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Occurrence of bioactive health promoting compounds in commercial products of mango, pineapple and wood apple in Sri Lanka

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ABSTRACT

Bioactive health promoting compounds are present in foods that provide health benefits beyond their nutritional value. Processing of fruits into products can have significant consequences on the nutritional composition. This research was conducted to determine the compositional variation of vitamin C, total phenolic content (TPC), antioxidant activity (DPPH Radical Scavenging assay), β-carotene, total soluble solids (°Bx value) and acidity in nectar, cordial and jam processed using ripe mango, pineapple and wood apple. Vitamin C content in unfortified cordials was 6.8±0.6 and 8.5±1.2 mg/100g FW for pineapple and wood apple respectively. However, vitamin C content in fortified cordials was comparatively higher in mango (56.7-67.6 mg/100g FW), pineapple (44.5-54.6 mg/100g FW) and wood apple (49.9 mg/100g FW) respectively. TPC in nectars ranged from 1.0-4.0 mg tannic acid equivalent (TAE)/100g FW (mango), 2.4-3.8 mg (TAE)/100g FW (pineapple) and 0.7-2.3 mgTAE/100g FW (wood apple) respectively whereas it was 3.3-4.9 mgTAE/100g FW (mango), 2.4-5.3 mgTAE/100g FW (pineapple) and 1.3-4.7 mgTAE/100g FW (wood apple) in cordials. TPC in jam was higher than nectar and cordial products due to incorporation of 40% fruit pulp in jams. The antioxidant activity in nectar was within the range of 0.23-0.40 (mango), 0.29-0.38 (pineapple) and 0.21-0.38 (wood apple) μmolTrolox g^{-1} FW. The antioxidant activity was not correlated with vitamin C or TPC while total soluble solids vs dry weight was highly correlated (R^2 = 0.98). A substantial amount of β-carotene was measured in mango and pineapple products while β-carotene was not detected in wood apple products. The ways of minimizing the potential influential factors along the supply chain is yet to be investigated in broader perspective. It is recommended to promote cultivation of new fruit varieties rich in nutrients, designing new industrial fruit processing technologies including non-thermal processing techniques to minimize the loss of bioactive phytochemicals.

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INTRODUCTION

The consumption of tropical fruits has gradually increased over the years as these fruits provide high amounts of antioxidants and other health benefits (Ahn *et al*., 2020). Fruits are naturally rich in sugar, fiber, vitamin C and phytochemicals. Dietary recommendations and consumer awareness programs across the world on potential health benefits of fruits and vegetables against various chronic diseases is being implemented (Aune *et al*., 2017; Wallace *et al.,* 2020). There are more than 5000 dietary bioactive compounds identified to date and the most of these compounds possess substantial benefits to human health (Gonzalez-Gallego *et al*., 2010; Gonzalez-Vallinas *et al*., 2013: Liu[b], 2013; Casas *et al*., 2018). The available dietary bioactive compounds and their quantities are growing concerns of the consumers in choosing fruits and vegetables (Wallace *et al*., 2020).

Mango is rich in an array of bioactive compounds, high amounts of antioxidants, polyphenols, a blend of sugar (16–18% w/v) and carotene, as vitamin A (Pace *et al*., 2014; Schreinemachers *et al*., 2018). Vitamins, minerals and micronutrients available in pineapple play an important role in the human diet. Fruits with substantial quantities of flavonoids, polyphenols, vitamins, minerals and other secondary metabolites are more preferred than the exotic taste (Da Silva *et al*., 2014). Recent scientific epidemiological evidences revealed an association between consumption of foods rich in phytochemicals and reduction of risk of diseases such as cancer, cardiovascular diseases, inflammation, diabetes, cataracts, neurodegenerative diseases, and hypercholesterolemia (Tanaka *et al*., 2012; Liu[b], 2013; Colijn *et al*., 2017; Crowe-Whit *et al*., 2017).

Products with high amylose content induce lower blood glucose and insulin responses compared to amylopectin. Glycaemic Indices of thirteen tropical fruits ranging from 28 (African star apple) to 68 (watermelon) and a correlation between phenols and antioxidant activity were reported by Oboh *et al*., in 2015.

Identification, quantification and isolation of specific phytochemicals in pulps and by-products of tropical fruits for nutraceutical supplements, dietary additives, novel foods and pharmaceutical products were reported by many authors (Ayala-Zavala *et al*., 2011; Da Silva *et al*., 2014). The relative contribution of different fruit and vegetable products and the components in them (phytochemicals) to health benefits is still a topic of investigation. The food supply chain has been shown to have a large variation in the levels of various phytochemicals (Dekker *et al.*, 2000). Due to different conditions and processes in the supply chain, there is a large effect on the final health benefits for the consumer (Dekker and Verkerk, 2003).

Like many other tropical countries, Sri Lanka also produces many tropical fruits. These fruits are available for consumers in fresh, minimally processed, and processed forms. Due to the seasonal nature of availability of these fresh fruits, processed products with an extended shelf life have emerged in the market in the form of juice, nectar, cordial, jam, canned and dehydrated fruits. Analysis of potential health promoting compounds such as vitamin C, carotenoids, flavonoids and antioxidant activity of many fresh fruits and vegetables have extensively been studied during the last decade, including several processed products (Malta *et al*., 2013). However, the information on tropical fruits and especially processed products of tropical fruits in Sri Lanka is scarce.

Mango (*Mangifera indica* L.), pineapple (*Ananas comosus* L. Marril) and wood apple (*Limonia acidissima* L.) are highly popular fruits in many tropical countries and the demand for these fruits and processed products exists throughout the year. Wood apple is consumed as homemade or industrially processed drinks or jam. Mango and pineapple processed products include juice, nectar, cordial, canned slices in syrup or in juices, jam, chutney, dehydrated pieces and fruit leathers. Exportation of tropical fruits in fresh forms is a common method. However, exportation of mango and pineapple juice to non-tropical countries is usually in the form of concentrates (Somsri, 2014; Arampath and Matthijs, 2019). Different tropical and non-tropical fruit juices are often combined to produce mixed juices, nectars and cordials with commercial attractive aroma, colour and flavour combinations.

Processing of tropical fruits into various products can have significant consequences on the nutritional composition of these products. This will have an impact on the potential health promoting properties. Loss of phytochemicals and nutrients can occur due to thermal processes, separation of parts of the fruit matrices and by dilution with sugar solutions. This could lead to substantial deviations in health beneficial phytochemicals in the processed fruit products.

The agricultural practices, climatic/soil conditions, postharvest handling and processing methods are influenced on the composition of mango fruit and processed products (*Ali et al*., 1992; Siddiq *et al*., 2012). The intensity of some influential intrinsic or extrinsic factors can be manipulated along the supply chain to remain substantial quantities of health promoting compounds. The information on compositional variation in commercial fruit-based products in Sri Lanka is scanty. Therefore, this research was conducted to determine the compositional variation of vitamin C, total polyphenolic content, antioxidant activity (DPPH Radical Scavenging assay), β-carotene, total soluble solids (°Bx value) and acidity in nectar, cordial and jam processed using ripe mango, pineapple and wood apple. This research finding is useful in reformulating the ingredients, process designing to improve the potential health beneficial compounds in commercial fruit-based products, to statutory and regulatory bodies, nutritionists and for consumer awareness of the processed fruit-based products.

METHODOLOGY

Commercial Fruit Products

Commercially available pulp or juice-based products of mango, pineapple and wood apple, were selected based on the availability throughout the country. The samples of bottled nectar (190 mL), cordial (750 mL) and jam (450 g) were purchased directly from five leading fruit processing industries (names are non-disclosed) with the manufacturing date not more than 10 days. Samples of the juice products were prepared shaking the bottles thoroughly and filtering through previously washed and then dried muslin cloth to remove traces of objectionable solid particles. The samples of jam were blended and mixed thoroughly to assure the homogeneity.

Chemicals

Dichlorophenol-indophenol (DCP), Folin-Ciocalteu's reagent, Na_2CO_3 ,β-carotene (Merck, Germany), sodium sulphate, 1,1-diphenyl-2-picrylhydrazyl (DPPH), tannic acid (Sigma-Aldrich, Germany), methanol, tetrahydroxyfuran (THF) (BioSolve, The Netherlands), and oxalic acid, magnesium carbonate and L-ascorbic acid (HiMedia, India) were used for the chemical analysis.

Ascorbic Acid

A sample (5 g) of nectar or cordial was homogenized with 0.25% oxalic acid solution (2-3 ml) and centrifuged at 4000 rpm for 15 min. The supernatant was transferred into a 50 mL volumetric flask and brought up to the mark with 0.25% oxalic acid solution. An aliquot of 10 mL solution was pipetted into a 250 mL conical flask and titrated against 2, 6 dichlorophenol-indophenol (DCP) dye until colour changed to pink. DCP dye was standardized with 10 mL of standard ascorbic acid solution (200 mg L-Ascorbic acid in 250 mL, 0.25% oxalic acid solution). Dye equivalents (mg ascorbic acid required to neutralize 1 mL of dye solution) were calculated (AOAC, 2000).

Total phenolics

Total phenolics were analysed by using the Folin-Ciocalteu's reagent as described by Singleton *et al*., (1998). Water extract of the phenolic compounds of the sample (5 g sample with 7.5 mL water) was prepared and filtered. The filtered sample was centrifuged at 4000 rpm for 15 min and supernatant was taken for analysis. The supernatant (1 mL), demi-water (5 mL) and Folon-Ciocalteu's reagent (1 mL) were pipetted into volumetric flask (25 mL) and mixed well. Subsequently, saturated Na_2CO_3 solution (1 mL) was added and mixed well. Finally, the volume was adjusted to 25 mL with demi-water and swirled the flask several times. Measurement of absorbance of the prepared solution was done using a spectrophotometer at 725 nm after 15 min. A calibration curve was prepared using tannic acid and values were expressed as tannic acid equivalents, mg TAE/100 g FW (fresh weight).

Antioxidant Activity

The free radical scavenging capacity of the different compounds in the samples was measured using DPPH (1,1-diphenyl-2-picrylhydrazyl) assay explained by Sánchez-Moreno, *et al*., (1998) and later modified by Jiménez-Escrig *et al*., (2000) for measuring lipophilic compounds. A dilution series of the samples of processed fruit products was prepared in methanol.

DPPH, 236 mg was dissolved in 100 mL methanol; 10 mL aliquots of this solution were prepared and stored at 0 °C. A working solution ($6x10^{-5}$ M) was prepared by diluting the stock solution 100 times in methanol. A standard curve for DPPH was developed using a series of DPPH concentrations in methanol. The absorptions were measured at 515 nm. DPPH solutions ($6x10^{-5}$M, 3.9 mL) were taken into the cuvette, and then 0.1 mL of sample was added, kept in dark at 23±1 °C for 30 min and measured at 515 nm. Trolox was the reference standard antioxidant. The amount of DPPH not reacted was determined using the DPPH standard curve. Efficiency Coefficient (EC_{50}), the amount of sample (dry weight) necessary to reduce the initial DPPH concentration by 50% was determined in comparison to trolox. The antioxidant capacity was expressed as Trolox Equivalent Antioxidant Capacity (TEAC) μmol/g FW.

β-Carotene

β-Carotene content was determined by Reversed Phase High Performance Liquid Chromatography (RP-HPLC). The HPLC instrument (SHIMADZU, CTO-10A vp) consisted of a Vydac 218TP54 (C_{18}, 5 μm, 4.6 mm ID x 250 mm) reversed phase analytical column with a guard column. The extraction method of β-carotene was a slightly modified method (Bushway,1985; Bushway and Wilson, 1992).

Extraction was carried out under red dimmed light, while flushing with nitrogen to minimize oxidation. Two grams of sample with 4 μL 0.1% Butylated Hydroxy Toluene (BHT) in ethanol were combined with 1.0 mL of internal standard, β-apo-8-carotenal 0.08 mg/mL in tetrahydroxyfuran (THF). Thereafter 4 g anhydrous sodium sulfate, 0.5 g magnesium carbonate and 30 mL of THF were added. The suspension was mixed by vortexing for one minute, at 1200 rpm and the mixture was allowed to precipitate to a clear supernatant. This supernatant was filtered through a filter paper (Whatman No.1) into a 250 mL round-bottom flask. Then, 20 mL THF were added to the remaining precipitate, and extracted as described previously. This procedure was repeated thrice until the filtrate and residue were colourless. The filtrate was concentrated until near dryness by a vacuum rotary evaporator (40 °C, ± 260 mbar) and flushed with nitrogen. Subsequently, the concentrate was dissolved in 10 mL methanol: THF mixture (3:1) containing 0.01% BHT. An aliquot of 1 mL was filtered through a 0.45 μm PTFE HPLC syringe filter (All-tech, DeerfieldIL) into a vial prior to HPLC injection.

The eluent, composed of 92.5% methanol, 7.5% THF and 0.1% triethylamine, was degassed by an All-Tech degassing system. A series of samples and standard solutions of 20 μL each were injected into the column, and eluted using isocratic mode for 25 minutes with a flow rate of 1.0 mL/min. β-Carotene was identified by internal standard (β-apo-8-carotenal) and quantified by spectrum and peak area.

Total Soluble Solids (TSS)

TSS were determined using a hand-held refractometer (ATAGO, Japan) and expressed as Brix (°Bx) value.

Titratable Acidity

An aliquot of blended and filtered sample was titrated against 0.1N sodium hydroxide solution with phenolphthalein indicator (AOAC, 2000). Acidity of highly coloured juices (mango or wood apple) was determined by titrating the sample with known volume of distilled water until the colour change of the sample.

Dry Matter Content

The dry matter content was determined by using the oven drying method. Fruit juice samples of 3-4 g were drawn into labelled moisture cans and 1 g sea-sand was added and mixed them using a spatula, heated with the lid open overnight at 80 °C followed by 3 hours drying at 105 °C. Samples were cooled in a desiccator prior to weighing the cans.

Statistical Analysis

One-way Analysis of Variance (ANOVA) at 0.05 significance level ($\alpha = 0.05$) was conducted using Minitab-15 version followed by Tukey pairwise comparisons at 95% Confidence. Values measured from triplicate samples were subjected to the analysis. Correlation coefficient (R^2) was determined by linear regression analysis using MS Excel-2017 vision.

RESULTS AND DISCUSSION

Dry weight, total soluble solid (TSS), acidity, vitamin C, TPC, β-carotene, and antioxidant activity measured in commercial products (nectar, cordial, jam) using mango, pineapple and wood apple are given in Table 1.

Dry Matter Content, Acidity and Total Soluble Solids

The variability of dry matter, acidity and TSS is substantially lower in processed products of mango, pineapple and wood apple. The dry matter content of mango, pineapple and wood apple nectars varied between 15.3 - 19.4%, whereas in cordial and jam, it was 49.9 - 60.8% and 68.2-73.6% respectively (Table 1). The variation of dry matter content within the same product categories of three fruits was significantly different ($P<0.05$) among the fruit processors except for pineapple nectar and cordial. In commercial operations, percentage fruit pulp or juice content in the same product formulation varied among the fruit processors. Therefore, fruit pulp or juice content in the formulation has a direct impact on dry matter content of the product. Similarly, acidity in nectar varied between 0.27- 0.52%, whereas in cordial and jam the variation was 0.31-0.69% and 0.62-0.92%, respectively (Table 1). According to the government regulation in Sri Lanka, Sri Lanka Standard (SLS) product certification is compulsory for the marketable products of nectar (SLS 729:2010) and cordial (SLS 214:2010 – fresh fruit cordials). The SLS standard (SLS 729:2010) requirements for nectar are TSS 16% w/w (maximum) and acidity (as anhydrous citric acid) 1% w/w (maximum) respectively. The similar limits specified for cordial are TSS 48 ^{o}Bx and acidity 1% w/w (SLS 214:2010). TSS in jam is not less than 65% by mass (SLS 265:2011) while minimum fruit content is not less than 40%. SLS logo is not compulsory for commercial products of jam. TSS value of mango, pineapple and wood apple jam was within 62-66% in the tested sample and the values were not significantly different (P>0.05) except in the product band A (Table 1). TSS and acidity limits of the analyzed commercial products of nectar and cordial fulfilled the SLS compulsory product standards.

In tested samples, dry weight and acidity values were significantly different (P<0.05) within the same product category. TSS in each commercial brand was significantly different (P<0.05) except in mango cordial and jam. TSS and acidity are the key chemical parameters specified in the SLS standards in fruit-based products. The most of the commercial fruit-based products are formulated to fulfil these key parameters, TSS and acidity while neglecting the attention on health promoting phytochemicals unintentionally. Further, nutritional composition in the product label is confined to the major constituents of foods and energy value. Because of this reason, consumer perception on health beneficial compounds and trust on experimented product categories are greatly influenced.

Fresh fruit pulp or juice is processed into products during the peak season of fruits. The thermally and/or chemically processed bulk preserved pulp or juice in single strength or concentrated forms are stored at ambient, cold or frozen storage (Arampath and Matthijs, 2019). These semi-processed bulk preserved juice or pulp are mainly used during the off season or exported as the raw material. Formulation of fruit-based products is mainly calculated using TSS, acidity, fruit content and sensory attributes of the products. Attention on available health beneficial phytochemicals in fruit pulp or juice has been disregarded in product formulation. Thus, occurrences of these health beneficial compounds are unknown to the consumers. In this study, the result proved that despite the variation in variety, location of cultivation and certain environmental factors, there can be a huge variation in finished products during product formulation, raw material selection (fresh or bulk preserved forms) and process control parameters applied during the production by the fruit processors. Interestingly, the specified key indices (TSS, acidity) are well maintained to fulfil the products' standards. However, the utmost beneficial nutrients, the secondary metabolites, such as flavonoids are unavailable to the end users. Further, the health beneficial compounds in bulk stored fruit pulp or juice at cold storage (4 °C) possessed substantially low or negligible amounts of health beneficial compounds than the fresh counterparts (Arampath and Matthijs, 2019).

Variation in sugar, ascorbic acid, organic acids, and TSS content in different varieties and cultivars of mango are reported by Liu[a], *et al.*, (2013). In Sri Lanka, fructose content in mango pulp was 67.4 - 141 mg/g (db), followed by glucose and sucrose (Thanaraj *et al.,* 2009). Variation in sugars, amino acids and hydroxymethylfurfural (HMF) in concentrated pineapple juice in different regions of the world has also been reported (Ooghe and Dresselaerts, 1995). TSS content in the finished product is mainly a sum of soluble sugars in fruit juice or pulp and the added sugar during mixing of ingredients.

Processing of pineapple mostly involves heat treatments resulting in variation in sensory and nutritional quality of the commercial products (Mohamed, 2014; Chua and Leong, 2020). Loss of vitamin C during heat treatment and non-enzymatic browning, the Maillard reaction after processing (Vollmer *et al.,* 2020) are also documented.

Hydrolysis of starch increases the sugar content in climacteric fruits during ripening and results in better eating quality of mango. TSS has been increased from 9.1% to 17.3% while titratable acidity reduced from 0.6% to 0.2% during the ripening of mango. Saranwong *et al*., (2004) reported the sugar content in pineapple consists of nearly 50% sucrose, 33% fructose and 17 % of glucose. A strong correlation between starch content and the eating quality of mango was reported by Padda *et al*., (2011).

Commercial pineapple juice, nectars, pineapple juice and juice concentrates consist of sucrose (4.1±0.7 g/100 mL), fructose (2.5 ± 0.5 g/100 mL) and glucose (2.3 ± 0.4 g/100 mL) in more or less similar concentrations (Cárnara *et al*., 1995). The energy value, acceptability and sensory perception of the juices and processed products are determined by the available sugar products.

TSS of nectars, cordial and jam made from three fruits (mango, pineapple and wood apple) were found to be in between 12.8 - 16.8, 45.5 - 49.8 and 61-66.9 °Bx respectively. TSS value in the SLS standard is 48 °Bx for cordial (SLS 214:1985) and 64 °Bx for jam (SLS 265:1985). In this study, deviations among the commercial branded products were observed (Table 1). Although the composition of these commercial products is regulated in juice-based products through the Sri Lanka Standards as compulsory requirement, the results of this experiments has proved that the tested marketable products did not conform to the SLS product specification.

Ascorbic Acid Content

Variation in sugar, ascorbic acid, organic acids, and TSS content in different varieties and cultivars of mango has previously been reported (Ali *et al*., 1992; Liu[a] *et al*., 2013). In the present study, a significant variation in ascorbic acid content measured in different products was observed (Table 1). There is a considerable variation due to addition of different fruit fraction and fortification with vitamin C. There is no clear relationship with the type of fruit even though levels in fresh fruit are increasing in the order: Mango > Pineapple > Wood apple. Therefore, the observed variation has been resulted mainly due to fortification. The product label provides evidence for the fortification.

Variation of vitamin C in fresh pineapple juice was 9.2 - 93.8 mg/100 mL (Achinewhu and Hart, 1994). The vitamin C content in fresh pineapple juice (84.2 ± 9.6 mg/100 mL) and commercial pineapple juice produced using the concentrate were varied from 8.5±1.4 to 58 ± 4.9 mg/100 (Cárnara *et al*., 1995).

In nectar, vitamin C contents with minimum and maximum values were 1.3-37.4 mg/100g FW (mango), 24.1-33.8 mg/100g FW (pineapple), and 3.7- 6.9 mg/100g FW (wood apple), respectively. The standard limit for vitamin C is not given in the SLS standards. The higher levels of vitamin C in commercial products were resulted due to fortification of vitamin C as indicated in labels.

Vitamin C contents in unfortified cordials; 0.6±0.3 mg/100g FW for mango, 6.8±0.6 mg/100g FW for pineapple, and 8.5±1.2 mg/100g FW for wood apple were significantly different ($P<0.05$) from that of fortified products. Vitamin C in fortified cordials ranged from 56.7-67.6 mg/100g FW for mango, 44.5-54.6 mg/100g FW for pineapple and 46.1-48.9 mg/100g FW for wood apple. In jams, vitamin C content varied, 45.1-63.9 mg/100g FW (mango), 4.3-61.2 (pineapple) and 38.8-63.2 mg/100g FW (wood apple). Results revealed that wood apple jam is a rich source of ascorbic acid due to high content of fruit pulp (40 %). However, wood apple nectar had low in vitamin C content. Mango cordials and jams, and wood apple jams were relatively high in vitamin C. Other product categories had variable quantities. Since only three samples of each category were analyzed in this experiment, no general conclusions could be drawn.

Total phenolic content

Phenolic content in mango, 56.0±2.1 mgGAE/100g FW (Luximon-Ramma *et al*., 2003) and in pineapple, 119±6.0 µmol/g (Vinson *et al*., 2001) were reported with obvious variations. In this research, total phenols in the processed products were substantially lower than the fresh or ripe fruits. Total phenolics in fresh pineapple juice, 36.2±0.5 mg GAE/100 mL (Mahdavi *et al*., 2010), 67.4 mg GAE/100mL (Lugas and Hóvári 2003) and commercial packaged fruit juice 35.7±0.3 mgGAE/100mL (Mahdavi *et al*., 2010) were reported. Total phenols content of nectars made from mango, pineapple and wood apple ranged from 1.0- 4.0, 2.4-3.8 and 0.7-2.3 mg Tannic acid equivalent (TAE)/100g FW, respectively.

The phenol content for cordials were little higher than nectars and, 3.3-4.9 for mango, 2.4-5.3 for pineapple and 1.3-4.7 mg/100g FW for wood apple (Table 1). However, due to high fruit content (40%) of jam, relatively higher values of total phenol were reported for commercial jams; 3.4-6.5 mgTAE/100g FW (mango), 3.9-7.2 mgTAE/100g FW (pineapple) and 4.2-7.0 mgTAE/100g FW (wood apple).

TPC in methanolic extracts of mango and pineapple pulp were 20.0±2.6 and 21.7±45 mg GAE 100 g^{-1} of dried fruits (Kuskoski *et al*., 2006). TPC in pineapple was 40.4±1.0 mgGAE100 g^{-1} fresh dry total fruit (Sun *et al*., 2002) while in dry extract pineapple powder, TPC was 9.1±1.3 mgGAE/g (de Oliveira *et al*., 2009) Therefore, the determined measured values of phenolic compounds in nectars, cordials and jams are extremely lower than the reported values by other authors. The reason would be loss of phenolic compounds during washing, cutting and processing at subsequent processing steps. The intensity of thermal treatment and exposure time fruit during the processing are the influential factors to reduce the phenoilc compounds.

Table I. Dry weight, total soluble solid, acidity, vitamin C, total phenolic content, β-carotene, and antioxidant activity measured in mango, pineapple and wood apple in commercial products, nectar, cordial and jam.

Product		Industry	Dry weight (%)	Brix (°Bx)	Acidity (%)	Vitamin (mg/100g)	TPC* mg (TAE)/100g	β-carotene μg/g	AOX** μmol Troloxg^{-1}
Mango	Nectar	A	18.5 ± 0.4a	13.6 ±0.8a	0.35±0.04a	35.8 ± 1.6a	2.4 ± 0.9ab	al <dl-1.24	0.38 ± 0.01a
		B	17.3 ± 0.3b	14.5 ±1.2a	0.28±0.01b	1.6 ± 0.3c	1.2 ± 0.2b	1.2 ± 0.04	0.24 ± 0.01c
		E	15.9 ± 0.6c	15.5 ±0.7a	0.36±0.00a	32.0 ±1.2b	3.2 ± 0.8a	al <dl-1.24	0.33 ± 0.01b
	Cordial	A	53.9 ± 0.4b	48.5 ±0.9a	0.56±0.02b	58.0±1.3b	4.2 ± 0.3ab	1.35 ± 0.08a	0.56 ± 0.02a
		C	56.0 ± 0.5a	46.8 ±0.1b	0.66±0.03a	61 ± 1.3b	4.8 ± 0.1a	0.86 ± 0.03b	0.52 ± 0.04ab
		D	54.4 ± 0.2b	48.0±01ab	0.52±0.02b	66 ± 1.6a	3.6±0.3b	1.24± 0.25ab	0.42 ± 0.06b
	Jam	A	71.1 ± 0.8a	62.0 ±1.0b	0.72±0.02b	62 ±1.9a	3.8±0.5b	2.6 ± 0.16a	0.47 ± 0.02a
		C	68.6 ± 0.4b	65.0 ±1.0a	0.83±0.02a	46 ± 0.9c	3.54±0.1b	1.54 ± 0.11b	0.44 ± 0.02a
		D	70.5 ± 0.1a	66.0 ±0.9a	0.76±0.01b	57 ± 2.3b	6.2±0.3a	1.2 ± 0.05c	0.37 ± 0.01b
Pineapple	Nectar	A	16.13 ±0.2a	14.6 ±0.9a	0.38±0.02b	32.5±1.3a	2.8 ± 0.4a	al <dl-0.64	0.32 ± 0.03b
		C	16.7 ± 0.3a	15.6 ±0.7a	0.49±0.03a	28.00 ±1.4b	3.2±0.6a	0.85 ± 0.06a	0.37 ± 0.01a
		E	16.4 ± 0.5a	16 ± 0.8a	0.32±0.03b	26.00 1.9b	2.8±0.1a	0.65 ± 0.01b	0.35 ± 0.01ab
	Cordial	B	52.4 ± 0.4a	49.0 ±0.9a	0.59±0.01a	6.8 ± 0.6c	3.4±0.3b	1.10 ± 0.05a	0.49 ± 0.02b
		D	51.1 ± 0.8a	48.5 ±1.2a	0.35±0.04b	54 ± 0.6a	2.5±0.1c	1.20 ± 0.35a	0.55 ± 0.03a
		E	51.1 ± 1.2a	47.5 ±0.77a	0.37±0.01b	46 ± 1.5b	4.8 ± 0.5a	0.84 ± 0.06a	0.43 ± 0.02c
	Jam	B	68.8 ± 0.5b	64.0 ± 0.8a	0.84± 02ab	4.8 ± 0.5c	5.5 ± 0.6b	1.80 ± 0.06a	0.36 ± 0.02b
		C	71.4 ± 0.5a	63.5 ±1.0a	0.86±0.03a	60.0 ± 1.2a	4.2 ± 0.2c	1.20 ± 0.08ab	0.42 ± 0.03a
		E	69.4 ± 0.4b	65.0 ±1.2a	0.80±0.02b	52 ± 3.2b	6.9 ± 0.4a	0.86 ± 0.06b	0.39 ± 0.02ab

Table I. (Continued from the previous page) Dry weight, total soluble solid, acidity, vitamin C, total phenolic content, β-carotene, and antioxidant activity measured in mango, pineapple and wood apple in commercial products, nectar, cordial and jam.

Product		Industry	Dry weight (%)	Brix (°Bx)	Acidity (%)	Vitamin (mg/100g)	TPC* mg (TAE)/100g	β-carotene µg/g	AOX** µmol Troloxg^{-1}
Wood apple	Nectar	A	18.8 ± 0.6a	15.6 ±1.0a	0.45±0.04a	6.4 ± 0.5	0.8 ±0.1b	nd	0.37 ± 0.01a
		B	17.6 ± 0.2b	14.5 ± 0.7a	0.38±0.02b	al<dl-3.7	1.8 ± 0.5a	nd	0.22 ± 0.01c
		C	16.2 ± 0.4c	14.0 ± 0.8a	0.46±0.01a	4.0 ± 0.3	1.5 ± 0.4ab	nd	0.31 ± 0.02b
	Cordial	B	60.4 ± 0.4a	47.0 ± 0.5a	0.62±0.03a	al<dl-7.3	3.8 ± 0.4b	nd	0.26 ± 0.04a
		C	58.6 ± 0.5b	46.0 ± 0.5a	0.56±0.02b	8.5 ± 1.2b	1.4 ± 0.1c	nd	0.24 ± 0.01a
		D	58.0 ± 1.0b	47.5 ±1.0a	0.46±0.02c	48 ± 1.9a	4.5 ± 0.2a	nd	0.37 ± 0.08a
	Jam	C	73.2 ± 0.4a	63.0±0.8a	0.91±0.01a	62 ± 1.2a	6.2 ± 0.8a	nd	0.31 ± 0.05b
		D	69.4 ± 0.5c	64.0 ±1.1a	0.63±0.01c	40 ± 1.2c	4.4 ± 0.2b	nd	0.33 ± 0.07b
		E	72.1 ± 0.4b	64.8 ± 0.9a	0.7± 0.02b	48 ± 0.8b	5.8 ± 0.4a	nd	0.49 ± 0.03a

TPC* Total phenolic compounds (mg tannic acid equivalent (TAE)/100g FW), AOX** Antioxidant activity (µmol Trolox g^{-1} FW)
Results represented as Means [± standard deviation (SD)] sharing similar letters in a column (represent three commercial brands, A to E of single product) are statistically non-significant ($P < 0.05$).
Data expressed as mean value ± SD (n = 3). Number of replicates: n=3, FW: fresh weight.

Table 2. Correlation matrix between tested variables of the commercial products.

Constituent	Vitamin C	TPC	TEAC	β-carotene	Brix	Acidity	Dry wt.
Vitamin C	1.00						
TPC	0.35	1.00					
TEAC	0.26	0.13	1.00				
β-carotene	0.01	0.08	0.06	1.00			
Brix	0.29	0.53	0.18	0.22	1.00		
Acidity	0.14	0.44	0.04	0.17	0.68	1.00	
Dry wt	0.29	0.50	0.14	0.25	0.98	0.48	1.00

TPC: Total phenolic content, TEAC: Trolox Equivalent Antioxidant Capacity

Trolox Equivalent Antioxidant Capacity (TEAC)

The minimum and maximum values of TEAC values nectars made from mango, pineapple and wood apple were 0.23-0.39, 0.29-0.38, and 0.21-0.38 µmolTrolox g^{-1} FW respectively. The variation resulted was due to the differences in antioxidant capacities in fruit pulp or juice used for nectar production. Similarly, the TEAC values for cordials made from mango, pineapple and wood apple were 0.36-0.58, 0.39-0.58 and 0.23-0.45 µmolTrolox g^{-1} FW, respectively (Table 1). The result revealed that fortification has greatly influenced on the TEAC values of the products.

β-Carotene

β-Carotene content in nectar made from mango and pineapple were 1.16-1.24 and 0.64-0.91 µg/g FW, respectively (Table 1). β-Carotene could not be detected in wood apple nectar, cordial and jam. The pulp of wood apple is dark brown in colour. The fruit is covered with a hard shell, and no yellow-red pigments are available in wood apple pulp. Similarly, β-carotene in mango and pineapple cordial was 0.83-1.43 and 0.78-1.55 µg/g FW, respectively. A substantial amount of β-carotene was detected in jam products due to higher fruit pulp content (40 %) than other products. Variation in β-carotene content, 800 µg (Mulgoa cultivar), 13,000 µg/g (Alphonso cultivar) (Hymavathi and Khader, 2005) and 1.7-18 µg/g in different varieties of mango (Rodriguez-Amaya *et al*., 2008) are reported. β-Carotene content of processed products substantially reduced during the processing and storage of the product irrespective of the inherent varietal difference of the fruits.

Correlation between Quality Characteristics

The correlation matrix between tested variables of the market products is given Table 2. As generally expected, a very high correlation coefficient was established between dry weight and °Bx (R^2 = 0.98). All the other combinations of correlation coefficients were relatively low and not significantly different ($P>0.05$). A lower positive relationship between the antioxidant capacity vs vitamin C (R^2=0.26), and antioxidant capacity vs total phenolic compounds (R^2=0.35) was observed in the present study. Apparently, the other compounds in the product may contribute significantly to the TEAC value. The highly variable composition of the tested products could be due to the variations in raw material quality, formulation, and the processing technique of nectar, cordial and jam.

However, to improve the nutritional quality and health benefits of these fruit products, a higher level of health beneficial compounds in the products is desirable. Producers can improve this situation by applying strict quality control measures, selection of high-quality raw materials, adapting compatible process control measures and selecting proper storage conditions.

CONCLUSION

Vitamin, β-carotene, TPC, TSS and antioxidant activity in nectar, cordial and jam produced from mango, pineapple and wood apple were significantly different ($P<0.05$). Vitamin and β-carotene concentrations were substantially lower or even undetectable in some of the tested products. However, the variation of TSS (°Bx), acidity and dry weight of the tested marketable products were comparatively low because of the compulsory Sri Lanka Standards (SLS) for nectar, cordial and jam. The antioxidant activity of three marketable products of mango, pineapple and wood apple was also significantly different ($P<0.05$). The raw materials (fresh fruits or semi processed pulp/juice), history of stored pulp/juice, product formulation, processing techniques, and adherence to the products standards were affected by the compositional variation. Fortification of vitamin C is mostly practiced by the processors and significantly influenced on vitamin C content in fortified products. The correlation coefficients of vitamin C, total phenolics, TEAC, β-carotene, TSS, acidity and dry weight were comparatively lower. However significant correlation was found in-between dry weight and TSS (R^2= 0.98), which is a previously known fact. Present consumers prefer more nutritious and healthy fruit pulp or juice based commercial products. However, the influential factors on health beneficial bioactive phytochemicals throughout the supply chain are yet to be investigated in broader perspective. It is recommended to develop nutrient rich new varieties of fruits that can be used to produce high quality processed food products. Designing of novel products and processes with non-thermal techniques and modern process technologies are essential for the development of commercial fruit products with higher levels of bioactive phytochemicals with health benefits to fulfil the demand of the health-conscious consumers.

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