Non-thermal or Alternative Food Processing Methods to Enhance Microbial Safety and Quality

Frequently Asked Questions

11/1/2014

Lori F Pivarnik, Ph.D. and Randy Worobo, Ph.D.

(USDA-NIFA #2011-68003-30005)

Introduction

In an attempt to enhance the safety of fresh produce and shellfish, a group of researchers funded by USDA-NIFA #2011-68003-30005, have been actively investigating alternative processing methods (non-thermal) and their effectiveness against pertinent pathogens for different produce and shellfish items. This is a multistate project and includes personnel from the University of Delaware, Ohio State University, Cornell University, University of Rhode Island, Oregon State University, Delaware State University, University of Cincinnati and USDA ARS Eastern Regional Center.

As part of the outreach initiative for this project, the investigators have provided two informational documents for both produce/shellfish industry personnel and food safety educators. The first document is a Frequently Asked Questions (FAQs) pertaining to a variety of potential non-thermal methods for produce and shellfish processing that are being studied – how they work, any barriers to their use, and if they are currently being used. The FAQs also reflect the results of a survey administered at the onset of the project regarding knowledge of non-thermal processes and hopes to clarify misconceptions. The second document is a chart that represents some of the researchers' preliminary findings of the pathogen reductions, bacterial and viral, for the different non-thermal processing methods for different commodities. The table is intended to provide a quick reference for the feasibility of these alternative processing methods for the commodities tested to date.

In addition to the pathogen inactivation studies, some of these non-thermal processing methods have been evaluated for their impact on sensory changes for selected commodities. Due to the large number of different technologies and commodities tested, all the sensory evaluations have not been completed at this time. However, results of some of the sensory and shelf life work thus far has shown that non-thermal technologies show promise to both impact viral and bacterial pathogens and still result in a product with acceptable sensory properties. At the end of the research project, the sensory impact for all the different technologies and commodities tested will be reported.

Frequently Asked Questions

Non-thermal or Alternative Food Processing Methods to Enhance Microbial Safety and Quality

What is non-thermal or alternative food processing?

Traditional food processing relies on heat to kill foodborne pathogens, (bacteria, viruses, and parasites) to make food safe to eat. For many foods, heating is an effective way to treat foods. However, there are many foods that pose a risk for bacterial or viral foodborne disease for which heat is either undesirable or cannot be used e.g. raw oysters and produce. There has been a consumer demand for minimally processed food, such as pre-cut greens or fruit, or oysters that also has an extended shelf-life and is safe to eat. Researchers have been studying non-thermal processing methods (methods that do not use heat) that will destroy pathogens and keep foods safe to eat, while retaining the sensory attributes and nutrient content similar to raw or fresh products. These alternative processing methods are at various stages of development, and have the potential to destroy pathogens and retain desired food quality.

Foods treated with non-thermal process are safer to eat then untreated products (e.g. oysters, sprouts) but still require refrigeration to delay spoilage. However, like any traditional processing method used to preserve food and keep it safe, e.g. canning or pasteurization, a processor must validate that the non-thermal method will work to destroy the specific, targeted pathogen in their specific product. There are strict scientific parameters and data criteria that must be achieved to establish equivalence – you cannot just use it and hope it works! So, if a non-thermal method is proven effective on one food product it cannot simply be used on another – the same non-thermal method and processing parameters that may work on a fruit puree or salsa may not work on oysters or whole blueberries.

These non-thermal or alternative processing methods include high pressure, different forms of ionizing radiation, gases, light and chemical sanitizers.

What kinds of non-thermal processes have been investigated?

The kinds of non-thermal processing methods that are currently being explored for a variety of ready-to-eat products to retain fresh attributes of food while ensuring safety are:

- High Pressure Processing (HPP)
- Gases (ozone, chlorine dioxide, cold plasma)
- Light (ultraviolet, pulsed light)
- Chemical (chlorine, surfactants)
- Ionizing radiation (gamma irradiation, electron beam)

What is High Pressure Processing (HPP)?

This non-thermal process is currently being used commercially in the food industry to target specific pathogens in specific food products such as *Vibrio parahaemolyticus* and *Vibrio vulnificus* in oysters, and *Listeria monocytogenes* as post-process treatment on sliced deli meats, guacamole, and juices. High pressure processing kills microorganisms by exposing foods to very high pressures. The normal pressure used to kill pathogens in food using HPP can be 2000- 2,500 times higher than normally found in an automobile tire and as high as 6000 times higher than the pressure we are exposed to at sea level. The high pressure causes the microorganisms membrane to be disrupted and causes them to die. The food is largely protected from the damaging force of the pressure since pressure is uniformly distributed around and throughout the food. The amount of pressure needed to kill the pathogen will differ with the microorganism and the food product. This processing method can be performed on pre-packaged food, minimizing risks of recontaminating food. Using validated processing parameters of pressure, temperature and time combinations, high pressure processing is used commercially for certain food products, i.e. oysters, salsa, deli-meats, guacamole, juices, targeting specific bacterial pathogens (e.g. *Vibrio parahaemolyticus, Vibrio vulnificus*, *Salmonella*, *Listeria, E. coli* O157:H7). There is currently no commercial application of HPP on fresh produce, and HPP has not been used to target viruses.

What is Cold Plasma Processing?

Cold plasma is generated by using electricity and a carrier gas, such as air, oxygen, nitrogen, or helium; antimicrobial chemical agents are not required. The result is electrical discharges and subsequent ionization of atmospheric air. The microbial inactivation effect of plasma treatment can be attributed to the formation of a number of antimicrobial products in the air: UV, radiation, ozone, charged particles and “supercharged” oxygen. All of these products work together to kill pathogens (bacterial, viral). Cold plasma is an emerging, non-thermal technology that could potentially decontaminate the surfaces of fresh produce. It offers the advantage of being chemical and water-free because the antimicrobial products are formed in air. While not currently available for commercial use, this non-thermal processing technique is environmentally friendly and sustainable, as it does not require storage of chemicals or usage of large volumes of processing water. Since cold plasma is a waterless process and can be implemented in open air, it can be integrated into a forced air cooling process.

How Do You Process Using Ozone?

Ozone is a powerful sanitizer, similar to chlorine or common bleach. It’s a major advantage over other sanitizers, is that ozone leaves no residue and has no risk of causing undesirable organochloride cancer-causing by- products. Ozone is the sweet smell in the air after a lightning strike, and is commonly formed when a photocopy machine is operating. While the air we breathe contains two atoms of oxygen, O_2, ozone contains three atoms of oxygen, O_3 making it very reactive. Ozone is able to kill pathogens, and extend food shelf life, and is only toxic to humans at very high doses. A big advantage is that the toxicity does not stay with the food. Once the food is treated, the ozone decomposes quickly into oxygen, leaving a fresh safe food. However, ozone should not be used to treat high fat foods since it will cause oxidation of fat resulting in development of rancid off-flavors. Ozone is a gas but it can be bubbled into water and used as a washing method. Ozone itself, and the byproducts of ozone decomposition, work to make solid or liquid foods safe. Ozone is a very potent sanitizer that decomposes to ordinary oxygen that is safe to breathe. Nonetheless, both ozone formation and high concentrations are dangerous to humans so worker safety training is important. There are commercial applications for ozone use for specific foods.

What is Pulsed Light (PL) Processing?

Pulsed light (PL) is a non-thermal technology that uses short, intense pulses of white light which includes ultraviolet, infrared and visible light. Treatment of foods with PL has been approved by the FDA (21 CFR179.41). PL is the same as the light seen outside, but it is much more intense. It is like a camera flash that is used to take pictures but far more intense. When this light is flashed on a food, it kills microorganisms but has minimal impact on the food. Short flashes of this intense light are used to prevent the temperature of the food from increasing. Within PL, there is ultraviolet light (UV) – the same light that causes sunburns in people. The UV light kills pathogens by disrupting the DNA. There are companies commercially using pulsed light for the UV germicidal component to disinfect food contact surfaces but not for produce or seafood applications.

How Do You Process Using Ultra-Violet (UV) Light?

At high levels, UV light causes damage to a microorganism's DNA. It is this characteristic of UV light that is used to kill pathogens that are contained in food but does not impart any health concerns to the food. UV processing is being used in the juice and cider industries for pasteurization without heat targeting *E. coli* O157:H7 and *Cryptosporidium parvum*. UV has not been used on other produce or shellfish for pathogen reduction, but is commonly employed for water treatment systems, shellfish wet storage, and municipal water.

How Do You Process Using Sanitizer Washes?

Sanitizers, like chlorine, are used by the food industry to help kill pathogens in both food and on equipment/utensil surfaces. Sanitizers used in the food industry are regulated by the FDA for approved applications, types of sanitizers and allowable. However, microorganisms can attach to food, lowering the effectiveness of a sanitizer to help remove pathogens. To address this problem, use of surfactants is being studied to enhance the effectiveness of sanitizer. An example of surfactants currently being used is as a component of detergents to allow for more effective cleaning. Combining food-grade surfactants with sanitizers improves the killing effectiveness when applied to the surface of a food by "loosening" microorganism attachment and allowing the sanitizer to be a more potent antimicrobial agent.

Chlorine, or bleach, is not recommended for use by consumers, as the concentrations must be carefully monitored. While sanitizers are required in the food industry for use on processing equipment, certain chemicals are allowed at strict regulatory levels for direct treatment of food products. The combination of sanitizer and surfactant has not yet been commercialized but shows great potential.

How Do You Process with E-Beam?

Electron beam irradiation (E-beam) is another non-thermal technology where high energy accelerated electrons (close to the speed of light) are aimed at solid or liquid foods, reducing the number of or eliminating pathogens, pests or insects. Unlike Gamma irradiation, E-beam technology uses no radioactive isotopes. An electron beam generator uses electricity as the energy source and can be turned on and off. E-beam may work against pathogens such as viruses and bacteria by breaking the linkages in DNA or RNA and by disrupting other parts that are essential to the organism. E-beam is used to ensure the safety of packaged ground meats by killing pathogens such as *E. coli* O157:H7.Major advantages of e-beam irradiation include the absence of heat, and the fact that it is precise and controllable. Some drawbacks include a limited penetration depth through food and a high initial cost of this technology.

What is Gamma Irradiation?

Gamma irradiation is approved in the US and worldwide for a variety of food products. Although this type of irradiation has been studied for close to 50 years, it is often misunderstood. Inaccurate information often cited about this process has led to an unwarranted fear of its use in food products. This process does not make food radioactive - energies from irradiation are far too low to induce radioactivity. Worldwide organizations have concluded that irradiation, used within regulatory parameters with upper levels clearly defined, is safe to use to control targeted pathogens in food products. Cobalt 60, properly shielded, is primarily used as the gamma irradiation source. This irradiation has good food penetration.. Doses used must be established for each specific food product taking into account product composition, texture, density and impacts on quality. . Thus far, irradiation has been approved in low doses for a variety of food products that include lettuce, spinach, mushrooms and fresh fish. Slightly higher doses of irradiation have been approved for use on dried spices, and herbs. However, FDA approval, so far, has only targeted bacterial pathogens. Researchers are currently studying the use of gamma irradiation on produce and shellfish to help kill viruses.

Food is safer without compromising texture, taste and nutrition and can be used effectively on frozen products. Many products will be labeled, indicating they have been irradiated. If whole foods are treated with ionizing radiation, such as shellfish or a strawberries, then the product must be labeled with the radura symbol ( )or a written phrase “treated with radiation”. If irradiated ingredients are added to foods that have not been irradiated, no special labeling is required on retail packages.

	Cold Plasma		Pulsed Light		High Pressure		Ozone		E-Beam		Gamma Irradiation		Sanitizers and Surfactants		Ultraviolet	
	Target organism	Range log reduction	Target organism	[1/2]Range log reduction	Target organism	[4/6]Range log reduction	Target organism	[3]Range log reduction	Target organism	[3]Range log reduction	Target organism	[5]Range log reduction	Target organism	[1/2]Range log reduction	Target organism	[2]Range log reduction
Blueberries	Norovirus surrogate	2.0	*E. coli* O157:H7 *Salmonella*	2.8-5.8 3.1-5.9									*E. coli* O157:H7 *Salmonella*	2.7-4.0 2.8-4.3	*E. coli* O157:H7 *Salmonella*	1.3-5.2 1.0
Strawberries Fresh							Norovirus surrogate(s)	0-5.8	Norovirus surrogate	1.4-4.4	Norovirus surrogate	2-3	Norovirus surrogate	3	*E. coli* O157:H7 *Salmonella*	1.3-1.5 1.0
Puree					*E. coli* O157:H7 *Salmonella*	>5 >5										
Raspberries			*E. coli* O157:H7 *Salmonella*	3.9 4.5									Norovirus surrogate	2		
Green Onions			*E. coli* O157:H7 *Salmonella*	0.9-4.9 0.8-4.6			*Salmonella*	1.9-3.5					*Salmonella*	4.5-5.3	*E. coli* O157:H7 *Salmonella*	1.3-1.5 1.0
Salsa					*Salmonella*	[7]>5										
Oysters					Norovirus surrogate Total spoilage microflora	0.8-4.3 1-2					Virus surrogate	1.5-2				
Shucked					[6]*Vibrio parahaemolyticus*	3.4-7.1										
Whole-In shell					[6]*Vibrio parahaemolyticus*	5.0 - 6.5										

1: Depends on treatment time, and inoculation cite (calyx vs. skin vs. stems vs. leaves)

2: Depends on wet or dry, inoculation site and type (calyx vs. skin vs. dip vs. spot)
3: Depends on internal or surface target and treatment time, surrogate used
4: Depends on pressure, time and temperature.
5: Depends on dose used
6: *Vibrio parahaemolyticus* (Vp) is more pressure-resistant then *Vibrio vulificus*. Vp reduction further impacted with frozen storage following pressure treatment.
7: Depends on pressure, time and temperature as well as type added acid and final pH used in preparation (vinegar, lemon juice)