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Processing of clear and turbid grape juice by a continuous flow UV system

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ABSTRACT

The inactivation of inoculated (*S. cerevisiae*) and spoilage microorganisms, i.e. yeasts and lactic acid bacteria (LAB), in clear and turbid grape juice was investigated using a pilot scale UV system. The biodosimetry method was used for UV dose prediction in a continuous flow UV reactor. Weibull model was applied for fitting the inactivation data. The flow rates (774, 820 ml/min) in this system were very close to the ones used in fruit juice processing. *S. cerevisiae* in clear juice was reduced by 3.39 ± 0.04 at 65.50 mJ/cm^2 of UV dose. 1.54 ± 0.04 and 1.64 ± 0.03 log CFU/ml reductions were obtained for spoilage yeasts and LAB in turbid juice at UV dose of 78.56 and 67.97 mJ/cm^2, respectively. The soluble solids (°Brix) and pH of grape juice samples were not affected by UV-C treatment ($p > 0.05$). Although the color parameters slightly were changed after irradiation, the color of PCGJ and FSTGJ did not show visual difference compared to the untreated samples.

Industrial relevance: UV light has a potential to reduce the levels of microbial contamination in liquid foods. Although grape juice has many beneficial health effects, it has a fairly short shelf life. Therefore, pasteurization is required. But the thermal pasteurization has some undesired effects on the juice quality. Consumer demands for high quality fruit juice with fresh-like characteristics have markedly expanded in recent years. In the current study, the microbial inactivation efficiency of a pilot scale UV system for non-thermal treatment of clear and turbid grape juice was evaluated under conservative conditions. Most of the physicochemical properties of grape juice samples were not significantly affected from UV-C treatment ($p > 0.05$). This would be a major advantage in the processing of nutritious juice products.

1. Introduction

Spoilage microorganisms such as yeasts, moulds and acid-tolerant bacteria that can grow naturally in fruit juices may lead to off-flavors and off-odors reducing the quality of the juices (Tournas, Heeres, & Burgess, 2006). On the other hand, the spoilage and contamination of fruit juice by pathogenic microorganisms are the major concerns. The growth of those microorganisms must be avoided in the juice by applying several prevention methods.

Although the thermal processing provides an effective pasteurization, long and stable shelf life for the juices, several sensorial and nutritional quality problems can occur such as permanent loss of flavor and taste, degradation of nutrients and development of undesirable browning reactions emerged from heating (Garde-Cerdan, Arias-Gil, Marselles-Fontanet, Ancin-Azpilicueta, & Martin-Belloso, 2007). In order to prevent harmful effects of the heat, non-thermal processes are investigated as an alternative preservation method for more fresh-like fruit juices (Noci et al., 2008).

UV-C irradiation can be an alternative cost effective non-thermal process for heat sensitive products such as liquid egg products, fruit juices and beverages (Donahue, Canitez, & Bushway, 2004; Unluturk, Atilgan, Baysal, & Tarı, 2008; Gayan, Monfort, Alvarez, & Condon, 2011). UV-C light between 200 and 280 nm in the electromagnetic spectrum has a lethal impact on microorganisms such as bacteria, yeasts, moulds and viruses (Bintsis, Litopoulou-Tzanetaki, & Robinson, 2000). The most efficient germicidal UV light is emitted at 254 nm (Koutchma, Forney, & Moraru, 2009). There are numerous studies about evaluating the efficacy of UV light for the inactivation of spoilage and pathogenic microorganisms in liquid foods (Ngadi, Smith, & Cayouette, 2003; Tran & Farid, 2004; Koutchma & Parisi, 2004; Koutchma, Parisi, & Unluturk, 2006; Noci et al., 2008; Unluturk et al., 2008; Gabriel & Nakano, 2009; Unluturk, Atilgan, Baysal, & Unluturk, 2010).

UV-C light has been used in the water treatment for many years (Guerrero-Beltran & Barbosa-Canovas, 2004). Small, medium and large volume of water can be disinfected efficiently by using different types of commercial UV units available in the market based on different transmittance properties. But the stringent optical properties of liquid foods do not allow using most of these commercial units in the processing of these foods. The efficiency of UV-C treatment is highly affected by the reduced penetration depth as a result of the presence of solutes and

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particles (Wright, Sumner, Hackney, Pierson, & Zoecklein, 2000). Different types of UV reactors have been designed to overcome this limitation. The first design approach used a thin-film flow for liquid foods, e.g. CiderSure reactor that was developed as a UV light processing equipment in 1998 (FPE Inc., Macedon, NY) (CiderSure, 2010) and the Taylor–Couette flow UV reactor constructed by Forney and Pierson in 2003 (Forney & Pierson, 2003). A second design approach focused on increasing of the turbulence within a UV reactor, e.g. Aquionics UV reactor (Hanovia Ltd., Slough, England), SurePure (SurePure Inc., Milnerton, South Africa) and Dean Flow UV reactors such as Salcor UV module (Salcor Inc., CA) and UVivatec System (Bayer Technology Services GmbH, Leverkusen, Germany) (Koutchma, 2008; Müller et al., 2013). Only, CiderSure (FPE Inc., Rochester, NY) and SurePure (SurePure Inc., Milnerton, South Africa) offer some commercial UV systems suitable for small, midsize and large operations of liquid food products (Koutchma, 2008; CiderSure, 2010). On the other hand, some UV systems that are mostly appropriate for the water disinfection can also be used for low transmittance liquids. These systems can be more economical and feasible for small juice production.

The objective of this study was to assess the effectiveness of UV-C irradiation in non-thermal treatment of clear and turbid grape juice using a pilot scale continuous flow UV system, i.e. a typical of those used for water sterilization, under conservative processing conditions. For this purpose freshly squeezed turbid white grape juice (FSTGJ) and pasteurized clear white grape juice (PCGJ) were selected to represent turbid and clear liquid foods. The flow rates (774 and 820 ml/min) used with this system were very close to the ones used in fruit juice processing. Applied UV doses for each product processed in a continuous UV system were determined by a biodosimetry method. The effect of UV-C irradiation on the physicochemical properties of grape juice samples before and after treatment was also evaluated.

2. Materials and methods

2.1. Grape juice

Commercial PCGJ made from seedless grapes (Sultana variety of *Vitis vinifera L.*) (Kavaklıdere, Ankara) was purchased from a local market in Izmir, Turkey. Commercial PCGJ contains citric acid and no other preservatives. Background flora of pasteurized samples was checked by surface plating on Tryptic Soy Agar (TSA, Merck, Darmstadt, Germany) for enumeration of total aerobic bacteria and Violet Red Bile Agar (VRBA, Merck, Darmstadt, Germany) to determine the number of coliforms prior to UV treatment.

White grapes (seedless sultana) were purchased from a market place in Izmir, Turkey. They were washed with tap water and pressed by a household table top fruit juice extractor (Arcelik, Robolio, Istanbul, Turkey). The juice was then filtered through a two layer cheese cloth. In order to protect the color of juice, L-ascorbic acid (400 mg/l) (Merck, Germany) was added in the allowable range of Codex Alimentarious Commission (FAO, Food and Agriculture Organization of the United Nations, 1981). FSTGJ samples were packed in plastic bottles and stored in the freezer (−18 °C) until used.

2.2. Physicochemical properties of grape juice samples

Absorbance of the samples was measured by a UV–Visible Spectrophotometer (Carry 100 Bio, Varian Inc., CA, USA). Absorption coefficient (A_e) was calculated according to Unluturk et al. (2008). Turbidity of the samples was measured by a turbidimeter (Model 2100AN IS, HACH Co., USA). Results were expressed as Nephelometric Turbidity Unit (NTU).

CIE color parameters (L^*, a^*, b^*) were determined by a Chromometer (Minolta CR 400, Konica Inc., Japan). Total color difference (ΔE) and browning index (BI) (Palou, Lopez-Malo, Barbosa-Canovas, Welti-Chanes, & Swanson, 1999) of the samples were calculated from Eqs. (1) and (2), respectively:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

$$BI = 100 * \frac{\frac{(a^* + 1.75L^*)}{(5.645L^* + a^* - 3.012b^*)} - 0.31}{0.172} \quad (2)$$

The reference value for ΔE was the untreated juice. Soluble solids (°Brix) and pH were measured at 20 °C by a refractometer (Mettler-Toledo RE40D, AEA Investors Inc., USA) and a pH meter (HANNA Instruments, USA), respectively. A densitometer (Kyoto Electronics DA, Japan) was used to measure the density of samples. Viscosity measurements were conducted by using concentric cylinder viscometer (Brookfield DV II + Pro, Brookfield Engineering Lab. Inc., MA, USA) equipped with a cylindrical spindle (LV-1) (cylinder diameter 18.84 mm, length 115 mm, beaker diameter 86.30 mm and 600 ml of sample volume).

Titratable acidity of the white grape juice samples was measured by titrating juice samples with a standardized 0.1 N sodium hydroxide (NaOH) solution and the results were expressed as grams of tartaric acid per 100 ml of fruit juice (Eq. (3)):

$$TA\ (\%) = (V) * (f) * (E) * 100/M \quad (3)$$

where V is the volume of 0.1 N NaOH (ml), f is the normality factor of NaOH, E and M are the milliequivalent weight of tartaric acid and volume of the sample, respectively.

Particle size distribution of FSTGJ was determined by a particle size analyzer (Mastersizer 2000, Malvern Instruments Ltd., Malvern, UK) that utilizes the phenomenon of scattered light from laser beams projected through a stream of particles. The grape juice particle size distribution was measured based on the volume percentage. Particle size was explicated in terms of diameter at maximum peak of the graph (Dpeak) and the volume-weighted mean diameter (D[4,3]) was calculated from Eq. (4) where n_i was a symbolized number of particles of diameter (d_i) (Betoret, Betoret, Carbonell, & Fito, 2009).

$$(D[4,3]) = \sum_i n_i d_i^3 / \sum_i n_i d_i^4 \quad (4)$$

Microbiological quality and some of the physical properties of the samples were summarized in Table 1.

2.3. Biodosimetry method

It is challenging to measure the dose distribution delivered by a continuous flow UV reactor. Computing methods, actinometry and biodosimetry are different approaches that can be used for evaluating the dose of UV processing systems. Among them biodosimetry is commonly used (Koutchma et al., 2009). In this method, UV dose–response

Table 1
Microbiological quality and some of the physical properties of untreated PCGJ and FSTGJ.

Property	PCGJ	FSTGJ
Total aerobic count (log CFU/ml)	ND	5.38 ± 0.01
Total coliform (log CFU/ml)	ND	ND
Density (g/cm^3)	1.068 ± 0.002	1.065 ± 0.00
Viscosity (cP)	2.10	5.30
pH	3.45 ± 0.01	4.40 ± 0.01
Titratable acidity (%)	0.37 ± 0.00	0.17 ± 0.03
Turbidity (NTU)	32.5 ± 0.14	105 ± 2.12
Brix (%)	17.42 ± 0.01	16.38 ± 0.00
Absorbance coefficient (at 254 nm)	5.63 ± 0.01	13.26 ± 0.02

Results were presented as mean ± standard error ($n = 3$). ND: not detectable.

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