CHAPTER 1

EMERGING FRUIT JUICE PROCESSING TECHNOLOGIES: QUALITY IMPROVEMENT

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ABSTRACT

Fruit juice has the highest acceptability among other beverages, generally due to its natural taste as well as its nutritional value. The presence of various phytochemicals in fruit juice is related to various health-promoting properties such as protection against several chronic human diseases such
as cancer, cardiovascular diseases, and diabetes. However, the number of outbreaks and cases of illness caused by consumption of contaminated juices, especially unpasteurized juices, has increased over the last decade. Currently, conventional thermal treatment is the preferred technology to inactivate microorganisms and enzymes causing spoilage, thus prolonging the shelf-life of juice. Because of the relatively high temperatures generally needed to inactivate food poisoning- and spoilage-causing microorganisms, thermal treatment can adversely affect the quality of food products, by reducing their nutritional value and altering sensory attributes such as color and flavor. The growing interest for fresh-like products has promoted the effort for the development of innovative nonthermal food preservation methods. Nonthermal processing techniques have been explored for their efficacy in extending shelf-life and enhancing the safety of fresh juice while preserving organoleptic and nutritional qualities. As consumers continue to seek food products with improved nutritional value and functionality, juice producers have the opportunity of improving product marketability through the use of these novel technologies that provide better retention of phytonutrients. Therefore, there is a need for nonthermal processing techniques to be tested on a pilot scale, so that these methods can be developed as an alternative to thermal pasteurization.

1.1 INTRODUCTION

According to Business Insights (2010), the global market for juices valued about US$ 93 billion in 2014. The key driver for the growth of fruit juice market is the increase in awareness among consumers on preventive healthcare and wellness benefits. Natural fruit juices are susceptible to spoilage, mainly due to their intrinsic properties such as pH, water activity, redox potential, and nutrients (Odumeru, 2012).

Fruit juice deterioration is mostly caused by enzymatic, chemical, and microbial reactions. Enzymes in fruit juices such as polyphenol oxidase and peroxidase may react with oxygen, thus contributing to juice browning and off-flavor (Bharate and Bharate, 2014). The causal agents of microbial spoilage of fruit juices are bacteria, yeast, and molds. Yeast and molds are the main spoilage agents due to the low pH of fruit juices. According to the
Centre for Disease Control and Prevention (1996), one of the current food-borne disease outbreaks has been linked to pathogens such as *Escherichia coli* O157:H7, where the emphasis was on unpasteurized juices.

Spoilage of fruit juice and related products as a result of microbial growth may contribute to physical and chemical changes in food products. These alterations include unacceptable flavor and odor, changes in color and turbidity, gas production, and formation of slime. Usually, growth of microorganisms to high numbers is necessary before spoilage becomes noticeable. Hence, it is important to control the growth of spoilage organisms in order to inhibit microbial spoilage (Odumeru, 2012).

The increase in outbreaks and cases of illness related to consumption of unpasteurized juices have urged the development of a more effective food safety control program, known as the hazard analysis and critical control point (HACCP) program. HACCP is a systematic approach to identify, assess, and control microbiological, chemical, and physical hazards of public health concern (Odumeru, 2012). Currently, there are a number of fruit juice preservation technologies for controlling microbial growth and survival. These preservation methods must be evaluated to avoid significant organoleptic changes in food products (Bates et al., 2001).

This paper will provide an overview of emerging thermal and non-thermal processing methods. This information is necessary to improve the progress of positive implementation of novel processing methods in the fruit juice industry.

### 1.2 FRUIT JUICE PROCESSING

The main objective of fruit juice processing is to prevent microbiological spoilage while assuring safety and maintaining quality characteristics. Fruit juice processing technologies can be divided into two groups, namely thermal and nonthermal processing.

#### 1.2.1 THERMAL PROCESSING

Conventional thermal treatment is the preferred technology to inactivate microorganisms and enzymes causing spoilage, thus prolonging the shelf-
life of juice. Traditional thermal processing depends on the generation of heat outside the product to be heated and its transfer into the product via convection and conduction mechanisms (Pereira and Vicente, 2010). Pasteurization is an example of thermal treatment that is commonly practiced in the food industry. The most common pasteurization method for fruit juice is high temperature short time (HTST) or also known as flash pasteurization (David et al., 1996).

According to Nagy et al. (1993), HTST treatment for fruit juices range from 90°C to 95°C for 15 to 60 seconds to assure at least 5-log reduction in microbial count. The time and temperature variables for pasteurization of juice depend on the type of juice, initial microbial count, pH, water activity, and thermal inactivation kinetics of microorganisms present in juice. Hence, pasteurization conditions should be selected appropriately to avoid overprocessing. However, underprocessing may not completely inactivate microbial growth, thus resulting in juice spoilage (Rawson et al., 2011).

Because of the relatively high temperatures generally needed to inactivate food poisoning- and spoilage-causing microorganisms, conventional pasteurization can adversely affect the quality of food products by reducing their nutritional value or altering sensory attributes such as color and flavor (Rawson et al., 2011). Some studies on thermally treated fruit juices such as orange (Cortes et al., 2008) and strawberry (Aguilo-Aguayo et al., 2009) reported significant loss of quality and degradation of bioactive compounds such as ascorbic acid. In addition, Rattanathanalerk et al. (2005) reported significant color degradation in thermal-treated pineapple juice (at 85°C and 95°C for 60 seconds).

1.2.2 NON-THERMAL PROCESSING

The growing interest for fresh-like products has promoted the effort for developing innovative nonthermal food preservation methods. Nonthermal processing techniques have been explored for their efficacy to extend shelf-life and enhance the safety of fresh juice while preserving organoleptic and nutritional qualities. In addition, these preservation methods
are considered to be more energy efficient and provide better retention of quality when compared to conventional thermal processing. Some of the nonthermal processing methods extensively studied for juice preservation include ultrasound, ultraviolet light irradiation, and pulsed electric field (Morris et al., 2007).

1.2.2.1 Ultrasound

Power ultrasound (10–1000 W/cm²) is used to alter food properties, either physically or chemically, such as by disrupting cells and inactivating enzymes. Ultrasonic processing equipment includes ultrasonic bath and probe system (Carcel et al., 2012). The mechanism of action for ultrasonic processing or sonication is explained in three different approaches, which include cavitation, localized heating, and formation of free radicals. When high power ultrasound at low frequencies (20–100 kHz) propagates in a liquid, cavitation (formation and collapse of bubbles) occurs. As a result, there is elevation of localized pressure (up to 500 MPa) and temperature (up to 5000°C). These “tiny hotspots” provide the energy to alter the properties of food product either physically or chemically. Accordingly, these cavitation bubbles induce microstreaming and shear stress, resulting in the disintegration of the microbial cells. Besides that, cavitation causes intracellular micromechanical shock that disrupts the functional components of the cell, thus inactivating enzymes (O’Donnell et al., 2010; Abid et al., 2013).

Sonication is a potential technology to achieve the US FDA condition of a 5-log reduction of foodborne pathogens in fruit juices. Several studies using ultrasonic processing on fruit juice reported minimal effect on the degradation of quality parameters and improved functionalities, such as in kasturi lime (Bhat et al., 2011a), apple (Abid et al., 2013), and carrot juice (Jabbar et al., 2014). Besides that, Rawson et al. (2011) reported that sonication provides better retention of bioactive compounds. In addition, Tiwari et al. (2009) reported that ultrasonic processing (25 kHz for 2 min) improves the cloud value and stability of orange juice during storage. However, significant color degradation was observed in orange juice subjected to sonication (Tiwari et al., 2009).
1.2.2.2 Ultraviolet-C (UV-C) Light

Ultraviolet-C (UV-C) light is a part of the electromagnetic spectrum with wavelengths between 200 to 280 nm and exhibits germicidal properties as it inactivates bacterial and viral microorganisms. Although UV-C radiation technology is considered as an effective method for food preservation, consumers’ misconception about this process have delayed many of its potential applications in the food industry. Actually, UV-C radiation is a physical treatment that does not result in chemical residues. Hence, the consumption of UV-C-treated food products is not harmful to humans.

One of the limitations of the application of UV in juice processing is associated with the high absorbance coefficients of juice. According to Koutchma et al. (2004), UV-C penetration largely depends on the presence of dissolved organic solutes (suspended solids) and colored compounds that act as a barrier, thus exhibiting UV-C attenuation effects. Hence, an appropriate UV reactor should be designed to reduce the interference of UV absorbance and improve microbial inactivation efficiency. The reactor design should include a narrow laminar flow or conditions with high turbulence, where juices are mixed resulting in all parts of the juice being exposed to the UV light source (Koutchma et al., 2004).

The US FDA criterion of a 5-log reduction of the chosen pathogen in fruit juices can be achieved by UV-C radiation. Several studies using short-wave UV-C light treatment on fruit juices reported better retention of nutritional and quality attributes, such as in starfruit (Bhat et al., 2011b) and orange juice (Pala and Tokhucu, 2013). Besides that, Bhat et al. (2011b) reported that UV-C processing (for 30 and 60 minutes) induces a significant increase in polyphenol and flavonoid content of starfruit juice. However, there is an increasing trend in browning degree and color changes corresponding to increased UV-C treatment time, as previously reported by Bhat et al. (2011b).

1.2.2.3 Pulsed Electric Field (PEF)

Pulsed electric field (PEF) treatment applies short pulses (1 to 100 microseconds) with high voltage (10 to 50 kV/cm) to liquid products in a continuous system. A simple PEF system consists of a high voltage power supply, a pulse generator, treatment chamber, and a switch to discharge energy to electrodes.
In addition, there is a cooling system to balance moderate temperature rise during treatment (Morris et al., 2007; Lopez-Gomez et al., 2009). The effectiveness of PEF processing is dependent on variables such as pulse width, electric field strength, flow rate, treatment temperature, and time of exposure. Some studies reported that juices treated with lower intensity pulse fields and shorter pulse width exhibited higher retention of ascorbic acid, such as observed in orange (Elez-Martinez and Martin-Belloso, 2007). In addition, an enhancement of antioxidant capacity was observed in PEF-processed juices due to increased extraction yield of secondary metabolites and generation of free radicals (Rawson et al., 2011).

1.3 CONCLUSION

The value for fruit juices has been increasing in the global market due to their health benefits. Conventional thermal pasteurization is the preferred technology used to achieve microbial inactivation and extend the shelf-life of juices. Lately however, consumers’ demand for a new preservation technology that retains freshness and at the same time ensures food safety has resulted in growing interest for nonthermal processing methods. Therefore, there is a need for other nonthermal processing techniques to be tested on a pilot scale, so that these methods can be developed as an alternative to thermal pasteurization. In future, the combination of nonthermal processing methods as a hurdle concept would be a new trend of preservation of fruit juices that improves the microbiological quality and safety with minimal impact on the quality of the food product.

KEYWORDS

- fruit juice
- non-thermal processing
- quality
- safety
- thermal processing
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