Ultraviolet Technology – An Alternative to Juice Pasteurization



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INTRODUCTION

One of the biggest challenges in the food industry is the production of environmentally-friendly, sustainable and chemical-free food. In a tropical country such as Malaysia, consumers prefer freshly cut fruits and juices as compared to processed juices (Suguna *et al.*, 2011). Local consumers believe that fresh fruit juice retains the original nutritional and sensory attributes. However, there is a rising concern about the safety of consuming unpasteurised or unprocessed fruit juices due to outbreaks of food borne disease. Hence, there is an increasing demand for safer food products which conform to Hazard Analysis and Critical Control Point (HACCP) and Good Manufacturing Practices (GMP) in the beverage industry in Malaysia.

Most fruit contain 75 to 95 percent of water and they are low in protein but high in carbohydrates such as dextrose, fructose, sucrose and starch. In Malaysia, the preservation methods for fruit juice include heat treatment, freezing, dehydration, concentration, salting, addition of preservative and fermentation. Drying using spray dryer, freeze dryer or sun drying can remove the moisture content and decrease the water activity, which may have a negative impact on the fruit. On the other hand, concentration is the process that increases the solids content to about 50 to 60 percent while keeping the juice in liquid form.

Thermal pasteurisation is the most common preservation method for the inactivation of microorganisms in fruit juice to achieve the required 5-log reduction in number of the most resistant pathogens (FDA, 2000). According to Silva and Gibbs (2004), pasteurisation can be defined as a mild heat treatment which is a very old method used for food material preservation. It is designed to inactivate important enzymes with respect to quality and vegetative forms of microorganisms that can be found in food products. It can be applied in high acidic fruit products to kill heat-resistant or common spoilage microorganisms. However, pasteurisation has some disadvantages due to its thermal energy and processing time. It can affect the overall quality of the juice by changing its nutritional and biochemical properties (Sanchez-Vega *et al.*, 2009). It causes adverse flavour on some juices too. Thus, using non-thermal technology is an alternative. Research relating to ultraviolet technology is emphasized, particularly its effect on the quality of fruit juices (pittaya, pineapple, watermelon and guava), together with cost comparisons between thermal pasteurisation and ultraviolet light.

NON-THERMAL PASTEURISATION

The growth of non-thermal processing methods for processing of food has shown an outstanding balance between safety and minimal processing as well as between cost and superior quality. Among those non-thermal methods, ultraviolet irradiation has a great potential to become a low-cost, non-thermal pasteurisation technology in juice.

According to Kozempel *et al.*, 1998; Majchrowicz, 1999, the estimated cost of thermal pasteurisation is in the range of $20,000 to $30,000 which is much higher as compared to UV irradiation equipment ($10,000 to $15,000). The advantages and disadvantage of this minimal juice processing method are summarised in Table 2.

Table 1: Comparison of Non-thermal Juices Processes

Process	Temperature	Enzyme Inactivation	Equipment Costs
Pulsed Electric field	Ambient (slight increase due to process)	None	$$$$$
UV light	Ambient	None	$
Minimal thermal process	70°C for 6 seconds	Minimum	$$
Batch high pressure	Ambient plus compression heating	Selective inactivation	$$$$$
Continuous high pressure	Ambient plus compression heating	Selective inactivation	$$$$$

(Source: Sizer and Balasubramaniam, 1999)
Note: The '$' sign is an indication of the cost whereby '$$$$$' is the highest cost and '$' is the lowest

Table 2: Advantages and Disadvantages of Minimal Processed Juice

Advantages	Disadvantages
To consumer: Health image Fresh sensory appeal: flavour, colour Closer to self-preparation but convenient "Natural" image	**To consumer:** More expensive Shorter shelf life Quality demands proper storage
To marketer: Increased profit Attractive sales display Promotes fresh produce sales High turnover	**To marketer:** More costly display space Shorter sales life Handling mistakes are costly
To manufacturer: Simplest process Add value to cull fruit All juice pass through this step High seasonal turnover	**To manufacturer:** Higher quality fruit required Dictates very careful handling Safety responsibility is high

(Source: Bates et al., 2001)

WHY ULTRAVIOLET LIGHT?

The US Food and Drug Administration has approved UV light for use in processing of fresh juices to achieve a 5 $\log_{10}$ reduction of target pathogenic organisms, as mandatory by regulations. UV processing could reduce contamination levels due to its broad antimicrobial action, resulting in effective inactivation of viruses, vegetative bacteria, bacterial spores, yeast, conidia (fungal spores), and parasites. On the other hand, UV-light treatment of foods not only does not involve the use of any chemicals or the generation of waste effluents, it also does not produce any byproducts.

Hence, it is ecologically friendly. Furthermore, this approach can improve chemical and toxicological safety of a wide variety of liquid foods and beverages. In addition, most nutritional components which are sensitive to heat will not be damaged by UV light or will potentially suffer less destruction as compared to thermal treatment (Koutchma, 2009).

WHAT IS ULTRAVIOLET LIGHT?

Ultraviolet light is one energy region of the electromagnetic spectrum, which lies between the x-ray region and the visible region. The ultraviolet spectrum can be sub-divided into 3 parts for practical purposes and a vacuum range (Sastry *et al.*, 2000, Koutchma, 2009):

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- Short wave UV (UVC): with wavelengths from 200 nm to 280 nm
- Medium wave UV (UVB): with wavelengths from 280 nm to 320 nm
- Long wave UV (UVA): with wavelengths from 320 nm to 400 nm
- Vacuum range (UVV): with wavelengths from 100-200 nm.

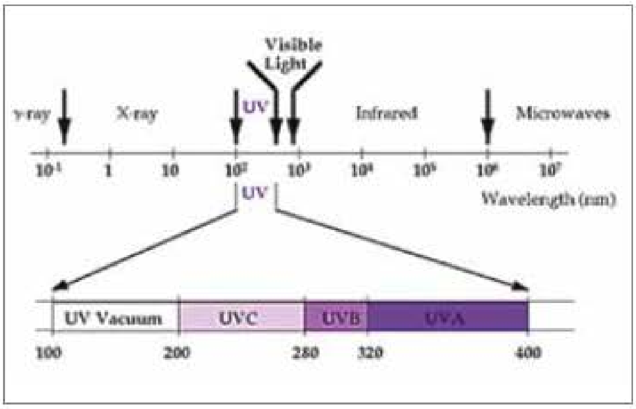

Figure 1: The electromagnetic spectrum

Based on Figure 1, the range of the UV spectrum can be described as UVA for the changes in skin that lead to tanning in humans, UVB for burning of the skin which may lead to cancer, UVC which is effective against inactivating bacteria and viruses (Beggs *et al.*, 2000) and, lastly the vacuum range which is absorbed by almost all substances and can only be transmitted in a vacuum (Fraise *et al.*, 2004; Koutchma, 2009; Sastry *et al.*, 2000). It was indicated that UV irradiation is lethal to most microorganism when they are in the range of 250-260 nm (Begum *et al.*, 2009; Bintsis *et al.*, 2000). According to Tran and Farid (2004) and Guerero-Beltran and Canovas (2005), the highest germicidal effect from ultraviolet spectrum is between 250 nm and 270 nm (UVC), but the effect might decrease when the wavelength is increased. Hence, a wavelength of 254 nm is used for disinfection of surfaces, water and also food products (Bintsis *et al.*, 2000). Koutchma *et al.* (2009) and Oteiza *et al.*, (2009) stated that the most efficient inactivation can be obtained at 253.7 nm due to the maximum absorption of UV photons by the genetic materials of microorganisms at this specific wavelength.

HOW DOES ULTRAVIOLET TECHNOLOGY WORK?

The effect of the UV irradiation on microorganisms is different from species to species. Even though it is in the same species, the effect might be influenced by the strain, growth media, stage of culture, (Wright *et al.*, 2000), density of microorganism and type or composition of the food. The DNA of the microorganism absorbs the radiation and causes the cell to stop growing which then leads to cell death (Liltved and Landfald, 2000). The method of inactivation is related to the absorption of UV photons by the DNA or RNA pyrmidine base, specifically thymine and cytosine in DNA and uracil and cytosine in RNA (Bolton *et al.*, 2003, and Koutchma, 2009). A dimer formation is caused by the incidence of light in the same DNA strand between two adjacent nucleotids. This is shown in Figure 2. As a result, transcription and replication are inhibited which cause the cell death (Bolton *et al.*, 2003; Wang *et al.*, 2005).

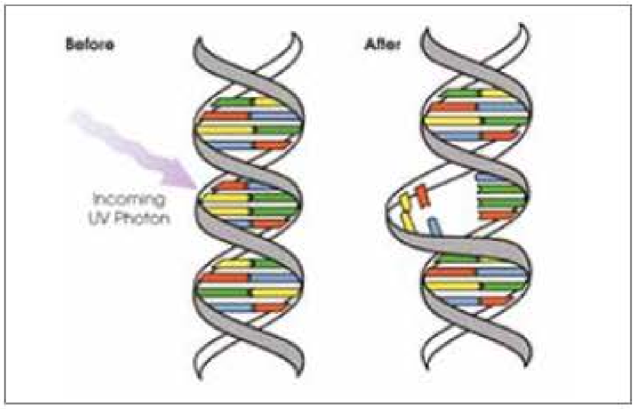

Figure 2: Effect of UV-C light on DNA structure (Source: Infralight, 2007)

The efficiency of UV irradiation relies on the absorbance of the medium, moisture content, amount of solid particles and suspended materials, flow rate of the fluid, fluid thickness, reactor design, UV intensity which is interconnected to the age of lamps used, exposure time, type of microorganisms and growth phase of the organism, and initial microbial density (Begum *et al.*, 2009; Bintsis *et al.*, 2000; Guerero-Beltran and Barbosa-Canovas, 2005; Koutchma *et al.*, 2009). The poor penetration property of UV light is the main limitation. The penetration depth of UVC through the surface of liquids is very short, except for clear water. According to Sizer and Balasubramaniam (1999), UV light penetration into juices is about 1 mm for absorption of 90% of the light. The presence of small amounts of particulates in a liquid can greatly reduce the penetration of UV light (Shama, 1999). As a result, it is difficult for ultraviolet treatment to be applied in juice due to its low UV transmittance through juice which has high suspended and soluble solids.

Figure 3: Ultraviolet light

CONCLUSION

Due to the limitations of ultraviolet light, its application requires more research to overcome the drawbacks so that ultraviolet technology can in future be more practicable for commercial use. As a result, ultraviolet technology is definitely one of the best choices for non-thermal pasteurisation as it maintains the overall quality of the juice. However, due to the characteristics of tropical juices which tend to be less acidic and which could increase the risk of cross contamination, the design of a local ultraviolet pasteurisation machine should be further researched. The on-going progress on data collecting and machine design has been carried out and it is hoped that greater awareness of the benefits of ultraviolet technology in the juice industry could be generated through the success of such research in the future. ■

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