Incorporation of Antimicrobials into Packaging Materials

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Overview

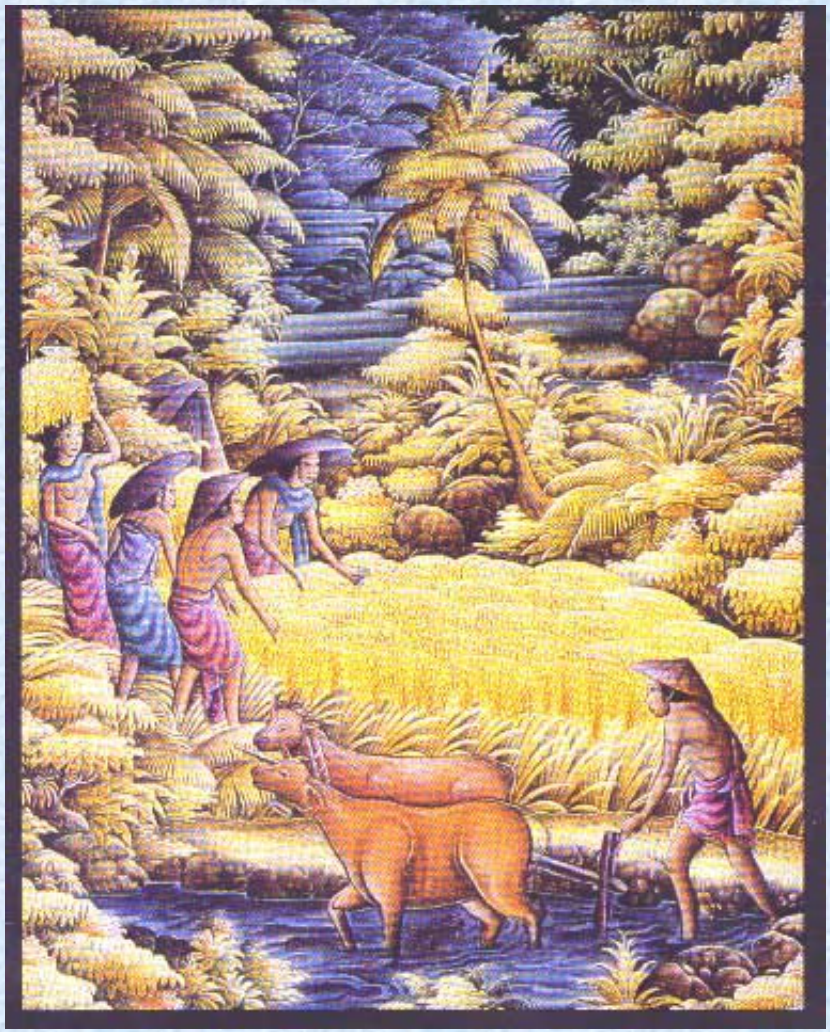
- History of Packaging
- Types of Packaging
  - Flexible
  - Active
  - Antimicrobial Edible Gels, Films and Coatings
  - Antimicrobial Polymers
- Summary

History of Packaging

Food packaging can be considered the direct result of humans' progression from hunter and forager to a producer and processor of foods.

(Sacharow and Griffin, 1970)

History of Packaging



As humans learned to hunt more efficiently, to till the soil, and to specialize in the manufacture of weapons, tools, and household utensils, humans also invented methods to protect food products from dirt and damage.

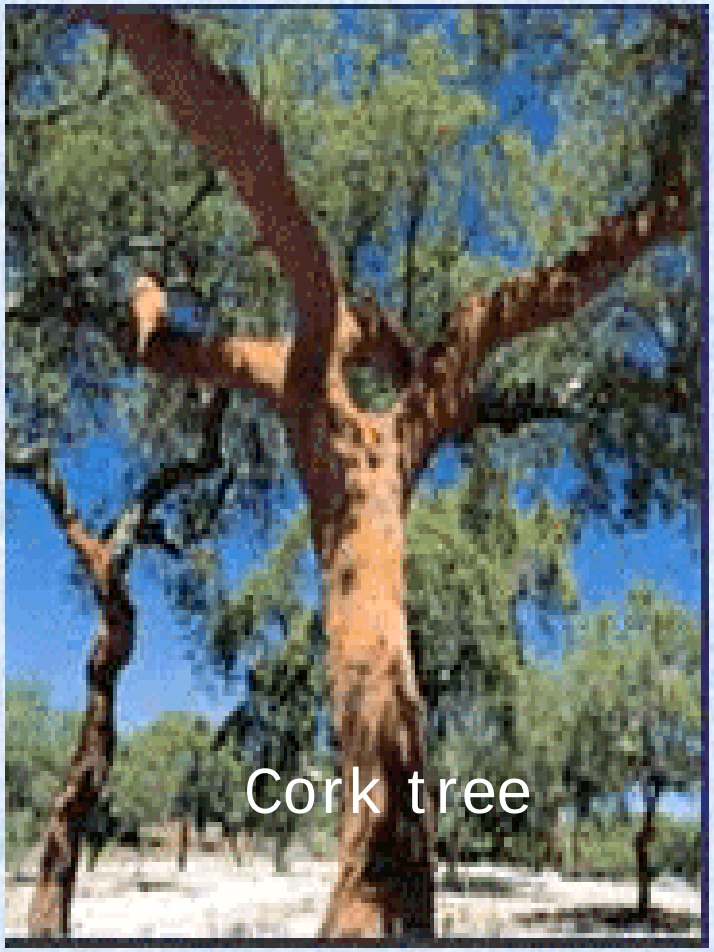
(Kelsey, 1989).

History of Packaging

Early examples of natural containers to store and eat foods included tree trunks, gourds, shells, leaves, papyrus, woven twigs, animal hides, animal parts such as bladders or horns, and pieces of bark.

(Sacharow and Griffin, 1970; Kelsey, 1989).

History of Packaging



Soon, humans learned to seal out contaminants by adding beeswax or pitch, pouring honey, lard, or oil directly over the food or plugging the openings to the containers with cork. (Sullivan, 1976).

History of Packaging

Significant advancements in food preservation included the invention of preserving foods in corked glass containers subjected to heating in a water bath by Appert.

(Kelsey, 1989).

History of Packaging

During the early 20th century, improvements were made to both rigid and flexible packaging materials: aluminum foil was manufactured and cellophane film was given heat sealability and resistance to moisture…

(Sacharow and Griffin, 1970)

History of Packaging

…heat shrinkable polyvinyl chloride (PVC) was introduced and nylon was integrated into packaging films…

(Sacharow and Griffin, 1970)

History of Packaging

…steel cans were modified with coatings; cans were developed with aluminum alloys; and improvements were made to the formation of cans used in food processing.

(Sacharow and Griffin, 1970).

History of Packaging

During the latter part of the twentieth century, plastic jars, bottles, tubs, and films from polyolefins, polyvinyl, …

History of Packaging

….polyethylene, vinyl chloride, surlyn, and nylon became the packaging of choice for food manufacturers as well as consumers.

(Sacharow and Griffin, 1970)

Types of Packaging

- Flexible
  - Non-Edible
  - Edible
- Active
- Antimicrobial Edible Gels, Films and Coatings
- Antimicrobial Polymers

Types of Non-Edible Flexible Packaging Materials

- Vacuum packaging
- Modified atmosphere packaging
- Controlled atmosphere packaging
- Shrink wrap
- Plastic wraps and storage bags

Types of Edible Flexible Packaging Materials

- Gels
- Coatings
- Films

Active Packaging

- Preferential permeability
- Temperature compensating
- Scavenging systems
- Moisture absorbing
- Controlled release (colorants, flavors, spices, minerals, antimicrobials, ethanol, or antioxidants)
- Odor absorbing

Active Antimicrobial Packaging

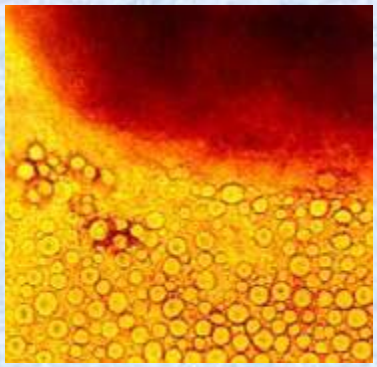
- The incorporation and/or slow release of antimicrobials from packaging materials is receiving considerable attention as a means of extending the bacterial lag phase, slowing the growth rate of microorganisms, prolonging shelf life, and maintaining food safety.

Active Antimicrobial Packaging

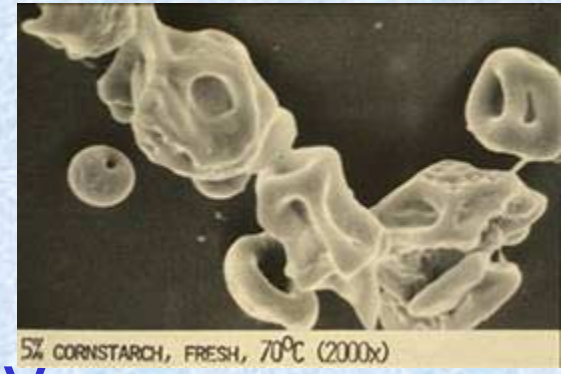
- The general premise of antimicrobial packaging is a controlled migration of the compound to the food through diffusion or partitioning which not only allows for initial inhibition of undesirable microorganisms, but also residual activity over time

(Han, 2000)

Types of Edible Gels, Films or Coatings



- Lipid (fats, waxes, or oils)
- Polysaccharide (starch, alginate, cellulose ethers, chitosan, carageenan, or pectin)
- Protein (casein, whey protein, gelatin/collagen, fibrinogen, soy protein, wheat gluten, corn zein or egg albumen)



Use of Edible Gels, Films or Coatings with Muscle Foods

- Reduce moisture loss
- Minimize lipid oxidation
- Prevent discoloration
- Reduced drip
- Control levels of spoilage or pathogenic microorganisms

(Gennadios et al., 1997)

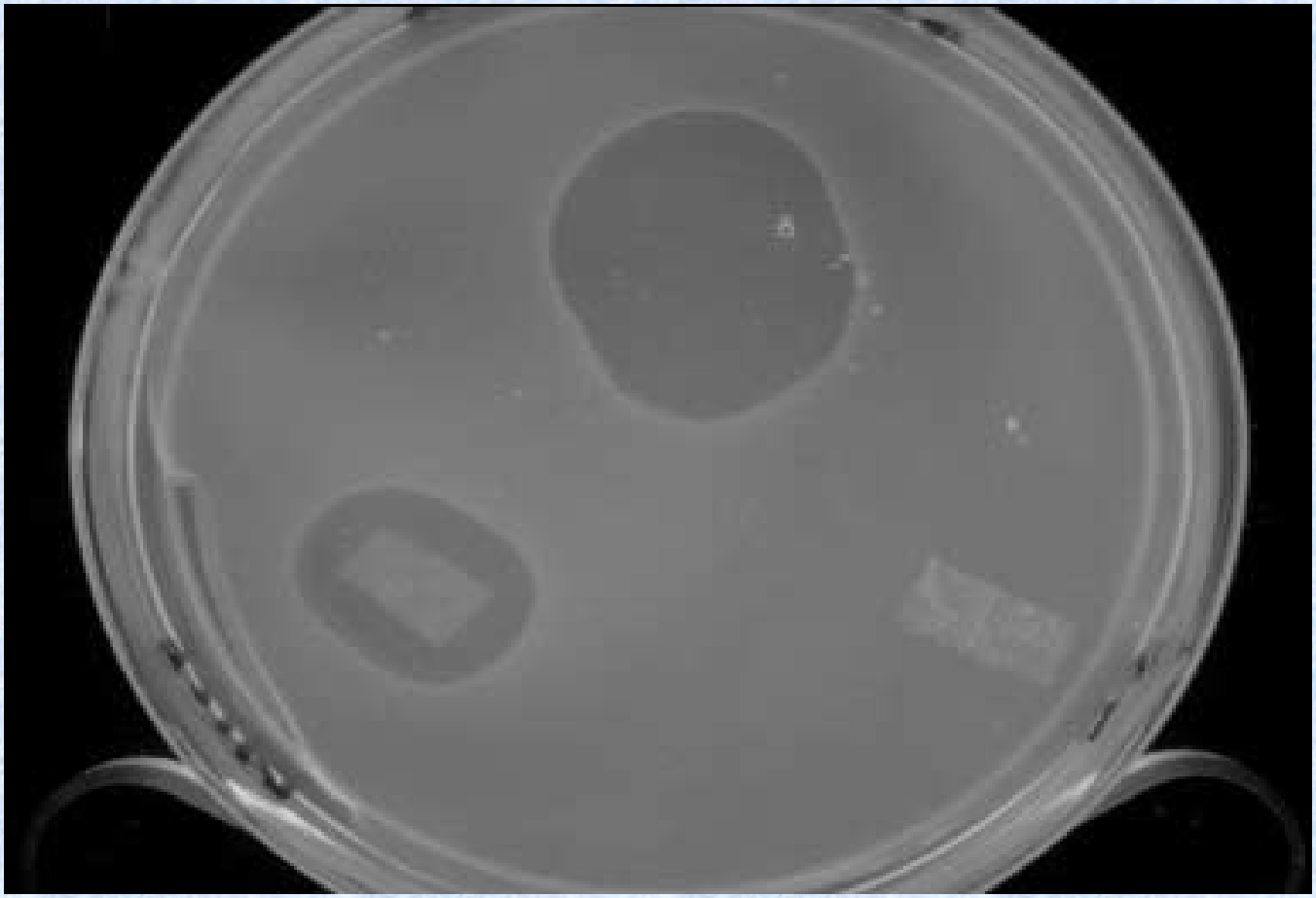
Antimicrobials Incorporated Into Edible Gels, Films and Coatings

- organic acids (acetic, propionic, benzoic, sorbic, lactic, lauric)
- potassium sorbate
- bacteriocins (nisin, lacticin)
- grape seed extracts
- spice extracts (thymol, cinnamaldehyde)
- thiosulfinates (allicin)
- enzymes

Antimicrobials Incorporated Into Edible Gels, Films and Coatings

- proteins (conalbumin)
- isothiocyanates (allylisothicyanate)
- antibiotics (imazalil)
- fungicides (benomyl)
- chelating agents (EDTA)
- metals (silver)
- parabens (heptylparaben)

Antimicrobial Edible Gels, Films and Coatings



Antimicrobial Edible Gels, Films and Coatings

- Meyer et al. (1959) added antibiotics, antifungal compounds to carageenan film to reduce bacteria by 2 $\log_{10}$ on poultry
- Siragusa and Dickson (1992, 1993) demonstrated that organic acids reduced levels of *L. monocytogenes, S.* Typhimurium, and *E. coli* O157:H7 to a greater extent when immobilized in calcium alginate and applied to beef carcass surfaces than when applied alone

Antimicrobial Edible Gels, Films and Coatings

- Baron and Sumner (1994) demonstrated that potassium sorbate and lactic acid could be incorporated into an edible cornstarch film to inhibit *S.* Typhimurium and *E. coli* O157:H7 on poultry
- Fang and Lin (1995) applied calcium alginate containing nisin to pork and demonstrated reductions in bacterial populations

Antimicrobial Edible Gels, Films and Coatings

- Cutter and Siragusa (1996, 1997) immobilized nisin in calcium alginate gels to reduce bacterial populations on lean and adipose beef surfaces
- Dawson et al. (1996) and Padgett et al (1997) demonstrated that nisin and lysozyme could be incorporated into edible heat-set and cast films made from corn zein or soy protein and exhibit activity against *E. coli* and *Lactobacillus plantarum*

Antimicrobial Edible Gels, Films and Coatings

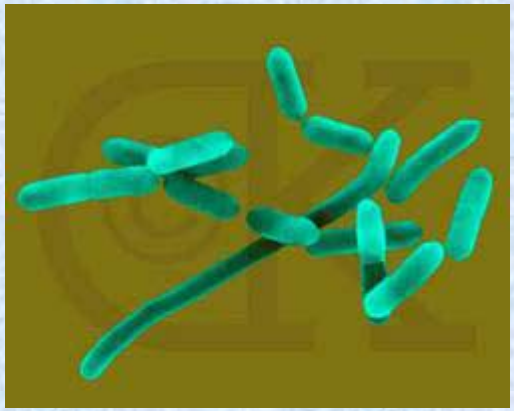
- Cutter and Siragusa (1998) demonstrated that nisin in a fibrinogen/thrombin based gel (Fibrimex®), may provide an added antimicrobial advantage to restructured raw meat products that incorporate surface tissues into product interior or as a delivery system for antimicrobials to meat surfaces.

Antimicrobial Edible Gels, Films and Coatings

- Gill (2000) applied gelatin-based coatings containing lysozyme, nisin, and EDTA to ham and sausage to control spoilage and pathogenic organisms such as *Lactobacillus sake, Leuconostoc mesenteroides*, *Listeria monocytogenes,* and *Salmonella Typhimurium*.

Antimicrobial Edible Gels, Films and Coatings

- Hoffman et al (2001) demonstrated that corn zein films incorporated with EDTA, lauric acid, nisin, and combinations of the three compounds resulted in significant reductions of *Listeria monocytogenes* in solution.



Antimicrobial Edible Gels, Films and Coatings

- Weng et al., 1999; Chen et al., 1996; and Field et al., 1986 demonstrated microbial inhibition in culture media or fish treated with methyl cellulose, chitosan, and alginate impregnated with benzoic acid, sodium benzoate, and glucose oxidase, respectively.

Polymers

- polyester
- polypropylene
- polyethylene
- polyvinyl
- polyolefins
- vinylidene
- vinyl chloride
- surlyn
- nylon

Antimicrobial Polymers

- Patent issued for a thermoplastic polymer blended with a 10% concentration of olefinic oxide polymer, with any of the following modifiers: antioxidants, fragrances, colorants or dyes, antimycotic agents, or biocides (Juhl et al., 1994)

Antimicrobial Polymers

- In 1996, Wilhoit et al. were issued a patent in which it was proposed using the bacteriocins nisin or pediocin, with or without a chelating agent, in conjunction with a food packaging film to protect foodstuffs from harmful bacteria

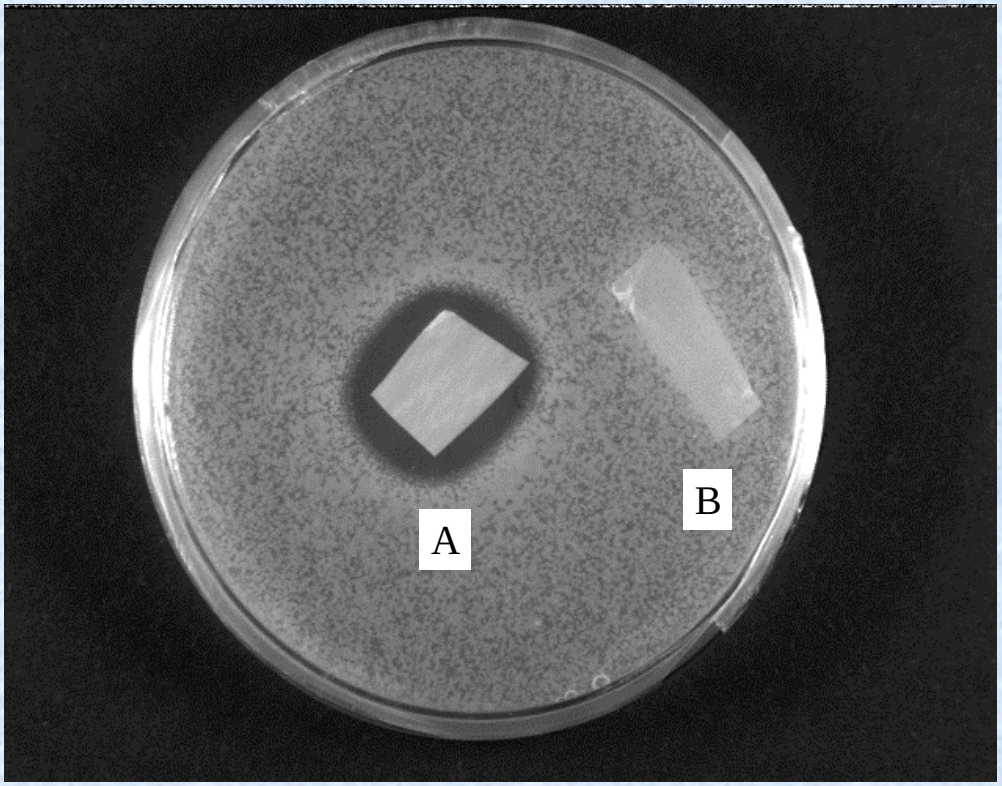
Antimicrobial Polymers

- Natrajan and Sheldon (1995, 2000a, 2000b) demonstrated a > 99.99% reduction of *Salmonella* Typhimurium on inoculated broiler skin exposed to nisin-coated polyvinyl chloride film and agar coating.

Antimicrobial Polymers

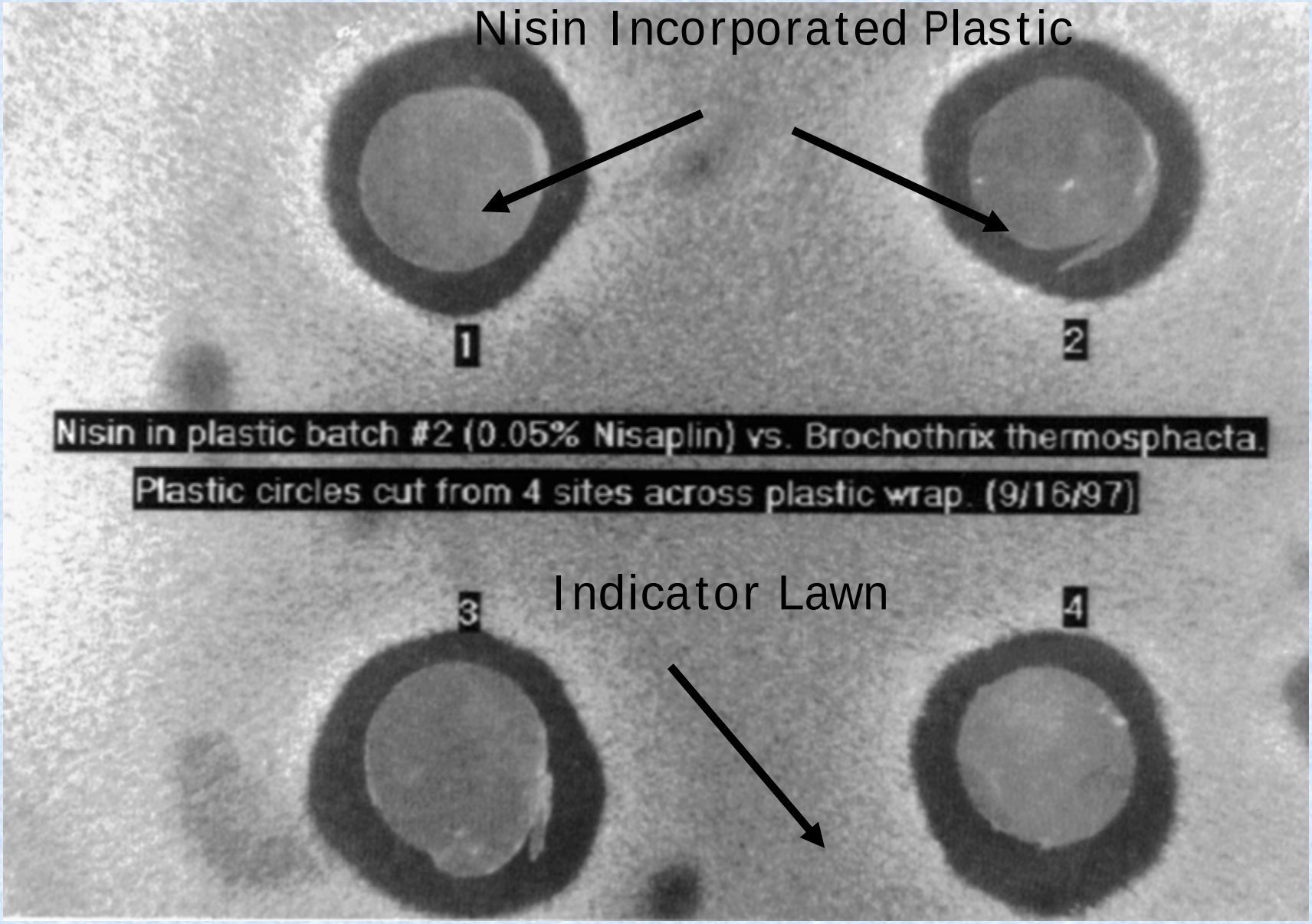
- Cutter (1999) demonstrated antimicrobial activity of triclosan-incorporated plastic (TIP) against bacterial cultures in antimicrobial plate assays, but bacterial populations on refrigerated, vacuum packaged meat surfaces were not significantly inhibited by the TIP.

Antimicrobial Polymers



Antimicrobial Polymers

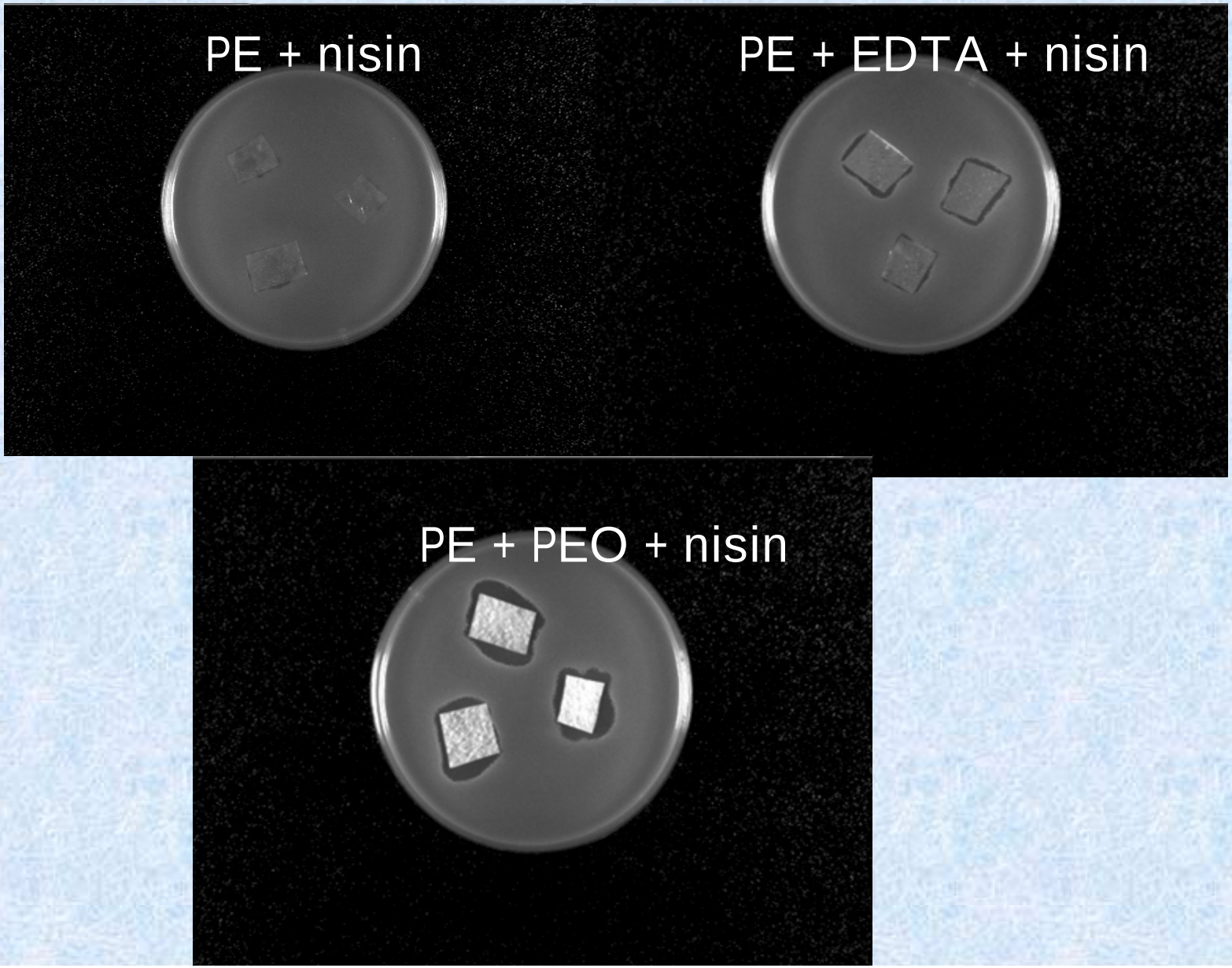
- Siragusa et al (1999) demonstrated that incorporation of nisin into polyethylene films not only retained nisin activity in plate overlay assays, but also effectively reduced the psychrotrophic, meat spoilage organism, *B. thermosphacta,* on vacuum packaged beef surfaces under long term, refrigerated storage


Nisin Incorporated Plastic
1
2
Nisin in plastic batch #2 (0.05% Nisaplin) vs. Brochothrix thermosphacta.
Plastic circles cut from 4 sites across plastic wrap. (9/16/97)
Indicator Lawn
3
4

Antimicrobial Polymers

- A subsequent study also demonstrated that nisin and EDTA incorporated into a blend of polyethylene and polyethylene oxide was more effective for reducing *B. thermosphacta* than control films (Cutter et al., 2001).

Antimicrobial Polymers



Antimicrobial Polymers

- Polyethylene was incorporated with potassium sorbate (Devlieghere et al., 2000; Han and Floros, 1997), benzoic acid (Weng et al., 1999), sorbic acid anhydride (Weng and Chen, 1997; Weng and Hotchkiss, 1997); and benzoic acid anhydride (Huang et al., 1997), to inhibit microorganisms on meat or poultry.

Antimicrobial Polymers

- Scannell et al (2000) demonstrated that lacticin and nisin incorporated into cellulose-based bioactive inserts and polyethylene pouches reduced populations of *Lactococcus lactis*, *Listeria innocua*, and *Staphylococcus aureus* on ham and cheese surfaces.

Antimicrobial Polymers

- Ha et al., (2001) incorporated grapefruit seed extract into a polyethylene film by co-extrusion or coating to inhibit *E. coli*, coliforms, and aerobic bacteria in ground beef

Summary

- Research supports the application of natural or food grade antimicrobials into edible-based or polymer-derived food packaging materials as a promising concept and one that will find practical applications in the food industry.

Summary

- However, as with all packaging developments to this point, organoleptic, consumer preference, safety, and regulatory considerations must be addressed if these types of technologies are to be adopted and implemented by the food industry.

U.S. Department of Health and Human Services
Food and Drug Administration

Questions?