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Applicable Nonthermal Preservation and Decontamination Technologies for Small to Medium-Scale Perishable Juice Processing

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Abstract: Nonthermal decontamination technologies are gaining prominence as an alternative to thermal sterilization, aiming to prevent the thermal degradation of juice quality. This paper reviews existing studies and the commercial viability of nonthermal techniques for processing and decontaminating perishable juices. Effective nonthermal methods for small to medium-scale commercial operations include sanitation and refrigeration, chemical preservatives, freezing, UV-C processing, microfiltration, and ultrasonic and ozone sterilization. The paper discusses microfiltration, UV-C processing, and ultrasonic designs studied for perishable juices in the author's laboratory. A significant challenge with nonthermal processes is their product-specific nature, necessitating further research to establish optimal process parameters. The advantages of these technologies include improved sensory and nutritional qualities and minimal or no use of preservatives. However, combined treatments are often necessary to meet microbial safety standards.

Keywords: Fresh Juices, Thermal Oxidation, Nonthermal Techniques, UV-C processing

1. Introduction

Conservation and preservation of perishables are prerequisites for food security with population growth, solutions for surplus production, and changes in food habits. Supply and demand have an inclining gap and long distances between consumers and production stations. Also, most productions have seasonal characteristics, and all these causes more needs day by day. Consumers now tend to drink healthy beverages, creating an innovative and stabilized fruit juice industry [1, 2]. Juices can reduce chronic diseases due to the bio-available phytochemicals. According to epidemiologic studies, consuming vegetables, fruits and herbs causes reduced adverse health effects such as obesity, cancer, hypertension, stroke and cardiovascular diseases [3, 4]. Due to the disease's complexity, people focus on controlling chronic and cardiovascular diseases through bioactive compounds enriched with functional juices.

In juice, processing, high heat gives them a longer shelf life in the thermal decontamination of perishable juices. At the same time, many vitamins, minerals, and enzymes have been removed, destroying many of the benefits of freshly squeezed foods due to oxidative reactions. Some delicately flavoured juices cannot tolerate gentle pasteurization, resulting in quality loss. The heat dispersed tiny bubbles of oxygen and oxygen available in the air accelerates ageing and Nutrient quality with oxygen-reactive spices [5]. As a thermal preservation technique, pasteurization causes the colour and appearance of fruit juice due to the degradation of pigments [6]. Determinant loss of textural properties and adverse effects on fresh quality occurs due to most food processing practices, which exceed the threshold levels of plant cell membrane integrity [7]. Limitations of thermal processes and concerns about consumers' preference for fresh-like juices lead to finding alternative techniques for preservation and decontaminating fresh juices as alternate applicable non-thermal juice preservation techniques are worth investigating to eliminate some of these thermal ill effects. Potent nonthermal processing and decontamination techniques for small and medium commercial operations are refrigeration coupled with chemical preservatives, freezing, UV-C processing, hyperbaric pressure, irradiation, microfiltration, ultrasonic processing, and ozone sterilization.

2. Refrigeration with chemical preservatives

Correct use of hurdles except pasteurization can extend the shelf life of juices without affecting quality. Minimal processing employing hurdles is because instead of an individual preservation technique against microbial growth applying of collective approach. Several barriers are used to enhance product stability and to affect near-fresh juice character. Adequate sanitary application is the first method to reduce microbial load as a barrier and low storage temperature further controls the growth rate of food microorganisms. An acidic environment with a pH below 4.5, ideally 3.5, restricts the growth of any organisms, and excluding oxygen is an additional barrier. Antimicrobial properties of juices cause extended shelf life effectively. Sulphur dioxide effectively inhibits microbial growth and enzymatic and nonenzymatic browning.

Moreover, the undissociated H_2SO_4 molecule provides a preservative action. Lower pH favours its use. Due to their excellent solubility, potassium sorbate and sodium benzoate, which are used to form sorbic acid and benzoic acid, are preferred, and the best functions of these preservatives occur below pH 4.0[6]. Benzoate salt below this pH has the most effective action against fungi such as yeast and mould, while sorbate acts as a preservative in a broader pH range up to 6.5. The combination of these two extends the self-life of juice drinks, which were minimally processed under low-temperature storage [8].

The total process of reducing temperature and maintaining the reduced temperature during storage, thereby preservation, is referred to as refrigeration or cooling [9]. The shelf life of perishable juices is extended more significantly than 4 weeks to not less than 3 weeks due to hurdles of hygienic preparation, sanitation, and proper packaging. Hold the temperature close to the juice freezing point (2-8 °C), called chilling [10]. The nearby freezing point is super chilling if the product is chilled to 1°C-2°C [11]. This temperature reduction operation in the total process is introduced which called as chilling and causes the production of a chilled product. The chilling process is caused by forming ice while freezing, which forms ice crystals inside the food material. This method reduces the microbial growth rate and results in spoilage but cannot be eliminated. During storage and distribution of juice beverages, it is required to maintain a refrigeration temperature to minimize the rate of quality reducing enzymatic and oxidative reactions.

3. Freezing and freeze concentration

Fresh juice freezing is applied at a temperature below -18 °C, referred to as the freezing point [10], and storage in a low oxygen environment can maintain freshness better than other processes. Suspension and film freeze concentration, known as layer crystallization, are the main basic concentration methods. Suspension freeze concentration stems exist in juice manufacturing. In comparison, film freeze concentration or layer crystallization is still experimental [12]. The low-temperature processing of freezing concentration is beneficial for maintaining the quality of fruit juices. Isochoric freezing is a new juice preservation technique that can preserve food products at subfreezing temperatures in an unfrozen state, thereby preventing ice formation. The technique minimizes the juice equality loss while increasing nutrient content and reducing microbial counts [13]. The process known as cryo-freezing results in a more concentrated solid outcome. Cryo-concentrated fruit juice has relatively higher bioactive, organoleptic, and nutritional properties and lower microbial content than fresh condition [14]. The frozen state of a product can be transformed into a state where there are no ice crystals by thawing [15]. Novel methods, such as microwave thawing, acoustic thawing, ohmic thawing, and high-pressure thawing, remove ice crystals inside frozen foods [16].

4. UV Technology

Photons with 253 mm wavelengths responsible for UV light contain 470kJ of energy per mole [17]. UV photons cause photochemical changes and inactivate microorganisms [18]. In these mechanisms, microorganisms absorb the UV-light energy, which induces photo-physiochemical and/or photo-thermal impact on them to inactivate. The dose and treatment time of UV light directly affect the degree of microbial inactivation and required dosage.is pathogen specific. Moreover, the density and surface properties of food material, UV absorptivity, and the nature of food itself act as other variables in the microbial inactivation of food juices. UV-C light provides a germicidal effect on juice beverages, and according to composition, organic solutes, suspended matter, and colour compounds reduce the degree of UV transmission and efficiency of nonthermal preservative function of UV-C [19, 20]. Research carried out in the author's laboratory using pilot scale UV-C sterilizer (GYC-UUVE-40W, Ningbo Yinzhou Sija Lab Equipment Co., Ltd) technology) found that Microorganisms (APC and YM) of both Aloe vera (*Aloe barbadensis* Miller), curry leaf (*Murraya koenigii*) juices can be wholly inactivated using UV doses from 47.65 to 85.77 Jcm^{-2} This was achieved by re-circulation with the assurance of sound hygienic processing of raw juices, with a production capacity of 200 L per batch (during 8 hrs). The Study indicated that improving thin film technology and circulation intensity reduces microbial contaminations in colour beverages.

5. Ultrasonic Processing

Electrical energy converts to sound energy and sound waves between 18 kHz – 500 MHz are considered and ultrasonic (US) vibrations produced by US transducers. These vibrations form tiny bubbles subjected to rapid expansion and compression a thousand times within a second, directed to a phenomenon called cavitation. Rapid compression of bubbles causes the breakdown of cell walls, disrupts, and damages cell membranes and DNA of bacteria in liquid food with a high-localized temperature. Cell walls of microorganisms are punctured, and cell contents are released due to high-intensity citations from the US [21]. With mild heat, the US causes the inactivation of enzymes and microbes [22]. Research carried out at the authors' laboratory using an ultrasonic pace processor (SJIA-1500W) with a 15 mm probe for blended Starfruit (*Averrhoa carambola*), Aloe vera (*Aloe barbadensis* Miller), curry leaf (*Murraya koenigii*) and Watermelon (*Citrullus lanatus*) juice showed that ultrasonic processing can be used as a supportive technique to develop combine treatment with nonthermal techniques for effective microbial contamination [23].

6. Micro Filtration

Microfiltration (MF) can clarify and stabilize fruit juices [24, 25]. MF experiment carried out at the Authors laboratory using blended Starfruit (*Averrhoa carambola*), Aloe vera (*Aloe barbadensis* Miller), curry leaf (*Murraya koenigii*) and Watermelon (*Citrullus lanatus*) juice using polyvinylidene fluoride membrane (0.3μm) under the pressure 0.5 MPa showed that microfiltration can be an effective nonthermal processing technique [23].

7. Ozone sterilization

Ozone as an antimicrobial agent in aqueous and gaseous states was approved by the Food and Drug Administration (FDA), United States, in 2001 [26]. Researchers have found successful application of ozone for fruit juices of strawberry, orange, apple, and apple cider. Ozone is categorized as a tri atomic form of oxygen, and it breaks down to non-toxic diatomic oxygen without forming harmful residues in food [27]. Ozone acts as an antimicrobial agent on cellular compartments and matters such as cell envelopes, enzymes, peptidoglycans, proteins, and nucleic acids of microorganisms in foods under high oxidation potential such as 207 V. The cell lysis of bacteria starts when oxidizing cell envelopes due to contact ozone with microorganisms [28]. Research conducted in the authors' laboratory on pineapple juice indicated that ozone application could benefit juices with low contamination levels, achieving around a 2-log reduction of aerobic bacteria, yeast, and mould after 60 minutes of ozone at 200mg/hr dose concentration. However, ozone treatments significantly impacted some quality characteristics of pineapple juice, notably colour and antioxidant activity. The results suggest that ozone treatment can be effectively used with other nonthermal techniques for microbial decontaminating juices with low or clear colour [29] after determining the correct dose for the selected juice.

8. Concluding remarks

The survey indicated several applicable nonthermal processing and decontamination technologies for small to medium-scale perishable juice processing. These nonthermal technologies with hurdles inactivate microbial content or suppress the growth and maintain the fresh character of perishable juices. Low initial contamination levels by maintaining hygienic conditions before applying nonthermal technologies facilitate high microbial inactivation levels.

Policy initiation and standard development are essential to promote these technologies, considering the upcoming consumers and manufacturers' expectations with broader adoption by combined technologies.

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