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Synergistic potential of papaya and strawberry nectar blends focused on specific nutrients and antioxidants using alternative thermal and non-thermal processing techniques

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ABSTRACT

Traditional processing has detrimental effects on nutrient value of fruit nectars; however, combining fruit nectars prior to processing can result in synergistic outcomes, e.g., a combination of nutrients providing a greater effect than they would individually, thus offsetting these losses. To examine this food synergism, papaya and strawberry nectars and their respective blends (25P:75S, 50P:50S, 75P:25S) were processed using ultra high temperature (UHT) and irradiation and examined for ascorbic acid concentration, carotenoid concentration, and antioxidant capacity. Ascorbic acid concentration was best retained after UHT processing, with synergistic relationships in all blends. Synergistic relationships were observed for β-cryptoxanthin concentration after irradiation. β-Carotene experienced both antagonistic and additive relationships whereas lycopene concentration encountered synergistic relationships in the 25P:75S blend for both techniques. All blends exhibited synergistic relationships for antioxidant capacity after UHT processing. These findings demonstrate the benefits of blending fruit nectars; producing a superior product than either fruit processed individually.

1. Introduction

Food synergism results when a combination of nutrients provides a greater beneficial (e.g. antioxidant) effect than they would individually (Jacobs, Gross, & Tapsell, 2009). The idea of food synergy reinforces the importance of a varied diet to obtain maximum health benefits. Many potential bioactive components of papaya (vitamin A, ascorbic acid, α-tocopherol, B vitamins, flavonoids, and carotenes such as β-cryptoxanthin, β-carotene, and lycopene) and strawberry (ascorbic acid, ellagic acid, folic acid, and flavonoids such as anthocyanin, catechin, quercetin, and kaempferol) have significant synergistic potential (Basu, Nguyen, Betts, & Lyons, 2014; Krishna, Paridhavi, & Patel, 2008).

One potential benefit of a synergistic relationship is better absorption of nutrients. For example, flavonoids consumed with ascorbic acid can improve absorption of ascorbic acid and prevent its oxidation (Meletis & Barker, 2004). Since both papaya and strawberry contain ascorbic acid and strawberries also contain a variety of flavonoids, a potential synergistic effect of the two fruit nectars being combined is more efficient ascorbic acid absorption. Independently, both lipid-soluble vitamin E and aqueous-ascorbate are able to inhibit membrane lipid peroxidation by inactivating free radicals (Slausan & Cooper, 1990). Hazewindus, Haenen, Weseler, and Bast (2012) investigated the synergistic effects between lycopene, ascorbic acid, and α-tocopherol, and showed that lipid oxidation was more adequately inhibited when nutrients were combined. It was concluded that ascorbic acid with α-tocopherol is effective at inhibiting lipid peroxidation while also complimenting lycopene's anti-inflammatory effect. Furthermore, extended oxidation inhibitory periods occurred from a combination of flavonoids and α-tocopherol in both tert-butyl alcohol and chlorobenzene solutions, strongly suggesting a synergistic and/or co-antioxidative effect (Pedrielli & Skibsted, 2002). Independently and in combination with flavonoids, α-tocopherol showed similar effectiveness that Pedrielli and Skibsted (2002) compared to ascorbic acid's α-tocopherol regenerating effect, suggesting the same mechanism may result in the synergism between flavonoids and α-tocopherol. Specifically, in tert-butyl alcohol solution, flavonoids such as quercetin and (−)-epicatechin acted synergistically with α-tocopherol while in chlorobenzene solutions quercetin and (+)-catechin were concluded to regenerate α-tocopherol (Pedrielli & Skibsted, 2002). The catechin and quercetin flavonoid content of strawberry combined with α-tocopherol from

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papaya could produce a similar beneficial effect. Previous studies done by Meletis and Barker (2004) demonstrated that the mixing of flavonoids and ascorbic acid improved absorption of ascorbic acid and acted to reduce its oxidation, making it more widely available for use as an antioxidant in the human body. Synergistic relationships such as these may result when papaya and strawberry nectars are blended prior to processing, resulting in a higher quality processed product.

Thermal processing can negatively impact the nutritional and functional properties of papaya and strawberry nectars (Tansakul, Kantrong, Saengrayup, & Sura, 2012). In papaya fruit purees, rigorous boiling leads to a decrease in carotenoid content as well as discolouration of the product (Ahmed, Shivhare, & Sandhu, 2002). However, the conditions utilized in UHT processing are different from traditional thermal processing. UHT processing involves subjecting foods to high temperatures for a short span of time, typically a few seconds or less. Such high temperatures encourage rapid inactivation of microorganisms and enzymes, but since processing times are short, minimal product degradation occurs compared to traditional thermal processing (Barry-Ryan, Martin-Diana, Rico, & Barat, 2007). The average vitamin C content of UHT processed papaya nectar was not significantly different from refrigerated nectar samples (Zulueta, Esteve, Frasquet, & Frígola, 2006). This represents UHT processing's ability to preserve nutrient profiles from natural degradation. Irradiation processing is another alternative to traditional thermal processing. Recently, Rosario, Julieta, Emilia, and Valdivia-López (2013) studied the effects of irradiation on the chemical components of guavas, including sugars, pectin, ascorbic acid, and β-carotene. Ascorbic acid and β-carotene are two nutrients found to be most negatively affected by irradiation; however, these researchers commented that these impacts would likely be seen with other processing techniques as well. In addition to the possibility of greater nutrient retention and greater stability of bioactive compounds, reducing irradiation damage could be a benefit of combining papaya and strawberry nectars. According to Bates, Morris, and Crandall (2001), proper blending of fruit juices could reduce detrimental effects to juice quality and nutritional value.

Alternative forms of processing can result in greater nutrient retention in fruit nectars compared to traditional thermal processing (Satpute & Annapure, 2013). By determining the optimal papaya and strawberry nectar blend, it may be possible to produce a final processed product that is superior to either fruit nectar on their own, with respect to overall nutrient value and antioxidant capacity. In order to elucidate synergistic or antagonistic potentials that may exist between papaya and strawberry nectars, blends were exposed to UHT and irradiation. Following processing, blends were then analyzed for ascorbic acid, β-cryptoxanthin, β-carotene, and lycopene concentrations, in addition to antioxidant capacity (Oxygen Radical Absorbance Capacity, ORAC).

2. Materials and methods

2.1. Materials

Dithiothreitol (DTT) was obtained from Research Organics, Inc. (Cleveland, OH); potassium phosphate monohydrate was purchased from Mallinckrodt Baker, Inc. (Paris, KY); Potassium phosphate, ascorbic acid, m-phosphoric acid, 2,2′-azobis (2-methylpropionamidine), dihydrochloride (AAPH), and 6-hydroxy-2,5,7,8-teramethylchromane-2-carboxylic acid (Trolox), butylated hydroxytoluene (BHT) and β-carotene, type 1 were purchased from Sigma–Aldrich (St. Louis, MO); methanol, acetone, potassium phosphate dihydrate (KH_2PO_4), hexane, methyl-tert-butyl ether (MTBE), ammonium acetate, and glacial acetic acid were purchased from Fisher Scientific (Fair Lawn, NJ); Fluorescein was obtained from Sigma–Aldrich (Milwaukee, WI); Ethanol was acquired from Decon Laboratories, Inc. (King of Prussia, PA); β-cryptoxanthin was obtained from Indofine, Inc. (Hillsborough, NJ); lycopene, from tomato was obtained from Toronto Research Chemicals, Inc. (Ontario, Canada); ß-apo-8′-carotenal, trans was acquired from Fluka (Buchs, Switzerland).

2.2. Sample preparation and processing

2.2.1. Papaya and strawberry pulping

Ripe papaya (Red Flesh, Product of Brazil, www.ugbp.com) and strawberry (Crimson Gold Strawberries, GPC – Grimes Produce Co., Plant City, FL) pieces were pulped using a Kitchenaid™ mixer (Whirlpool, St. Joseph, MI) equipped with a pulping attachment. The pulp's initial total soluble solids concentration (°Bx) was determined using a refractometer (Westover Scientific, Seattle, WA) and diluted as necessary to achieve 8 °Bx and 6 °Bx nectar for papaya and strawberry, respectively. The pH was also determined for the diluted nectar using an ion analyzer meter (Orion Research EA 920, Cambridge, MA). Diluted papaya nectar was immediately frozen at −20 °C until thermally or non-thermally processed and diluted strawberry nectar, made from frozen whole strawberries, was immediately thermally or non-thermally processed after pulping. After being thermally or non-thermally processed, samples were stored at −20 °C until analyzed.

2.2.2. Control samples

UHT controls consisted of diluted papaya and strawberry nectar at 2 °Bx and irradiated controls consisted of diluted papaya and strawberry nectar at 8 °Bx and 6 °Bx, respectively. Controls traveled with treated samples, being handled and stored identically to treated samples, but not thermally or non-thermally processed. UHT controls were run through the UHT machine at room temperature, and irradiated controls remained frozen in a non-irradiated chamber directly next to the Cobalt-60 irradiator.

2.2.3. UHT processing

Due to particle size restrictions imposed to ensure processing of samples, fruit pulping procedures were modified for this technique. Papaya and strawberry were pulped as outlined in Section 2.2.1. The fruit nectar was then additionally pureed in a Bella High Powered food processor (Sensio Inc., Canada) for 60 s to further reduce pulp particle size. The pureed nectar was adjusted to 2 °Bx for both papaya and strawberry and either frozen at −20 °C until thawed or immediately UHT processed.

Samples were exposed to 80, 110 and 135 °C for approximately 1–3 s using a pilot plant scale Armfield FT74T Miniature UHT Heat Exchanger (Armfield, Ringwood, UK). Specific temperature and time combinations were chosen to mirror parameters used to process similar fruits in the literature (Chang & Toledo, 1990; Sanchez-Vega, Mujica-Paz, Marquez-Melendez, Ngadi, & Ortega-Rivas, 2009), and to determine if this method of thermal processing was applicable to papaya and strawberry nectars.

2.2.4. Irradiation

Samples were exposed to 2.5, 5, 7.5, and 10 kGy irradiation using a Gammacell 220 Cobalt-60 irradiator, model 375/2 (Ludlum Measurement, Inc., Sweetwater, TX) using a sealed radiation source, model GO 220E (CO-60, MDS Nordion, Inc., Ontario, CA). These exposure levels fall outside that of what is legally acceptable for processing of papaya and strawberry for consumer use at this current time (US GAO, 2000), but a wide range of doses coupled with overall high doses were chosen specifically to determine the full impact that irradiation has on fruit. Parker et al. (2010)