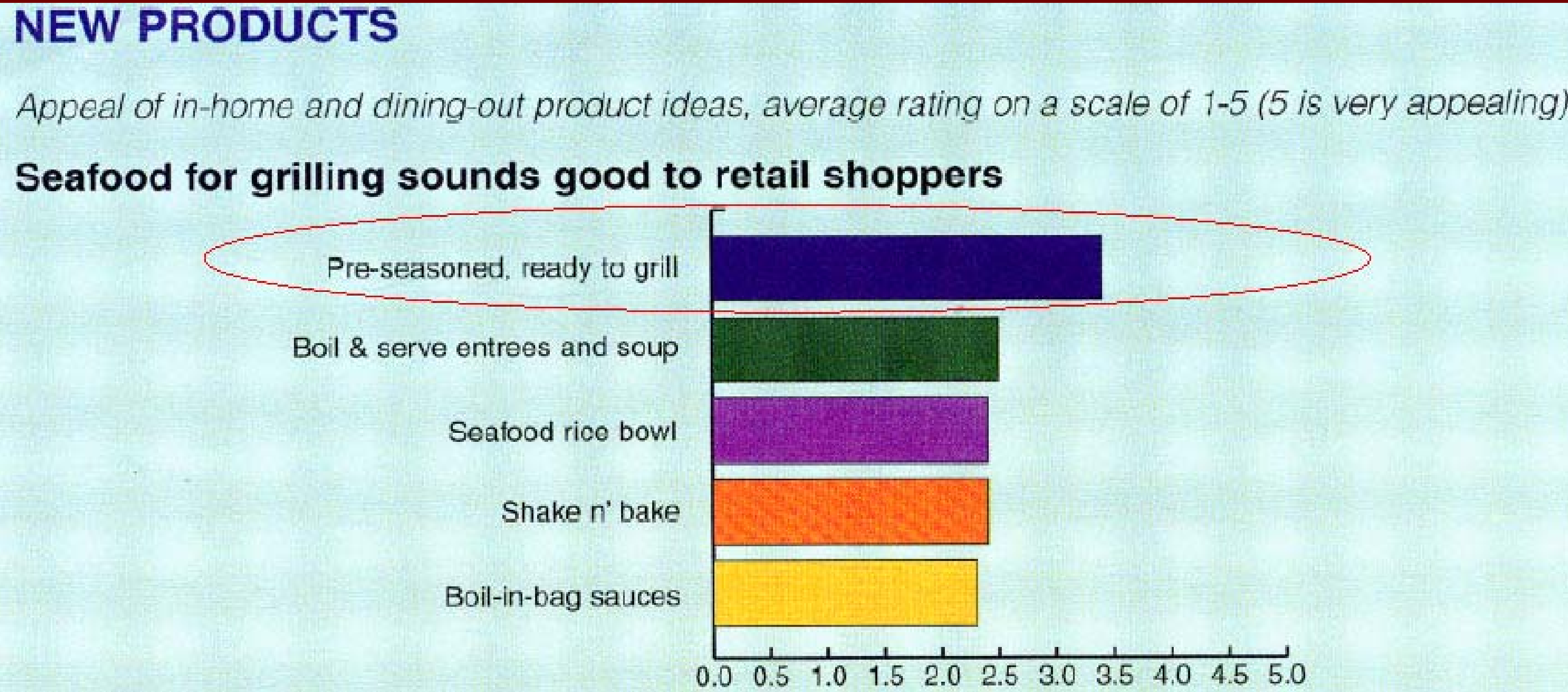
Comparison of energy usage for food freezing systems

Goals of marination

- Induce rapid uptake of solution
- Minimize purge loss
- Minimize cooking loss
- Enhance flavor

Marination: marinade

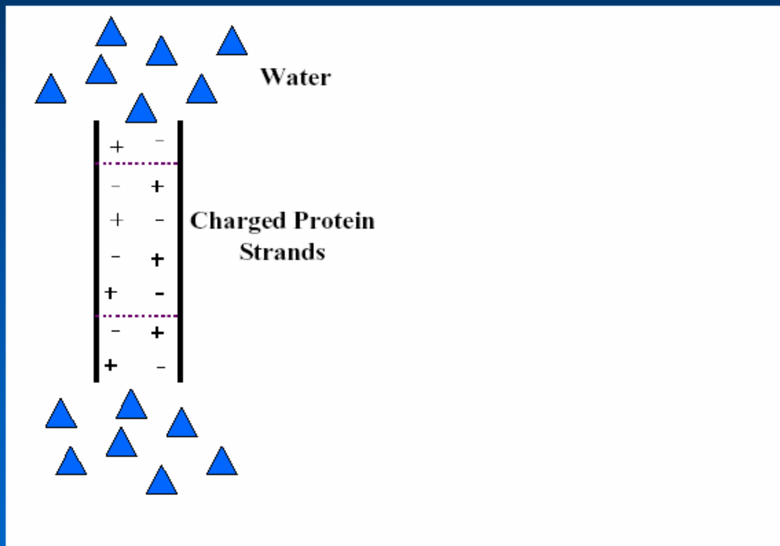
- Solution added to muscle to increase yield and enhance flavor



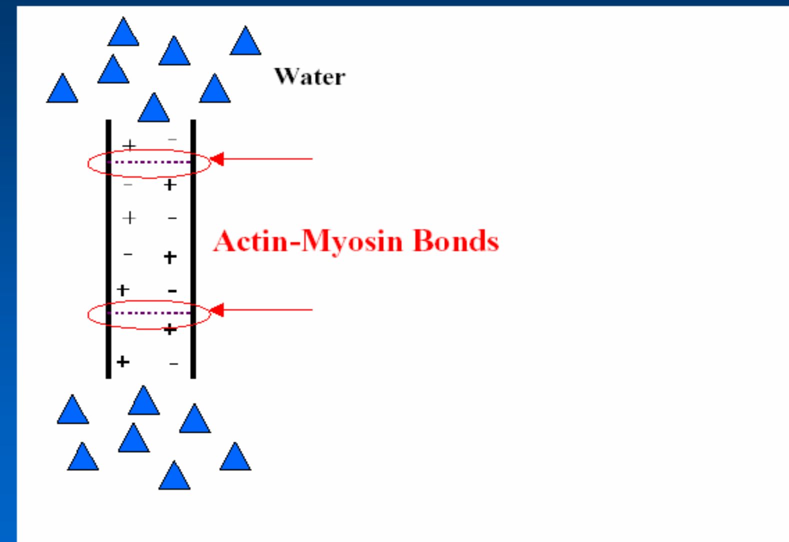
Solution uptake and retention is affected by

- pH (relative acidity)
- Ionic strength (salts)
- Specific phosphate effects
- Time & mechanical action
- Surface area of exposure
- Muscle history

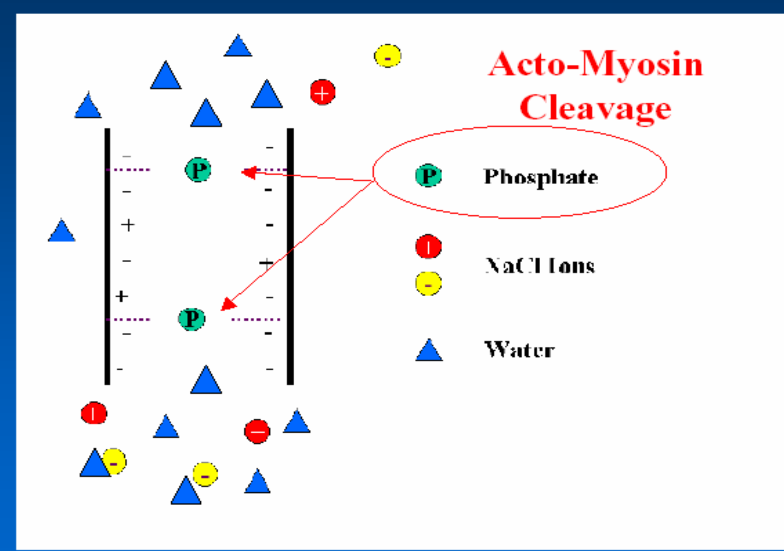
Progressive changes in muscle structu aiding water uptake and retention



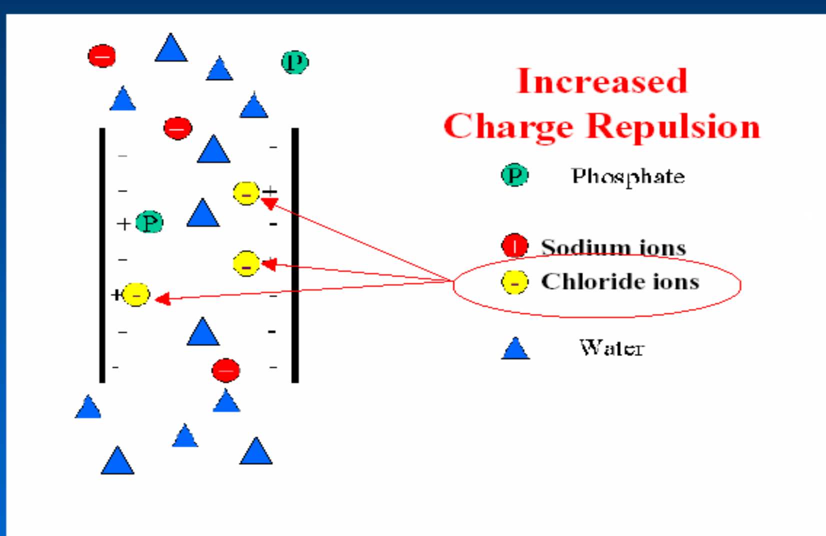
Progressive changes in muscle structu aiding water uptake and retention



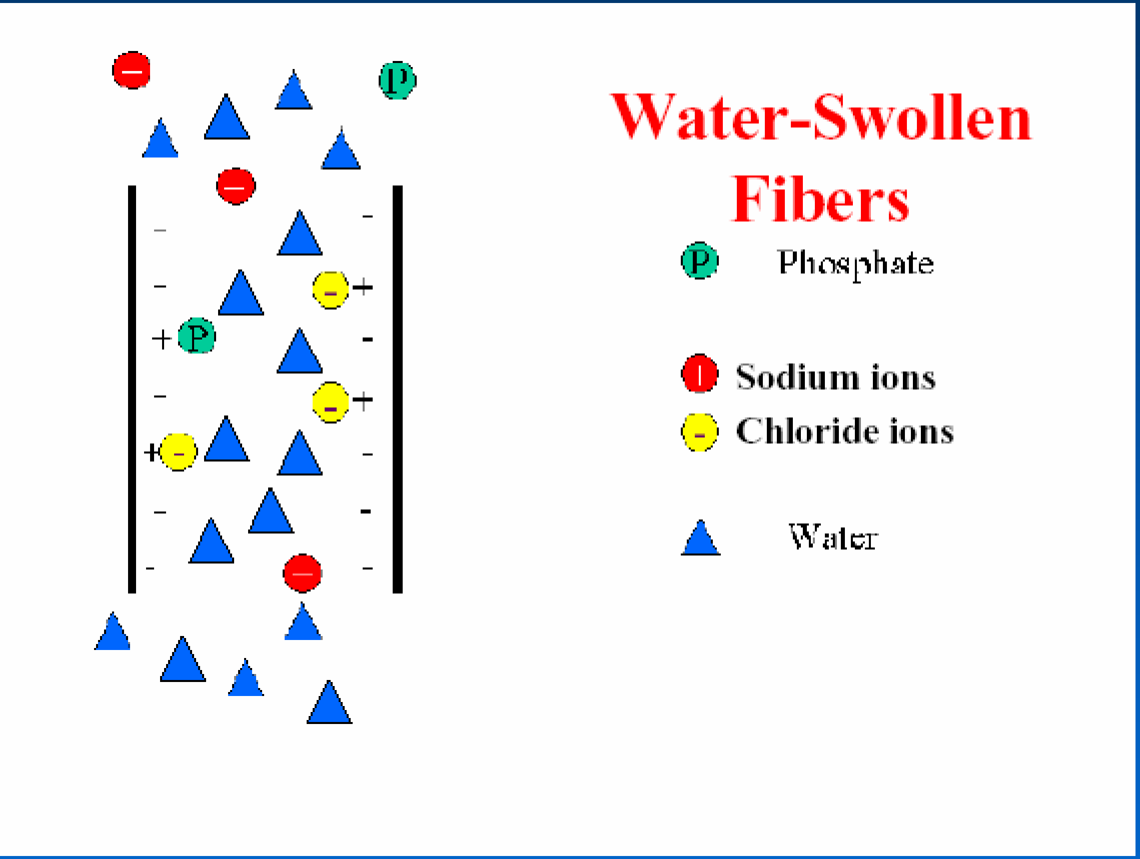
Progressive changes in muscle structure aiding water uptake and retention



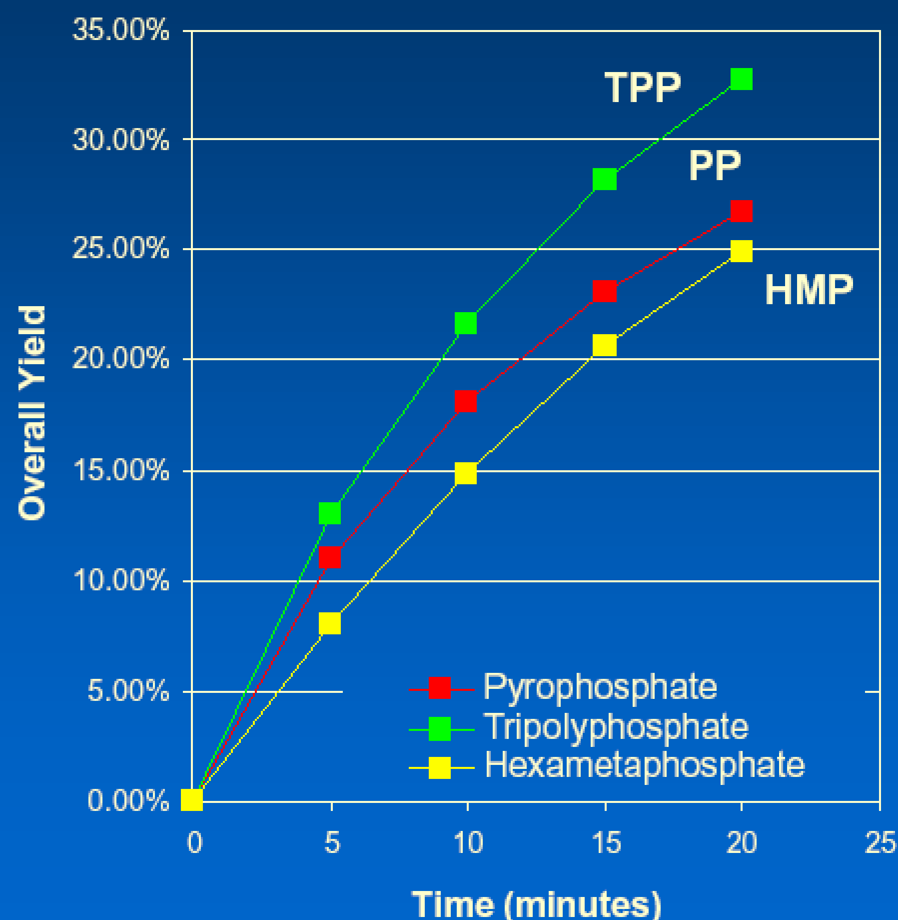
Progressive changes in muscle structu aiding water uptake and retention



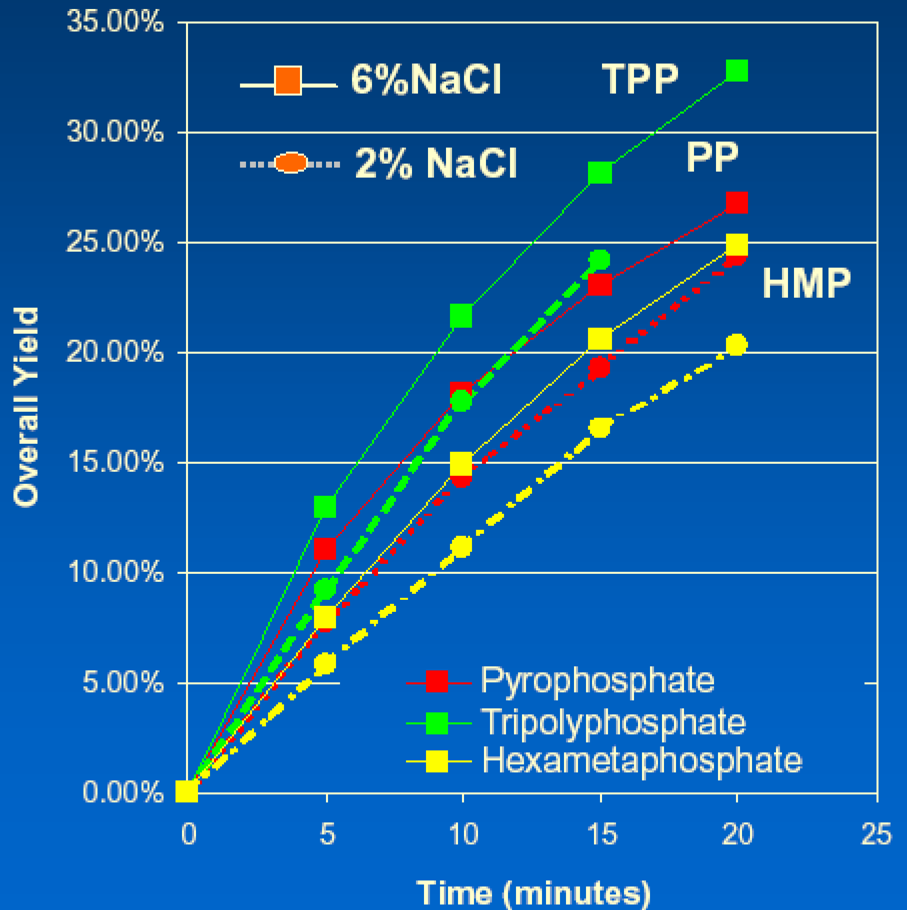
Progressive changes in muscle structure aiding water uptake and retention



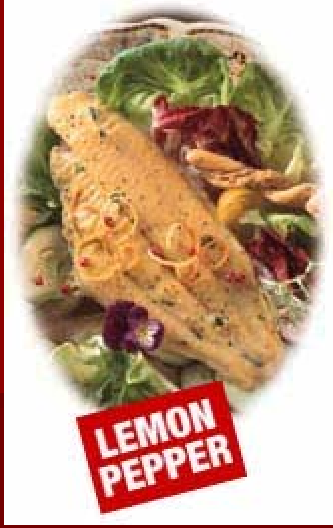
Uptake of Solution
(Phosphate effects @ pH 8, 6% NaCl)

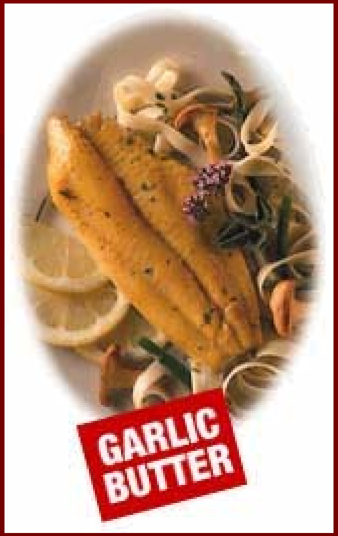


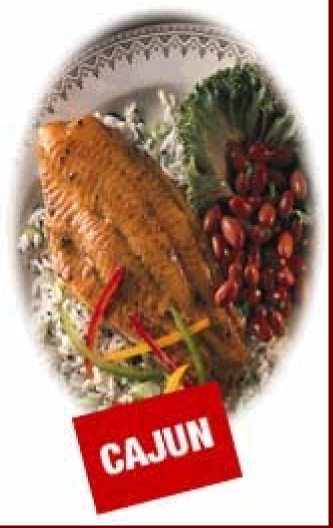
Uptake of Solution
(Phosphate and NaCl effects @ pH 8)



MARINATED FILLETS

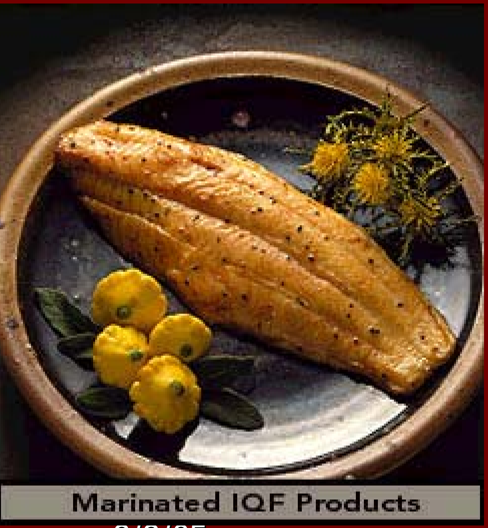






Ingredients: catfish, water, salt, spices, butter flavor, (flavor, annato, turmeric), sodium phosphates, dehydrated lemon peel, natural flavor (maltodextrin, sugar, flavoring, lecithin, BHT), citric acid, sugar natural flavor, poly-sorbate 80, extractive of turmeric

Ingredients: catfish, water, salt, paprika, spices, sugar, sodium phosphate, dehydrated dehydrated garlic, and less than 2% silicon dic to prevent caking



OXYGEN REDUCED (OR) STORAGE ADVANTAGES AND DISADVANTAGES

- Increased AQL/Shelf life
- Bulk handling (less labor)
- Can be retail pack in pallets/container

- Always subject to abuse (temperature)
- Expensive
- *Clostridium botulinum (anaerobic, psychrotrophic pathogens)*
- FDA