





e-Beam Lesson 3

Current Strategies used to Eliminate or Reduce Pathogenic Microorganisms from Fruits and Vegetables

Lesson 3 of 4

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This module is designed to describe how the 1996 outbreak of *E. coli* O157:H7 in unpasteurized apple cider changed the manufacturing of and regulatory criteria for the production of fruit juices. This outbreak created a standard for how the regulators and industry determine the effectiveness of anti-microbial intervention strategies designed to reduce or eliminate pathogenic microorganisms from the surface of fruits. This module may be used by educators and the food industry as a training system to provide a review of anti-microbial strategies.

You may or may not be familiar with the Hazard Analysis Critical Control Points (HACCP) regulations for producers of juice. The implementation of HACCP in the juice industry has significantly impacted this industry and improved the safety of those who consume their products. The focus of this module is not on HACCP but on the changes brought about by the juice HACCP rule. You may gain an in-depth introduction to HACCP through many web-based academic, regulatory agency, and industry sources. We recommend that you visit the International HACCP Alliance web-page at <http://haccpalliance.org> to learn more about HACCP.



Objectives

- Review the 1996 United States E. coli O157:H7 outbreak in apple Juice
- Define Microbial Intervention Strategies
- Discuss the regulatory aspects of Microbial Intervention Strategies
- Define Anti-microbial Intervention Strategies
- Discuss the current strategies being used to eliminate or reduce microbial load in foods



Learners who complete this lesson will be able to ...

- ...discuss historical events that led to new regulations for juice production
- ...describe and discuss alternative microbial intervention strategies
- ...describe and discuss regulatory aspects of microbial intervention
- ...describe contemporary microbial intervention strategies and their effectiveness

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Review

- Foodborne Disease
- Intrinsic & Extrinsic Factors
- Foodborne Pathogens



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In unit 1, we discussed foodborne disease from two perspectives: foodborne infection and foodborne intoxication. In this unit, we will review the strategies used by the produce industry to reduce or eliminate the presence of foodborne pathogens in produce. The goal for use of effective intervention strategies is the reduction of pathogens to a level where they will not cause foodborne disease. Use of intervention strategies applies our knowledge of extrinsic factors to control microbial growth. These extrinsic factors complement the intrinsic factors inherent in the produce (such as high acidity in fruit) to preserve and protect the product.

In module 2, we discussed the pathogens of importance in fresh-cut produce: *Listeria monocytogenes*, *Salmonella*, pathogenic *E. coli*, *E. coli* O157:H7, *Shigella*, *Clostridium botulinum*, *Bacillus cereus*, as well as viral and parasitic pathogens. We also discussed the sometimes low cell population level required of certain pathogens to cause foodborne disease.



**1996 Western U.S.; E. coli O157:H7
Outbreak in Unpasteurized Apple Cider**

66 ill & 1 dead

Low quality, end of season apples - apples harvested from the ground - used to produce apple cider.

Food Protection Trends, April 2004, pp. 222 - 238.



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In 1996, an outbreak occurred in which 66 people became ill and 1 died from hemolytic uremic syndrome (HUS) - a disease where *E. coli* O157:H7 attacks the kidneys.

In this outbreak from consuming unpasteurized apple cider, low quality apples from the end of the season were used to make cider. This is a common practice and, in fact previous outbreaks had occurred. For example, in 1996 an outbreak in Connecticut had apple cider as its source.

FDA estimates that between 16,000 and 48,000 cases of juice related illnesses occur each year. In 1991, an outbreak in Massachusetts resulted in 43 illnesses including 16 with bloody diarrhea, and 4 with HUS from drinking fresh-pressed, unpasteurized apple cider. The source of the bacteria may have been manure contacting the apples used to make cider, As the press operator raised cattle in a field adjacent to the cider facility.



Juice HACCP

- December 1996: After the Connecticut outbreak, FDA held a two-day meeting to discuss the manufacturing processes used in the production of juices.
- The National Advisory Committee on Microbiological Criteria for Foods recommended that juice processors adopt HACCP.
- April 21, 1998: FDA proposed two rules designed to protect consumers from foodborne disease from consumption of juices.
- September, 8, 1998: Apple Cider Processors required to have warning labels on products.
- November 5, 1998: All other juice products required to have warning labels.
- January 22, 2002: Processors required to have HACCP implemented.

Food Protection Trends, April 2004, pp. 222 - 238.

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HACCP, as a means of controlling biological, chemical, and physical hazards in foods, is not new. In the late 1950s and 1960s, the Pillsbury Co. developed a concept of controlling hazards in foods that today we know as Hazard Analysis and Critical Control Points (HACCP).

HACCP continued to evolve into the 1970s when FDA used the concept to develop the Low Acid Canned Foods regulations. The Food Safety Inspection Service of the US Department of Agriculture adopted the concept after an *E. coli* O157:H7 outbreak occurred in the Northwestern US in hamburgers prepared at a major fast-food chain. In 1996, President Clinton signed the Pathogen Reduction and HACCP Final Rule into law. This marked the beginning of HACCP as the primary food safety system in the United States.



7 HACCP Principles

- Conduct a hazard analysis including the construction of a process flow chart
- Determine the Critical Control Points (CCPs)
- Establish critical limits (CLs) such as temperature.
- Establish monitoring procedures
- Establish corrective actions to be taken when a deviation occurs
- Establish verification procedures
- Establish a recordkeeping system

Jay, James M., Modern Food Microbiology.
6th. Ed., 2000, Aspen Publishers.

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HACCP is a recognized system constructed of 7 steps or principles. The single most important step is the first - conducting a hazard analysis including the development of a flow chart. This step requires that the food processing facility understand its processes. This leads to the step of determining what hazards exist at each step.

Hazards can be chemical, physical, or biological. As these hazards are identified for each step of the process, the preventive measure is identified as well. From this list of preventive measures, the critical control points (CCPs) can be identified.



Warning Labels and the Requirement for Pathogen Reduction

- FDA requires that a warning statement for fruit and vegetable juice products that:
 - have not been pasteurized, or
 - have not been treated in a way to prevent or eliminate harmful bacteria, or
 - have not been treated to reduce harmful bacteria by 100,000 (i.e., 5-log reduction = 99.999%).

Food Protection Trends, April 2004, pp. 222 - 238.

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FDA requires warning labels on all juice products that have not been pasteurized, have not been treated to eliminate harmful bacteria, or have not not been treated to reduce harmful bacteria by 5-logs (99.999%)

Once under HACCP, the processors cannot use the warning label and must use effective strategies to reduce or eliminate harmful bacteria. In fact, in October 2002, FDA released a guidance document recommending ways to help processors achieve a 5-log reduction (99.999%).



Pathogen intervention in fresh-cut produce, fruits and vegetables.

Processors of fruits and vegetables and those who manufacture fresh-cut produce are "not" required to apply HACCP or intervention strategies to reduce harmful bacteria.



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Only fruit and vegetable juice manufacturers are required to meet this stringent FDA regulatory mandate.

If only juice processors are required to follow this regulation, then what about systems to control pathogens in fruits, vegetables, and fresh-cut produce?



Food Safety in Fresh-cut Produce

Currently many fresh-cut produce processing facilities do not believe HACCP has application to their process or products.

However, upon an industry review, it is evident that many processors apply microbial intervention strategies to control harmful bacteria in the processing of fresh-cut produce.



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HACCP is applicable in all food processing operations. Many produce industry segments state they do not have critical control points. If any step in the process is designed to minimize, reduce, or eliminate pathogenic organisms from a food product, a Critical Control Point (CCP) does exist.

An intervention strategy that eliminates any part of the commodity in an attempt to control pathogens for food safety purposes is a CCP. For example, removing apples with the outer peel or skin broken would be a CCP, as would elimination of bruised apples from an apple juice operation.



Strategies used to control harmful bacteria
(*Anti-microbial intervention strategies*)

- Fresh-cut Produce (*fruits & vegetables*)
 - organic acid rinse: lactic, acetic & propionic
 - ozonation
 - chlorinated water wash
 - hydrogen peroxide
 - combinations of acid and hydrogen peroxide (peroxyacetic acid)
 - acidified sodium chlorite
 - storage temperature after anti-microbial treatment

Food Protection Trends, November 2003, pp. 882 - 886.

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There are a number of anti-microbial intervention strategies which are proven to reduce food pathogens, but none of these are effective enough to qualify for the more stringent regulations required of juices (5-log kill = 99.999% kill).



Anti-microbial Intervention Strategy Defined

Any chemical or physical process or technology that, when applied, effectively reduces or eliminates pathogenic microorganisms from a product, process, or equipment surface.



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An anti-microbial intervention strategy is any chemical or physical process or technology that, when applied, effectively reduces or eliminates pathogenic microorganisms from a product, process, or equipment surface. Many fruit, vegetable, and fresh-cut produce processors rely on a combination of two or more intervention strategies to acquire a 3, 4, or maybe even a 5-log pathogen kill. Certainly extreme exposure to chemical (acids or gases) or physical processes (thermal or ionizing radiation) will be more effective in controlling pathogens, but extreme exposure lacks efficacy because it may be at the expense of food quality and nutrition.


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Antimicrobial Intervention Strategies

- Current anti-microbial intervention strategies only **reduce** the level of pathogenic microorganisms in fresh-cut produce.
- Only cooking completely destroys pathogenic microorganisms.
- Anti-microbial strategies are usually CCPs in the HACCP plan.

Food Protection Trends, November 2003, pp. 882 - 886.

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Only cooking or pasteurization completely destroys pathogenic microorganisms. Many companies use several chemical disinfection steps in conjunction with one another in an attempt to control contamination.

The most common disinfection steps are using acids and chlorinated water.

Acids have been used for centuries to preserve foods. However, many bacteria are acid tolerant. Bacteria, such as *E. coli* O157:H7, when exposed to acids do not grow or multiply, but they can survive. The *E. coli* outbreaks in apple cider have proven this to be the case. Other acidic foods have been shown to be the source of outbreaks as well. Mayonnaise based salad dressings, yogurt, and salami have all been implicated. The organism survives for weeks and even months at refrigerated temperatures in acidic foods. Different pathogens vary in their response to acidic environments. *E. coli* O157:H7 has been shown to tolerate a pH of 2.5 to 3.2 when stored at refrigeration temperatures¹.

¹ Jay, J. M., (2000). *Modern Food Microbiology*. Aspen Publishers.



How effective are the decontamination strategies?

- One study conducted in 2003 tested 13 disinfectants on strawberries.
- Of all the products tested, sodium chlorite acidified with citric acid was the most effective.
- None of the disinfectants achieved a 5-log reduction.
- In fact, a 2-log reduction or greater was seldom seen.

Food Protection Trends, November 2003, pp. 882 - 886.

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Although fruit, vegetable, and fresh-cut produce processors are not required to achieve the level of food safety required of juice processors (5-log kill), there is plenty of evidence that suggests they use a combination of two or more intervention strategies to improve the wholesomeness of their products.



Ozone and Chlorine Treatment of Minimally Processed Lettuce

- One published study examined the use of chlorine, ozone, and a combination of chlorine and ozone to reduce bacteria found on lettuce.
 - Chlorine reduced bacteria counts by 1.4-log.
 - ┆ (Note: 1 log = 90%)
 - Ozone reduced bacteria counts by 1.1-log.
 - Chlorine-ozone combinations reduced bacteria counts by 2.5-log.

Journal of Food Science, Vol. 68, Nr. 9., 2003, pp. 2747 - 2751.

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For example, this study quantified the effectiveness of individual intervention treatments versus a combination of the two. Still, only a 2.5-log kill of pathogens was achieved. Yes, the application was effective at reducing pathogens, but the safety level of the products may still be in question.



Recovery of Bacteria following Surface Sanitization of Cantaloupes

- One study examined a three-step approach to reducing bacteria from the surface of Cantaloupes in foodservice and restaurant establishments.
 - Scrubbing with a vegetable brush in tap water
 - | 70% reduction in bacterial load (<1-log kill)
 - Washing with Soap
 - | 80% reduction in bacterial load (<1-log kill)
 - Dipping in 150ppm Chlorine
 - | 90% reduction in bacterial load (1-log kill)
 - 3-step combination approach
 - | 99.8% reduction in bacterial load (almost 3-log kill)

Journal of Food Protection,
Vol. 66, No. 10, 2003,
pp. 1805 - 1810.

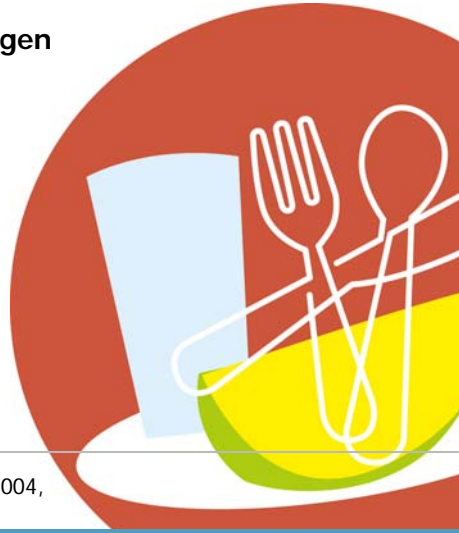
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This combination of three treatments achieved a 99.8% bacterial kill, almost 3-log kill (99.9%)



Effect of Hot Water and Hydrogen Peroxide Treatments on Cantaloupe

- Treatment with 158 deg. F. water
 - 2-log reduction of Salmonella
- Treatment with 206 deg. F. water
 - 3.4-log reduction of Salmonella
- Treatment with 5% Hydrogen Peroxide heated to 158 deg. F.
 - 3.8-log reduction of Salmonella



Journal of Food Protection, Vol. 67, No. 3, 2004, pp. 432-437.

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Still other studies indicate there is a need to improve intervention treatments. Thermal heating with hot water is very effective but must be limited to maximize the sensory qualities of the food items.

Efficacy of Chlorine and Peroxyacetic acid Sanitizer in killing *Listeria monocytogenes* in Lettuce

- Iceberg Lettuce
 - 1.04-log reduction using chlorine
 - 1.83-log reduction using peroxyacetic acid
- Shredded Iceberg Lettuce
 - 1.33-log reduction using chlorine
 - 1.59-log reduction using peroxyacetic acid
- Romaine Pieces
 - 1.68-log reduction using chlorine
 - 1.63-log reduction using peroxyacetic acid



Journal of Food Protection,
Vol. 67, No. 3, 2004,
pp. 432-437.

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Listeria monocytogenes is widespread in nature; found in dairy, meat, poultry, fish, fruits and vegetables¹.

Listeriosis the disease caused by this organism may cause:

Hemolytic Uremic Syndrome (HUS) the most common cause of kidney failure in childhood.

It has the highest mortality of all known foodborne pathogens.

Manifestations of the disease causes 1,600 illnesses and 415 deaths annually according to FDA/CFSAN.

Still, there is much to be done to achieve a 5-log kill level of food safety.

¹ Jay, J. M., (2000). *Modern Food Microbiology*. Aspen Publishers.



Assessment of control measures to achieve less than 100 cfu* of *Listeria monocytogenes* on Fresh Precut Iceberg Lettuce

- A study examined the effectiveness of achieving a 5-Log reduction in *Listeria monocytogenes* in chilled wash water used to clean lettuce.
 - Study shows that pathogen cells suspended in the wash water are readily killed by both chlorine and peroxyacetic acid when used at concentrations consistent with industry usage.
 - The 5-log reduction was not achieved when the pathogen was adhering to the surface of the lettuce.

*Colony Forming Unit (cfu)

Journal of Food Protection, Vol. 66, No. 2, 2003, pp. 256-264.

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Continuing food safety research delivers incredible knowledge of importance to the produce industry. For example, this study discovered that *Listeria m.* when detached from the surface of Iceberg lettuce and suspended in a solution of chlorine and peroxyactic acid were readily killed. But when the pathogen adheres to the leaf surface they survive.



Surface Pasteurization of Whole Fresh Cantaloupes

- Cantaloupes were inoculated with 5-log populations of *Salmonella* and *E. coli*.
- Cantaloupes were subjected to 169 deg. F. water for 3 minutes.
- Cantaloupes demonstrated a 5-log reduction in *E. coli* and *Salmonella*.
- Cantaloupes that were pasteurized then stored at 39.2° F for 21 days retained their firmness and quality. **Currently few retailers sell refrigerated cantaloupe.**

Journal of Food Protection, Vol. 67, No. 9, 2004, pp. 1876-1885.

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Still another test illustrates the significant effectiveness of an intervention strategy using heat pasteurization on the surface of cantaloupes. But most whole cantaloupe is transported, stored, and sold without costly refrigeration.



Summary of Effectiveness

- There are multiple intervention approaches available to the produce processor that will control microbial contamination to some degree.
- There is great variability in how intervention strategies are applied and the controls needed to maintain effectiveness.
- Heating remains the most effective technique used to control pathogenic microbial growth.
- Heating of all fruits and vegetables is not possible due to the negative effects on some products. However, it is possible to use heat on some products.

No notes.



New Strategies are Needed to Reduce Foodborne Disease in Produce & Juices

- We have reviewed the use of chemical disinfection and heat to reduce pathogenic microbial populations.
- There is a need to continue exploration of emerging technologies which can be beneficial to our efforts.
- Some new technologies are:
 - high pressure processing,
 - dense phase carbon dioxide processing,
 - ultra-violet irradiation processing,
 - Electron-beam irradiation processing.

In Module 4, we will introduce you to electron beam irradiation.

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Many new technologies are yet to be applied to food safety in fresh-cut produce. In fact, the International Fresh-cut Produce Association (IFPA) advocates an emphasis on food safety research including emerging technologies. In an interview with Food Safety Magazine, Dr. Jim Gorny said “Other hot new technologies gaining use in the industry include wash water disinfectants such as ozone, acidified sodium chlorite, and peroxyacetic acid, which are aimed at microbial intervention and reduction. Irradiation, also called cold pasteurization has been gaining interest in the produce industry¹.” Beginning in 1990, FDA approved irradiation (ionizing radiation) treatments as a safe and effective microbial reduction method for categories including spices, poultry and eggs, red meats, ground beef, seafood, sprouts, and fruits and vegetables².

Little is known about food irradiation among produce industry professionals; therefore, Electron Beam food irradiation, using common electricity, will be discussed in Module 4.

Dr. Gorny also pointed out that in addition to food safety research, the IFPA is focusing efforts on:

1. Improving trace-back investigations to more effectively identify and communicate causes of foodborne illness outbreaks,
2. Enhancing educational outreach efforts to improve produce food safety and,
6. Adoption of best practices by the industry.

¹ Food Safety Magazine. *A Fresh Look at Produce Safety* . Feb./March 2005. Retrieved August 1, 2006 from <http://www.foodsafetymagazine.com/issues/0502/feat0502-3.htm>.

² <http://www.foodsafetymagazine.com/issues/0504/col04.htm>



Conclusion

- The importance of continuing the investigations into new anti-microbial strategies cannot be overstated.
- As the consumption of minimally processed and ready-to-eat produce products continues to grow so does the risk of foodborne disease.
- Existing strategies need to be improved upon.
- The growth in the organically grown produce market creates new challenges with compost and irrigation water. Appropriate decontamination strategies designed to meet the requirements of this market need to be developed.
- Growing concerns for viral and parasitic foodborne diseases need to be taken into consideration as new technologies emerge.

No notes.