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Review of Potential Pasteurization Methods for Apple Cider

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INTRODUCTION

A 1993 New England Agricultural Statistics Service publication showed that, based on 1991 statistics, 650 apple growers harvested approximately 5,411,476 bushels of apples from 1,587,980 trees on 20,412 acres in Maine. This represents a substantial industry in Maine, from large orchards to family operations. Many, if not all, farmers offer apple cider (hereafter called cider) at roadside stands and/or through local supermarkets. For most, apples are their livelihoods, and all apple growers are paying close attention to the concerns over the recent contamination of cider by *Escherichia coli* 0157:H7 (*E. coli*).

Widespread public awareness of *E. coli* and apples stemmed from the October 1996 outbreak of *E. coli*, associated with Odwalla Juice Processors in Washington State (U.S. Dept. of Health and Human Services 1996). Unpreserved apple products were contaminated with *E. coli,* and this contamination affected a number people. Under intense, nationwide media coverage, Odwalla Juice Processors recalled all products containing apples. There were at least six other cases of *E. coli* outbreaks involving cider (multiple victims) reported between 1992 and 1993 (Loken 1995). All cases were related to refrigerated unpasteurized cider and were from the New England area. The apples used in production in these reported cases were well washed, non-drop, and tree-harvested. These documented incidents show that it took processing error to raise concerns from food groups and especially the Food and Drug Administration (FDA).

This survey and review are a response to a problem. There is a lack of regulations and good manufacturing practices (GMPs) in the cider industry and a general lack of knowledge concerning *E. coli* infection in apples and apple products. Research about *E. coli* in apples and about current cider-processing techniques could curb or even eliminate future outbreaks. This research could help the producers to continue to provide the public with safe, reasonably priced, high-quality cider.

Pasteurization offers a solution to such cider-related outbreaks of *E. coli*. Although further research is necessary, proper pasteurization effectively eliminates *E. coli*. This sounds simple, require that all cider be pasteurized. Should the FDA require pasteurization, however, small producers will suffer because of the high cost of equipment. Currently, thermal pasteurization units cost more than $20,000, a substantial financial burden for small processors.

With new and emerging technologies, cider can possibly be pasteurized inexpensively and effectively without affecting the taste. The main focus of this paper is to review the treatment methods that can be applied to the needs of the apple industry and to recommend further research. In addition to the review of methods, we conducted a sensory evaluation of cider to evaluate the acceptability of various pasteurized samples. This review of potential methods for product treatment will serve as an informative study with recommendations for future processing. Although not an exhaustive survey, conventional methods and the most promising new techniques are discussed.

METHODS AND MATERIALS

Although thermal type pasteurization methods have been used by the dairy industry for many years, other techniques are being developed that effectively kill pathogenic organisms. The sensory evaluation of thermal-treated cider samples can offer support for this type of processing or indicate drawbacks to heat pasteurization.

Sensory Evaluation

A preliminary sensory evaluation was performed to evaluate the acceptability of cider samples exposed to a dairy type thermal method of pasteurization. One sample was heated to 72°C and held for six seconds before being decanted and refrigerated. The second sample was heated to 54°C and held for 10 minutes before decanting and refrigeration. These values conform to suggested parameters from Cornell University for proper elimination of *E. coli* in cider (Food Science & Technology 1996). A control sample was not heated.

The consumer panel was recruited from the university community. Upon sampling, panelists established acceptability of color, texture, flavor, and overall acceptability. A nine-point hedonic scale was used to measure responses (1 = disliked extremely; 9 = liked extremely). Age and gender and additional comments were also noted.

Data were statistically analyzed using Analysis of Variance procedures with SAS software on the University of Maine mainframe computer. A multiple comparison test (Duncan's Multiple Range Test, $P \leq 0.05$) was used to identify treatment differences. Results of sensory evaluation are given later in the results section.

There are many advanced processing techniques capable of effectively killing pathogenic microorganisms. Thermal type pasteurization methods have been used by the dairy industry for many years. Many pasteurization techniques, including thermal, are currently under development, and all are supported by research. This gives rise to a section on major methods; techniques that would have the greatest impact on product quality or process efficiency. Also, other minor methods are included if they were deemed relevant to this study. Table 1 summarizes the types of methods, their mode of cellular destruction, and relative cost.

Table 1. Summary of methods, mode of pathogen kill, and relative cost by method type.

Method	Mode of Pathogen Kill	Relative Cost
Major Methods		
Conventional Thermal	Heat/time kills cells	Medium
Irradiation	Ionizing radiation kills cells	High
Light Pulse	Ionizing radiation kills cells	Low
Ultra-violet Light	Ionizing radiation kills cells	Low
Ohmic Heating	High voltage electric fields ruptures cells	High
Oscillating Magnetic Field	Magnetic fields rupture cells	High
Pulse Electric Field	Strong pulsed electric field ruptures cells	Medium
Minor Methods		
Microwave	High frequency radiation	High
Antimicrobials	Chemical cell destruction	Not known

Major Methods

Several major methods are discussed. These methods are either currently used with fruit juices or research is being conducted in this arena.

Conventional thermal pasteurization

To date, the most common method of liquid food pasteurization uses heat (thermal). The three most common methods of treatment are Batch or Vat, High-Temperature-Short-Time (HTST) called Flash Pasteurization, and Ultra-high Temperature (UHT) Pasteurization. The batch method stores a large quantity of the product (100+ gallons) in a vat that is heated and agitated simultaneously to a temperature of approximately 63°C and held for 30 minutes. This temperature and holding time eliminates all microorganisms and renders the product safe for consumption.

The HTST method was developed to help speed the processing of larger volumes of the product. Exposure to 67°C for six seconds should eliminate potential contaminants in cider (Food Science & Technology 1996). HTST devices are very effective in microbial elimination and less expensive due to the popularity of heat exchangers and advances in technology.

Flash pasteurization (HTST) units range from $22,000 to $47,000 (Goodnature 1997). Units can be either electric or propane fired. Other features include flow ranges of 2–20 gpm, adjustment capability of temperature setpoints, compact size, and optional glycol chiller systems. Because of advances in heat exchanger technology and their demand in the food industry, these HTST units are readily available and affordable.

Two companies (Goodnature, Inc., and Thermaline, Inc.) claim their systems are capable of pasteurizing many different types of juices. Their systems are basically heat exchangers, similar to those used for milk pasteurization. These systems comply with many of the FDA requirements for dairy-type pasteurization, such as food grade equipment, flow diversion valves, and clean-in-place (CIP) mechanisms.

A final thermal method, UHT, uses temperatures in excess 100°C and a slightly higher pressure, which allows the product to be brought up to temperature with less energy. When exposed to 110°C for a fraction of a second, a product can be stored without refrigeration. Europeans use UHT for their milk processing. Other global applications include coffee creamers and juice boxes (Dairy Engineering Company 1996).

Irradiation

Radiation is a process in which energy (radioactive isotopes) is emitted as particles or waves through space and is absorbed by another body. Irradiation of food involves exposing a substance to radiation or radioactive isotopes. High-energy radiation can effectively knock the electrons out of orbit, converting neutral atoms to positively charged particles called ions, thus giving rise to the term *ionizing radiation*. This ionization alters some vital molecules in microorganisms resulting in their destruction (Paparella 1996).

NASA uses irradiation to sterilize foods for space transportation. It has also been accepted as the treatment of Hawaiian papayas and other fruits coming to the U.S. mainland (Paparella 1996). Irradiators are very expensive and an investment of more than a million dollars would be required to construct a safe facility, therefore, usefulness to small operations is limited. Furthermore, although it is an effective method that does not significantly raise the temperature of the product, irradiation of solid foods is much different from that of liquids. Irradiation is best suited for solid foods, and at this point seems to have little application for cider processors.

Light pulses and ultra-violet

Ultra-Violet (UV) light is a form of radiation, and it has ionizing effects similar to irradiation. Typically UV sterilization units are used to treat air and water. The shortest UV rays, around 292 nm in length, cause alterations on the cellular level. High-intensity white light can also be an effective component of light treatment.

UV light (radiation) is known to trigger a variety of chemical reactions on its target. Radiation in the near-UV and even visible range causes the breakdown of a variety of organic compounds. The breakdown of plastics and rubber (such as tires) exposed to UV radiation is a familiar example. If photochemical breakdown is to occur in water, the contaminant must be located properly to absorb the solar radiation, typically on or near the surface of the liquid (Tchobanoglous 1987).

A typical UV unit, with a flow rate of 20 gpm, costs less than $1,000. Such devices are common in aquarium filtration and other small water and air applications. FDA-approved devices are available, but are 50% more expensive than typical water treatment units (Pure Pulse 1997). Advantages of this technique include fraction of a second kill time, minimal material degradation, and no chemicals. It is primarily used in the medical and the pharmaceutical industries for surface sterilization, but uses for food sterilization are being researched.

This method seems to be the most appropriate area for immediate research with respect to the small-scale apple grower/processor. Units, such as the water treatment units, should be immediately tested with apple juice and cider to determine their ability to kill microorganisms and their effects on the taste of the product. If studies show that this method can reduce pathogens to an acceptable level without negatively affecting the taste, the commercial market for such units will flourish.

Ohmic thermal treatment

Ohmic treatment incorporates the use of a high-voltage electric field to heat a food product to temperatures sufficiently high to kill microorganisms. The product acts as a resistor. When a current is passed through the product, the temperature increases and can effectively destroy undesirable pathogens. The most significant advantages of ohmic treatment over conventional thermal methods are the quick come-up time and the reduced wall temperatures, which lower the possibility of burning the product.

This particular method requires a pulsifier, which is a series of capacitors, that stores electricity in the range of 15–50 k volt. High-voltage current is delivered via special electrodes to a treatment chamber, which is in the order of 1–2 cm^2 wide and 2–10 cm long. Treatment time is on the order of a microsecond. Operating parameters are product specific and should be studied for each product.

The FDA (J. Larkin, FDA, pers. comm.) offered information on the application of ohmic treatment to cider and suggested that the cost of a test device would exceed $200,000. Pulsifiers have become more affordable, but electrodes are a significant part of the cost. The advantages in come-up time may be the most notable feature of ohmic treatment over conventional thermal methods. This can result in significant savings in the energy required to bring a product up to temperature. In many cases, products treated with ohmic heating maintain better sensory properties, which is an important factor for juices. As one of the newest experimental methods, further research in ohmic applications is proceeding.

Oscillating magnetic fields

The use of magnetism as a method of inactivating microorganisms by subjecting food to pulses of oscillating magnetic fields is described in world patent # 85/02094 (Anonymous 1985). Magnetic fields can cause a change in the formation of DNA and a change in the rate of cell reproduction (Pothakamury 1993).

Microorganisms can be exposed to Static Magnetic Fields (SMF) or Oscillating Magnetic Fields (OMF) and researchers have compiled data on the effects of these fields on some common food products (Mertens et al. 1992). Many design parameters affect the ability to use magnetism on foodstuffs, but are too detailed for this discussion. The most important requirement for the OMF application is that the food have a high electrical resistivity. Cider is considered a good conductor and therefore is not a good electrical resistor.

Coils capable of generating an OMF are available, but are presently designed and used for the magnetic forming of metal pieces. OMF cost is difficult to determine, but since the electrical componentry is comparable to what is required for ohmic heating, it is considered to be similar in price. Such components need to deliver high voltages or current at unique frequencies and are considered custom electronics.

Pulse Electric Field

US Patent # 4,695,472 describes a method and apparatus for preserving fluid food products by subjection to high-intensity electrical pulses (Anonymous 1987). Commonly referred to today as Pulsed Electric Field (PEF). Similar to ohmic and OMF, PEF relies on the lethal effects of strong electric fields for the destruction of unwanted microorganisms by rupturing the cell wall. The best attributes of PEF are its decreased thermal energy demands and its ability to maintain product nutritional properties and taste. The process works by applying repeated pulses of high voltage to a food. The electrical current is transmitted in a series of pulses between two electrodes for one microsecond. A pulsifier, similar to that explained in ohmic treatment, is used for charge generation in PEF.

Again a great deal of research has been conducted in this area, but is too exhaustive for this report (Qin et al. 1995; Mertens et al. 1992). PEF technology is used extensively by molecular biologists to introduce DNA into cells. Even for such small applications, molecular biologists find variations in cell destruction between 20% and 50%. This indicates that further investigation into the possible applications for elimination of *E. coli* from cider and other food products is warranted.

Energy savings are also a big advantage of PEF. Mittal (1996) suggests the cost of a complete small-scale PEF food treatment unit suitable for a commercial pulser, using the latest technology, has been reduced to approximately $20,000 from an initial cost of $100,000. In comparison, PurePulse Technologies, Inc., manufactures a PEF system called CoolPure. Cost of a unit capable of treating high volumes (60 gpm) would exceed $275,000 for the pulser and controls (PurePulse 1997). Initial tests proved that energy consumption is significantly less than thermal treatment (PurePulse 1997). Another benefit is that product does not stay at or above 50°C for more than 10–15 seconds. Although still under development, CoolPure has just received FDA approval for unit development.

Minor Methods

Several other methods can effectively eliminate harmful microorganisms. They are classified as minor methods due to the lack of research involving liquid food applications.

Antimicrobials

Chitosan (deacetylated chitin) possesses antimicrobial activity (Allen et al. 1984). The mechanism of chitosan action on microorganisms is currently under investigation. When *E. coli* was treated, a specific membrane-related enzyme was released because of membrane perturbation (Sundershan et al. 1991). The application of chitosan, due to its polycationic nature, leads to membrane-related effects. A critical concentration of chitosan released around a cell or group of cells coats the cell membrane with a polycationic polymer. Mass transfer is affected, and the cell functions are therefore disrupted (Mertens et al. 1992).

Little research has been done on liquid foods (Sundershan et al. 1991). The potential for alterations in taste would need to be investigated. Also, this technique may have effects on valuable nutrients and even beneficial bacteria. Because research in this area is in its infancy, an estimate of its expense is unavailable.

Microwave

Microwave technology involves the exposure of foodstuffs to high-frequency radiation. This area has been greatly ignored due to the implication of radioactivity of exposed product. Although this is arguable, such methods are not used extensively for food treatment in the United States.

Microwave technology is currently used in standard food processing systems that incorporates treatment on a conveyor. The system functions as a cooking system and a tempering system. Tempering brings the product from freezer temperatures to sellable temperatures without cooking. Several 75kW microwave transmitters can be mounted above a conveyor and food is passed through for the necessary treatment time. These units are fully automated, USDA approved, and operate at microwave frequencies of 896 MHz (megahertz) or 915 MHz. Typical food products include bacon strips, meats and poultry patties. Budgetary estimates of a multiple transmitter unit are in excess of $200,000 (Ferrite Components, Inc., 1997).

DISCUSSION AND CONCLUSIONS

Sensory Evaluation

Fifty-two panelists from the university community participated in a cider evaluation panel. This preliminary test supports further testing of the thermal effects on numerous brands of cider, due to the significance of the results. The results from the means comparison tests are given in Table 2.

The results of the taste test show that high-temperature treatment of cider significantly affects the acceptability of the product. The low-temperature sample was the most acceptable. This suggests a low-temperature heating may even enhance the flavor of cider. It should be noted that only one type of cider was tested, and testing several different brands would provide more conclusive evidence, with respect to the effects of heat on the cider product.

Table 2. Sensory panel test results, means followed by similar lettersare not significantly different ($P \leq 0.05$, Duncan's Multiple Range Test).

Heat Treatment	-------------------- Sample Attribute --------------------			
	Color	Texture	Sweetness	Overall
No heat	6.789 a*	6.471 a	6.558 a	6.601 ab
54°C/155°F	6.981 a	6.726 a	6.789 a	7.019 a
72°C/187°F	6.135 b	6.333 a	6.269 a	6.231 b

Where We Are and Where We Are Headed

The efforts of the various food committees and subcommittees of governmental and quasi-governmental groups are vital to ensure food safety for the public. It is apparent that progress is being made to ensure such future food safety. A complete outline of FPS and FDA recommendations and developments concerning *E. coli* treatment is available from the United Fresh Fruit and Vegetable Association (Aguirre 1997).

At present, the FPS does not recommend mandatory pasteurization of juices. Instead, they recommend that performance standards (risk standards) be established for juices and that juice processors can select the appropriate processes and/or technologies to assure that their juice meets the established performance standards (Aguirre 1997).

The FPS does recommend a mandatory requirement for juice processors to develop and to implement Hazardous Analysis and Critical Control Points (HACCP) systems. They add that the establishment of good manufacturing practices (GMPs) is extremely important before HACCP can be implemented. GMPs must be developed to govern production and harvesting of fruits and the handling of juice commodities, and GMPs for actual processing, packaging, and distribution of the juice product.

It has been shown that incidences of *E. coli* have developed from cider that was pressed from thoroughly washed and non-drop apples. HACCP ensures record keeping and the monitoring of determined critical control points. For producers, control points start in the field and end when the cider leaves their hands to go to consumer or market. All points must be investigated by each processor, and a HACCP document will outline these continually monitored areas. Documentation of operations and regular updates will provide increased control over the potential entrance of microorganisms. To ensure the proper development and implementation of these practices, FPS suggests that the National Advisory Committee on Microbiological Criteria for Foods (NACMCF) recommend industry education programs to address basic food microbiology, the principles of cleaning and sanitizing equipment, and HACCP and GMPs (Aguirre 1997). In addition, NACMCF suggests that initial focus of research be on determining at what point *E. coli* contaminates the apple and/or its products.

Opinion

In the end the customer just wants the same quality, good-tasting cider at an affordable price. Larger processors can afford advances in technology, and PEF should be at the top of their list. Smaller operations, like the mom-and-pop orchards, need a much less expensive method. If able, smaller processors should form cooperative processing facilities within established regions. This can spread the cost of equipment over a larger group, and PEF technology may be applicable. If smaller processors are interested in incorporating their own unit into their existing setup, a UV type system is most appropriate and affordable.

REFERENCES

Aguirre, J. 1997. Recommendations on Unpasteurized Juices. United Fresh Fruit and Vegetable Association.

Anonymous. 1987. Methods and apparatus for extending the shelf-life of fluid food products. U.S. patent # 4,695,472. Assigned to Maxwell Laboratories, Inc., San Diego, CA.

Dairy Engineering Company. 1996. Pasteurization of Apple (and other) Juices. http//www.dairyeng.com. (2/26/97)

New York State Agricultural Experiment Station. 1996. Food Safety Update, Apple Cider and *E. coli.* Food Science & Technology Bulletin, No. 5. Cornell University, Geneva, NY.

Goodnature, Inc. 1997. Product literature.

Larkin, J. 1997. Food and Drug Administration, personal communication.

Loken, D. 1995. Hazardous Analysis and Critical Contol Point Handbook. Swan Publishing.

Mertens, B., and D. Knorr. 1992. Development of nonthermal processes for food preservation. Food Tech. 46(5):124-133.

Mittal, G. 1996. New energy-efficient process could replace pasteurization. Newsfile. External Communications, University of Guelph, Guelph, Ontario, Canada. (3/18/97)

Paparella, M. 1996. Food Irradiation. Just What Is It? http://www.intercom.net/local/shore_journal/wp10331.html. (3/18/97)

PurePulse Technologies, Inc. 1997. Web Page. http://www.purepulse.com. (3/18/97)

Qin, B., U.R. Pothakamury, H. Vega, O. Martin, G.V. Barbosa-Canovas, and B.G. Swanson. 1995. Food pasteurization using high-intensity pulsed electric fields. Food Tech. 12:55-60.

Tchobanoglous, G., and E.D. Schroeder. 1987. Water Quality Management. Addison-Wesley Publishing Company, Inc.

U.S. Department of Health and Human Services. 1996. HHS News/WWW Press Release. *E. coli* Outbreak Associated with Odwalla Brand Apple Juice Procucts.(1/27/97)