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Carotenoids, Phenolics, Antioxidant Activity and Sensory Attributes of Carrot Jam: Effect of Turmeric Addition

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ORANGE carrot is one of the important vegetables because of the substantial quantity of bioactive compounds. So, the consumption of carrot and its products, especially jam, is increasing steadily. The aim of this study is evaluating carotenoids, phenolics profile, antioxidant activity and color properties of raw orange carrot and carrot jam made with different addition levels of turmeric powder. The raw carrot roots contained 79.320.29± mg of total phenols as gallic acid equivalent/100g FW, 12.7110.24± mg of total carotenoids as ß-carotene equivalent/ 100g FW and 47.1670.21± µM Trolox equivalents / 100g FW. The turmeric addition in carrot jam up to 6g/ 1000 g raw carrot caused an increase in total carotenoids, total phenols and antioxidant properties in all jams compared to the control. Two major phenolic compounds in raw carrot are p-hydroxybenzoic acid (22.356 mg/ 100 g FW) and caffeic acid (18.371 mg/ 100 g FW), while ß-carotene, α-carotene, lutein and lycopene were 8.210.01±0.21 ,0.05±0.465 ,0.09±3.38 ,0.04± mg/100g FW, respectively. The addition of turmeric as an ingredient of jam formulation significantly improved carotenoids retention, phenolics retention and antioxidation activity. In addition, turmeric powder could be essentially incorporated with jam formulation up to 4 gm /1000 gm raw carrot to improve its quality attributes without causing any sensorial defect.

.**Keywords:** Carrot, Turmeric, Carrot jam, Carotenoids, Phenols, Antioxidant activity

Introduction

Carrot *(Daucus carota L.)* is one of the most valuable vegetables, and it is an important source of nutritional compounds, such as carotenoids (Bozalan & Karadeniz, 2011 and Simon, 1990), vitamins (Riganakos et al., 2017), phenols (Assous et al., 2014, Bozalan & Karadeniz, 2011 and Zhang & Hamauzu, 2004), anthocyanins (Algarra et al., 2014, Kammerer et al., 2004 and Turkyilmaz et al., 2012) and polyacetylenes (Kidmose et al., 2004).

The unique profile of micronutrient compounds in carrot makes it effective in health promotion and protection of obesity, diabetes, heart disease, hypertension, inflammatory bowel, and cancers (Metzger et al., 2008, Sharma et al., 2011 and Tsuda, 2012). Moreover, carrots are widely used to many foods, such as soft drinks, juices, jams, confectionary, fermented sausage and yogurts (Ekici et al., 2015, Kamiloglu et al., 2015, Kirca et al., 2006 and Rozan et al., 2017).

The color of carrot roots gradates among white, yellow, orange, purple and red. Carotenoids content varies highly among carrot genotypes (Baranski et al., 2012). Carrots contain provitamin A activity as α and ß-carotene, and contain the non-provitamin A carotenoid lycopene. Orange carrots usually contain high amounts of carotenoids, especially α- and β-carotene, while yellow carrots contain lutein, and red carrots has high amounts of lycopene (Sun et al., 2009 and Arscott & Tanumihardjo, 2010).

Carotenoids and phenolics represent two major divisions of phytonutrients found in vegetables. The major amounts of carotenoids accumulate in the root tissues (Howard and Dewi, 1995).

Jam is one of the most popular shelf- stable products made from various vegetables and fruits. To manufacture jams, fruits and sugar are mixed in almost equal amounts, pectin added sometimes as a gelling agent, followed by cooking to produce a sweet product with satisfactory sensory qualities (Downing, 1996).

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Thermal processing is used for extending the shelf life of vegetable jams by inhibiting enzymes and inactivating microorganisms, however the thermal treatments often cause significant undesirable effects including loss of nutritional compounds, reducing biological activities, and alteration of color, flavor and texture (Gao & Rupasinghe, 2012 and Riganakos et al., 2017).

The percentage of phytonutrients losses during processing depends on cellular localization, chemical structure, solubility, enzymatic activity and processing conditions. Water-soluble compounds such as various classes of phenolics easily leach into the water during wet thermal processes. In contrast, nonpolar compounds such as carotenoids are well retained during wet thermal processes, but thermal degradation and oxidation cause losses due to the conjugated double bond structure of carotenoids (Hager and Haward, 2006). In addition, various transformations of phenolic compounds occur to produce brownish or yellowish pigments (Clifford, 2000).

Turmeric (*Curcuma longa* L.) is a herbaceous perennial plant of the ginger family, *Zingiberaceae*. It is originally from South and Southeast tropical-Asia (Li, et al. 2011). Turmeric is a yellow-colored rhizome known for its use in curries and in different medicinal preparations, it is widely used as a curative, spice, food preservative, flavoring and coloring agent. It is one of the most folk spices containing natural antioxidants, wherefore, it has several medicinal properties including antimicrobial, anti-protozoal, antiviral, anti-tumor, anti-inflammatory and anti-venom, anti-alzheimer and anti-mutagenic activities (Sasikumar, 2001, Tilak et al., 2004 and Valizadeh et al., 2016).

The current study focusses on the assessing carotenoids and polyphenols in raw orange carrot and their stability after thermal processing during carrot jam manufacture, and evaluating the effectiveness of turmeric addition on phytonutrients retention, physicochemical parameters, and sensory quality attributes of carrot jam.

Materials and Methods

Materials

Orange carrot (*Daucus carota* L. ssp. *sativus* var. *nanter)* (88.366% moisture content, 7.84% carbohydrate, 0.592% protein, 0.451% fat, 0.925 fibers, 0.826% ash) used in this study (season 2017) were purchased from the local market in Beheira Governorate, Egypt. White granulated sugar (35 IU color, 99.95% purity) was obtained from Nile Sugar Company, Km 54 Alexandria/ Cairo Desert Road, Egypt. Pectin (150 Grade pectin, rapid set) was purchased from Misr Chemicals Co., Cairo, Egypt. Butylated hydroxy toluene (BHT) and solvents used for spectral and HPLC analyses were of HPLC grade and were purchased from Sigma Chemical Company, USA.

Methods

Jam processing

Orange carrot jams were prepared considering the limits described in Egyptian standards (ES:129-2/ 2013). After washing, peeling, slicing, and boiling for 30 min, orange carrots was mixed with commercial sucrose at 1:1 (w/w) ratio. Turmeric powder with (0, 2, 4 or 6 gm/kg carrot) was added (as described in Table 1). The mixture was heated for 30 min in an open cooking pan with stirring, after which 3.5 g pectin/ 1kg sugar were added. Afterwards, jams were heated until 60 ºBrix of dry matters were achieved. All mixtures were adjusted to pH 3.0 with citric acid and hot-packed at 85 ºC into sterilized glass jars. The jars were left hot for 15 min then cooled at room temperature (25±2 ºC). Samples were stored at 4 ºC until the time of analysis.

Determination of total phenolic content

The total phenolic content was determined according to the Folin-Ciocalteu procedure (Zilic et al., 2012). Briefly, the extract (100 µL) was transferred into a test tube and the volume adjusted to 3.5 ml with distilled water and oxidized with the addition of 250 µL of Folin-Ciocalteau reagent. After 5 min, the mixture was neutralized with 1.25 ml of 20% aqueous sodium carbonate (Na_2CO_3) solution. After 40 min, the absorbance was measured at 725 nm against the solvent blank. The total phenolic content was determined by means of a calibration curve prepared with gallic acid, and expressed as µg of gallic acid equivalent (mg GAE) per 100 g of sample.

Determination of total carotenoids

Total carotenoids content was determined according to Moore et al. (2005) using the spectrophotometric method at 470 nm. The total carotenoids content was expressed based on β-carotene equivalents (β-carotene; mg/100g sample) using β-carotene standard curve. Additional dilution was done if the absorbance value measured was over the linear range of the standard curve.

TABLE 1. **The recipe for carrot jam with different levels of turmeric powder.**

Samples	Carrot (gm)	Sugar (gm)	Pectin (gm)	Citric acid (gm)	Turmeric powder (gm)
Control (FTCJ)	1000	1000	3.5	1.75	0
2TCJ	1000	1000	3.5	1.75	2
4TCJ	1000	1000	3.5	1.75	4
6TCJ	1000	1000	3.5	1.75	6

FTCJ mean free turmeric carrot jam, 2, 4, 6TCJ express the turmeric addition levels.

Determination of radical DPPH scavenging activity

Free radical scavenging capacity of extracts were determined using the stable DPPH according to Hwang and Do-Thi (2014). The final concentration was 200 µM for DPPH and the final reaction volume was 3.0 ml. The absorbance was measured at 517 nm against a blank of pure methanol after 60 min of incubation in a dark condition. Inhibition percentge of the DPPH free radical was calculated by the following equation:

$$\text{Inhibition (\%)} = 100 \times [(A_{control}-A_{sample})/A_{control}]$$

Where:

$A_{control}$ is the absorbance of the control reaction (containing all reagents except the test compound).

A_{sample} is the absorbance with the test compound.

The standard curve was prepared using Trolox. Results were expressed as µM Trolox equivalents (TE)/100g sample.

Phenolic profile

HPLC analysis was carried out according to Kim et al. (2006) using Agilent Technologies 1100 series liquid chromatograph equipped with an auto sampler and a diode-array detector. The analytical column was Eclipse XDB-C18 (150 X 4.6 µm; 5 µm) with a C18 guard column (Phenomenex, Torrance, CA). The mobile phase consisted of acetonitrile (solvent A) and 2% acetic acid in water (v/v) (solvent B). The flow rate was kept at 0.8 ml/min for a total run time of 60 min and the gradient programme was as follows: 100% B to 85% B in 30 min, 85% B to 50% B in 20 min, 50% B to 0% B in 5 min and 0% B to 100% B in 5 min. The injection volume was 20 µl and peaks were monitored simultaneously at 280, 320 and 360 nm. All samples were filtered through a 0.45 µm Arcadis syringe filter (Gelman Laboratory, MI) before injection. Peaks were identified by congruent retention times and UV spectra and compared with those of the standards.

Carotenoids profile

A 10 g of sample was homogenized in 30 ml of acetone and then 0.1% (BHT) solution in acetone was added as an antioxidant. The resulting extract was filtered through Buchnar's funnel. The residue was washed twice with acetone till it become colorless. The residue was discarded, and the filtrate was combined with 20 gm of anhydrous sodium sulfate. The anhydrous sodium sulfate was removed through filtration and the volume of extract was reduced by rotary evaporator. The extract was transferred quantitatively to 100ml volumetric flask and the volume was made up to the mark with acetone and water, so that the final extract contains 80% of acetone.

HPLC separation was performed with a HPLC system (Agilent Technologies 1100 series, USA) equipped with a solvent degasser, quaternary pump, an autosampler, UV/VIS diode array detectors and a Li Chrospher 5RPSelect B (4.0×250 mm Analytical column) were used in the HPLC analysis. The mobile phase was acetonitrile - methanol (70: 30 (v:v)). Detection wavelength was set at 450 nm with flow rate at 1 ml/min.

Color measurements

The color of carrot jam samples was measured using a spectrocolorimeter with the CIE color scale (Hunter, Lab scan XE). This instrument was standardized against the white tile of Hunter Lab color standard (LX No.16379): X= 77.26, Y= 81.94 and Z= 88.14. The L*, a* and b* values were reported. The Hunter L* (luminosity), a* (+, red, to -, green) and b* (+, yellow to -, blue) values were used for calculating the chroma (C), hue angle (H), and total color difference (ΔE) according to the following equations:

$$C = (a^2 + b^2)^{0.5} \quad (1)$$

$$H = \tan^{-1}(b/a) \quad (2)$$

$$\Delta E = (\Delta L^2+\Delta a^2+\Delta b^2)^{0.5} \quad (3)$$

where $\Delta L = L_{sample} - L_{standard}$, $\Delta a = a_{sample} - a_{standard}$, $\Delta b = b_{sample} - b_{standard}$

The raw carrot was used as the control in the calculation of ΔE. Samples of jams were taken from different parts of the jars (top, middle and bottom) and transferred into Petri dishes for color measurements.

Sensory evaluation of jam

The sensory evaluation of carrot jams was carried out 1 day after jam prepration. Fifteen untrained consumers (made up of 8 females and 7 males, aged between 18 and 55 years old), were asked to describe the sensory attributes of carrot jams. Color, odor, taste, texture, and overall acceptability of each carrot jam were evaluated using a hedonic scale from 9 to 1 (9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, 1 = dislike extremely) (Basu & Shivare, 2010; Renna et al., 2013). All jams were presented to the assessors at room temperature under normal lighting conditions in transparent plastic glass coded with random, three-digit numbers. Each panelist evaluated 8 samples (4 carrot jams, 2 replications). The sensorial test was conducted on two sessions, in which the panellists evaluated 4 samples at a time, working in individual booths and drinking water for oral rinsing. The average value scores of all sensory evaluations were used in the analysis.

Statistical analysis

Statistical analysis was performed according to SAS Institute (2017) using General Linear Model (GLM) with the main effect of addition ratios. Duncan's multiple range was used to separate among of three replicates at $p < 0.05$.

Results and Discussion

Total phenols content

Total phenols content of the extracted samples were determined using the diluted Folin-Ciocalteu reagent, the results are shown in Table 2. Results showed that the raw carrot root contained 79.32 mg GAE/100g FW.

Kähkönen et al. (1999) reported that carrot contained 0.6 mg gallic acid equivalent/g dry weight. Bozalan and Karadeniz (2011) found that the phenolics ranged from 11.4 to 30.6 mg catechin/100 g within different forms of carrot. Haq et al. (2016) reported the phenolics range of 39.136 to 44.675 mg gallic acid equivalent/100 g FW. Vinson et al. (1998) found in carrots 46.4 mg catechin equivalent/100 g fresh weight. The different values in the literature may be due to different cultivars of studied carrots, different extraction methods and the ways to express the results.

The turmeric addition caused an increase in total phenols in all jam comparing the control. The increase of percentage of turmeric addition was significantly increased total phenols (from 43.116 ±0.21 mg GA/ 100g FW in 2TCG to 46.027±0.09 mg GA/100g FW in 6TCJ). These obtained results indicate that turmeric addition in carrot jam improved the phenols retention. Also, turmeric powder is relatively rich in phenolic content (Kaur & Kapoor, 2002 and Maizura et al., 2011).

According to Renna et al. (2013), the longtime heat treatments caused phenol losses compared to raw carrots.

Total carotenoids content

Total carotenoid content in orange carrots was 12.711±0.24 mg ß-CE / 100g FW (Table 2). This result is close to that recorded by Baranski et al. (2012), they reported that orange carrot roots contained on average 9.3 mg carotenoids per 100 g fresh weight, the total carotenoid content depended on carrot root color, and the orange carrot root is richer than other carrots.

After jam processing, total carotenoid contents in jams decreased markedly due to dilution effect of adding sugar (1:1, W/W). This apparent dilution did not attribute to the jam heat processing itself. Moreover, addition of turmeric resulted in a significant increase ($P<0.05$) in total carotenoids compared with the control sample, that had 8.827±0.22 mg ß-CE per 100g FW, while carotenoids contents were 10.25± 0.09, 10.33±0.21 and 10.41 ± 0.17 mg ß-CE per 100g FW in 2TCJ, 4TCJ and 6TCJ, respectively. The lower carotenoids losses in carrot containing turmeric jams could be attributed to turmeric function as a possible protective ingredient against oxidation. In addition, Renna et al. (2013) reported that boiling step before the final cooking during carrot jam manufacturing probably improved ß-carotene retention in jams.

Antioxidant activity

The free radical scavenging activity of raw orange carrot and their jams extracts was assayed

using the DPPH method. Antioxidant activity of raw carrots and jams are shown in Table 2. Raw orange carrot roots had 47.167 (µM TE/ 100g) FW. This result is consistent with those recorded by Bozalan and Karadeniz (2011), who found that the antioxidant activity in carrots varied from 25.9 to 86.6 µM TE/100 g FW, on the other hand, it does not fit into that determined by Algarra et al. (2014), who found that the antioxidant capacities against ABTS cation radicals in black and orange carrot extracts, were 240±54 and 1.4±0.4 µM TE/ 100g FW, respectively.

The control treatment (without turmeric adding) had lowest antioxidant activity (28.529 ±0.24 µM TE per 100g FW) compared to turmeric adding treatments, that led to a 12.35, 19.66, 27.11% increase in antioxidant activity in 2TCJ, 4TCJ and 6TCJ, respectively. These results were anticipated attending to the phenolics amounts in jams.

Turmeric is a strong antioxidant. Abdeldaiem (2014) reported that the addition of 0.2% oil-soluble yellow pigment from turmeric rhizomes powder caused significant increments in the oxidative stability of soy bean oil compared with control and 0.02% BHT addition. Maizura et al. (2011) found that a significant positive relationship between the phenolic content of turmeric and antioxidant activity, thus indicating that phenols are a major contributor to antioxidant activity.

On the other hand, the prolonged heat treatment during jam cooking caused antioxidant activity losses, but the presence of protective ingredient such as lemon juice reduced antioxidant activity losses in carrot jam (González-Molina et al., 2009, Renna et al., 2013 and Soto-Zamora et al., 2005). They also reported that the common method of jam processing caused a reduction in antioxidant activity in carrot jams compared to raw carrots.

Phenolic compounds profile

Phenolic compounds accumulate in carrot roots as a defensive response against the cold injury, cellular stress, or ethylene exposure. they may have a role in plant resistance to microbial diseases (Howard et al., 1994).

Under study conditions, a total of 24 phenolic compounds could be identified among the raw carrot and turmeric-carrot jams. Phenolic acid profile in raw orange carrot and jams is shown in Table 3. orange carrot roots and all jams had appreciable amounts of fifteen phenolic compounds. Gallic acid, protocatechuic acid, p-hydroxybenzoic acid, catechin, chlorogenic acid, caffeic acid, ferulic acid, sinapic acid, rutin, p-coumaric acid, apigenin-7-O-glucoside, rosmarinic acid, cinnamic acid, apigenin and kaempferol were detected in all studied samples. Five phenolic compounds have not been detected in any of the raw carrot and control jam. However, they were detected in turmeric added carrot jam, including syringic acid, vanillic acid, hesperidin, luteolin and naringinin. This is probably due to the presence of these compounds in turmeric powder. This is confirmed by the increase in the amount of turmeric added which resulted in further increase in those compounds in the jams.

TABLE 2. Total phenolics, total carotenoids and their antioxidant activity in carrot and carrot containing turmeric jams

Samples*	Total phenolics (mg GAE/100 g FW)	Total carotenoids (mg ßCE/100 g FW)	DPPH (µM TE/ 100g FW)
Carrot	79.32±0.29	12.771±0.24	47.167±0.21
Control	41.788±0.12^{d}	8.827±0.22^{b}	28.529±0.19^{d}
2TC	43.116±0.46^{c}	10.25± 0.09^{a}	32.053±0.24^{c}
4TC	44.522±0.41^{b}	10.33±0.21^{a}	34.139±0.25^{b}
6TC	46.027±0.39^{a}	10.41 ± 0.17 ^{a}	36.263±0.33^{a}

*Control, 2TCJ, 4TCJ and 6TCJ: carrot jams were made using turmeric powder in amount of 0, 2, 4 and 6 g, respectively. Values (Mean ± standard deviation). Values with different letters in the same column are significant differed at $p< 0.05$.

As can be seen, the two major phenolic compounds in raw carrot are p-hydroxybenzoic acid (22.356 mg/100 g FW) and caffeic acid (18.371 mg/100 g FW). Phenolic compounds significantly decreased in the control comparing with raw carrot roots. The reduction in individual phenolic compounds was compatible with the decrease of total phenolic content. Except for catechin, sinapic and cinnamic acid, the addition of turmeric to carrot during jam processing resulted in a significant increase in phenolic compounds. This observation may be attributed to the absence of these compounds in turmeric powder. On the other hand, the increase in the other phenols is due to the addition of turmeric to the mixture, and to the effect of heat treatment that may release a significant amount of some phenolic compounds, which compensates the thermal treatment losses and dilution effect of sugar addition.

During jam cooking, cell structure is ruptured and the sensitive compounds, especially phenols, become susceptible to non-enzymatic oxidation (Patras et al., 2010).

Carotenoids profile

Carotenoids are a family of over 700 various compounds in nature, that are responsible for the color in many fruits and vegetables. The most common carotenoids include α-carotene, ß-carotene, β-cryptoxanthin, lutein, lycopene and zeaxanthin. The three-major compounds that have provitamin A activity are α-carotene, β-carotene, and β-cryptoxanthin (Arscott & Tanumihardjo, 2010).

In the current study, four of the most carotenoids in plants were presented including α, ß-carotene, lutein and lycopene (Table 4). In raw orange carrot roots, ß-carotene was 8.21±0.04 mg/100 g FW (64.29% from total carotenoids), while α-carotene, lutein and lycopene were 3.38±0.09, 0.465±0.05, 0.21±0.01 mg/100g FW, respectively. These results agree with the data for orange carrot roots reported by Alasalvar et al. (2001), EL-Qudah (2009), Grassmann et al. (2007), Koca & Karadeniz (2008), Nicolle et al. (2004), Sun et al. (2009) and Surles et al. (2004). They reported that ß-carotene and α-carotene were principal carotenoids in carrots, and lutein and lycopene were minor components. In general, they reported that α, ß-carotene, lutein and lycopene contents in orange carrots ranged between 2.2 -7, 3.22 -12.8, 0.04 -0.5 and 0-0.6 mg/100g raw roots, respectively. However, Simon and Wolff (1987) postulated that six carotene compounds including (α-, β-, γ -, and ζ -carotenes, β-zeacarotene, and lycopene) can be extracted and quantified in dark orange carrot roots. α- and β-carotene are the predominant provitamin A carotenes, α-carotene represent 13-40%, while ß-carotene represent 45-80% of the total carotenoids in orange carrot roots (Simon and Wolff, 1987).

Bozalan and Karadeniz (2011) found that the major carotenoids determined in carrots cultivars from three different locations in Turkey were β-carotene (4.61–7.12 mg/100g FW), α-carotene (1.344–3.011 mg/100g FW) and lutein (0.002-0.144 mg/100g FW).

TABLE 3. Phenolics profile of raw orange carrot and turmeric- carrot jams

Compound	Raw carrot (µg/g)	Control (µg/g)	2TCJ (µg/g)	4TCJ (µg/g)	6TCJ (µg/g)
Gallic	1.622	0.809	0.887	0.924	0.956
Protocatechuic acid	5.848	2.711	3.379	3.704	3.988
p-hydroxybenzoic acid	22.356	10.465	12.88	13.005	13.112
Catechin	2.821	1.214	1.403	1.401	1.399
Chlorogenic	9.251	4.17	4.261	4.358	4.455
Caffeic	18.371	8.636	9.328	9.606	9.91
Syringic	ND	ND	0.094	0.191	0.285
Vanillic	ND	ND	0.079	0.141	0.206
Ferulic	4.045	1.915	2.998	3.879	4.938
Sinapic	0.336	0.133	0.133	0.132	0.132
Rutin	0.282	0.136	0.163	0.189	0.216
p-coumaric	0.731	0.667	0.844	1.047	1.223
Hesperidin	ND	ND	0.014	0.031	0.043
Apigenin-7-O-glucoside	0.589	0.243	0.773	1.245	1.885
Rosmarinic acid	0.191	0.074	0.269	0.318	0.406
Cinnamic	0.163	0.036	0.037	0.037	0.037
Lutiolin	ND	ND	0.074	0.151	0.207
Naringinin	ND	ND	0.021	0.039	0.62
Apigenin	0.351	0.085	0.243	0.304	0.471
Kaempferol	0.379	0.141	0.203	0.366	0.424

Control, 2TCJ, 4TCJ and 6TCJ: carrot jams were made using turmeric powder in amount of 0, 2, 4 and 6 g, respectively.
ND = no detected.

The results of the current study indicated that the control has lower carotenoid contents than raw carrot roots (Table 4). This may be due to the thermal degradation and/ or the dilution effect of adding sugar during jam cooking. During cooking jam, all studied carotenoids significantly decreased in the control treatment, but turmeric adding improved the retention of carotenoids in all turmeric jams. The addition of turmeric as an ingredient of jam formulation improved antioxidation activity, and protected carotenoids. The level of turmeric added up to 6 g per 1000 g raw carrots did not effect in carotenoid compounds (Table 4).

Color properties

The color of processed food products may change depending on the processing conditions, ingredients, physical state and chemical structure. The CIE LAB color values of raw carrot and different jam samples are given in Table 5. Orange carrots showed a lightness value (L*) of 31.46±0.07 and hue angle (H°) of 46.89±0.75, confirming the orange- yellow color. All jams appeared to be significantly brighter than fresh carrots, as reflected by 1.02-4.83% and 7.89-43.49 increases in L* and yellowness (b*), respectively ($p < 0.05$). in addition, hue values shifted from 49.94±0.75 in control to 59.49±0.42 in 6TCJ, while a* value significantly decreased in all jams compared to fresh roots. Jam processing significantly reduced redness (a*) from 22.74±0.23 in raw roots to 22.07±0.27 in FTCJ. The addition of turmeric decreased a* value compared with control treatment, there was no significant difference in a* value between all jams. As was the case for a* value, b* value in control jam significantly decreased compared to raw roots, however, addition of turmeric increased b* from 24.33±0.95 in raw roots to 34.91±0.06 in 6TCJ.

TABLE 4. Carotenoids profile of raw orange carrot and turmeric- carrot jams

samples	α-carotene	ß-carotene	Lutein	Lycopene
Carrot	3.38±0.09^{a}	8.21±0.04^{a}	0.465±0.05^{a}	0.21±0.01^{a}
Control	2.041±0.04^{c}	5.91±0.06^{c}	0.202±0.04^{c}	0.128±0.04^{c}
2TC	2.683±0.05^{b}	6.534±0.04^{b}	0.379±0.02^{b}	0.168±0.09^{b}
4TC	2.794±0.05^{b}	6.746±0.07^{b}	0.385±0.02^{b}	0.172±0.07^{b}
6TC	2.822±0.03^{b}	6.831±0.07^{b}	0.389±0.03^{b}	0.177±0.08^{b}

*Control, 2TCJ, 4TCJ and 6TCJ: carrot jams were made using turmeric powder in amount of 0, 2, 4 and 6 g, respectively. Values (Mean ± standard deviation). Values with different letters in the same column are significant differed at $p< 0.05$.

TABLE 5. Color properties of raw orange carrot and turmeric- carrot jams

Samples	L*	a*	b*	Chroma	Hue	Total color difference (ΔE)
Carrot	31.46±0.07^{e}	22.74±0.23^{a}	24.33±0.95^{b}	38.82±0.08^{a}	46.89±0.75^{b}	0
Control	31.78±0.08^{d}	22.07±0.27^{b}	26.25±0.11^{b}	35.95±0.26^{b}	49.94±0.15^{b}	2.05±0.13^{b}
2TC	32.07±0.05^{c}	21.58±0.19^{c}	33.84±0.07^{a}	34.41±0.31^{bc}	57.46±0.12^{a}	9.62±0.08^{a}
4TC	32.54±0.02^{b}	21.04±0.06^{d}	34.17±0.15^{a}	32.84±0.11^{c}	58.36±0.16^{a}	10.04±0.12^{a}
6TC	32.98±0.03^{a}	20.57±0.06^{e}	34.91±0.06^{a}	31.41±0.17^{cd}	59.49±0.42^{a}	10.89±0.16^{a}

*Control, 2TCJ, 4TCJ and 6TCJ: carrot jams were made using turmeric powder in amount of 0, 2, 4 and 6 g, respectively. Values (Mean ± standard deviation). Values with different letters in the same column are significant differed at $p< 0.05$.

The chroma value indicated the degree of saturation of color and was proportional to the strength of the color.

Theoretically speaking, when total color difference value is 1 represents a just-noticeable color difference to the human eyes under ideal viewing conditions; while total color difference values between 2 and 3 could be considered equivalent by some viewers in less than ideal lighting (Vervoort et al., 2012). From Table 2, total color difference values between raw carrots and control jam was 2.05±0.13, while it was higher than 7 between turmeric-carrot jams and control, suggesting that the color differences between all the turmeric-carrot jams and the control are perceptible by human eyes under normal lighting conditions. No significant total color difference values were detected between jams with turmeric adding, confirming the sensory evaluation results.

Sensory evaluation

Sensory attributes of carrot jams were showed in (Table 6). Jams varied significantly in color, odor, texture and overall acceptability.

As for color, no significantly different was registered among all turmeric-carrot jams, but control registered significant lower color score. these results confirmed data obtained using the Hunter Lab, which colorimeter showed significant differences among turmeric-carrot jams and control. This might be directly related to the addition of turmeric powder as coloring agent.

As for the taste (Table 6), the control and samples with up to 4% turmeric powder did not show any significant differences, the 2TCJ, 0TCJ and control was described as like very much (7.78±0.25, 7.71±0.11 and 7.64±0.36, respectively), whereas 6TCJ was described as like slightly (6.21±0.74). This result may explain that increasing the turmeric added may have caused a bitterness.

As can be seen, the odor was like taste acceptability. The 4TCJ and 2TCJ samples were preferred followed by 6TCJ and control samples. It is known that turmeric is very rich in volatile compounds

TABLE 6. Sensory evaluation score of carrot jams with different amounts of turmeric powder.

Samples	Color	Taste	Odor	Texture	overall acceptability
0TCJ	7.05±0.19^{b}	7.66±0.34^{b}	7.68±0.16^{b}	8.11±0.07^{a}	7.52±0.13^{b}
2TCJ	7.49±0.41^{a}	7.78±0.25^{a}	7.94±0.09^{a}	8.09±0.1^{a}	7.79±0.11^{a}
4TCJ	7.56±0.23^{a}	7.74±0.41^{a}	7.96±0.22^{a}	8.05±0.06^{a}	7.76±0.18^{a}
6TCJ	7.41±0.36^{a}	6.48±0.11^{c}	7.91±0.12^{a}	8.06±0.09^{a}	7.13±0.09^{c}

*Control, 2TCJ, 4TCJ and 6TCJ: carrot jams were made using turmeric powder in amount of 0, 2, 4 and 6 g, respectively. Values (Mean ± standard deviation). Values with different letters in the same column are significant differed at $p< 0.05$.

As for texture, all carrot jams were appreciated without significant differences among samples. It is possible to assert that the addition of pectin to all samples with the same amount reduced the variation of jams texture, especially, turmeric is not rich in pectin content, as well we added it in a relatively small amount. We can suppose that contribution to the final texture might be insignificant.

Finally, higher overall acceptability scores registered for 2TCJ and 4TCJ (7.79±0.11, 7.76±0.1 respectively) could be attributed to the greater taste, odor and color scores of these jam as mentioned above (Table 6).

Conclusion

The results of the present work showed that the addition of turmeric up to 6g/1kg carrot jam significantly changed some physicochemical, sensorial and bioactive properties of the resultant jam. Total Phenolics, total carotenoid contents and antioxidation activity of jam samples increased significantly with the addition of turmeric powder. Also, some changes were observed in phenolics and carotenoids profiles of jams. Jam samples made with turmeric addition got acceptable sensory scores more than just carrot jam.

As a conclusion, turmeric powder could be essentially incorporated with jam formulation up to 4 gm /1000 gm raw carrot to improve its quality attributes without causing any sensorial defect.

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تأثير إضافة الكركم على الكاروتينات والفينولات ونشاط تضاد الأكسدة والتقبل الحسي لمربى الجزر

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يُعد نبات الجَزر واحدًا من أهم الخضروات، بسبب احتوائه على مجموعة كبيرة من المركبات الحيوية. لذلك فقد تزايد الطلب على استهلاك الجزر ومنتجاته وخصوصًا المربى في الآونة الأخيرة. وقد استهدفت هذه الدراسة تقييم الكاروتينات والفينولات وتضاد الأكسدة، وخصائص اللون في الجزر البرتقالي والمربى المصنّعة من الجزر بإضافة كميات مختلفة من مسحوق الكركم. وأظهرت النتائج احتواء الجزر البرتقالي مواد فينولية ٧٩,٣٢±٠,٢٩ مجم/ لكل ١٠٠ جم وزن طازج محسوبة على أساس حمض الجاليك، وكاروتينات ١٢,٧١١ مجم/١٠٠ جم محسوبة على أساس بيتا كاروتين، ونشاط تضاد الأكسدة ٤٧,١٦٧±٠,٢١ ميكروجرام/ ١٠٠جم وزن طازج محسوبة على أساس ترولوكس. وأوضحت النتائج أن إضافة مسحوق الكركم إلى مربى الجزر حتى ٦جم لكل ١٠٠٠ جم جزر طازج قد رفع محتواها معنويًّا من الفينولات والكاروتينات ونشاط تضاد الأكسدة مقارنة بالكنترول (بدون إضافة الكركم). كما أوضحت النتائج أنَّ أكثر مركبين فينوليين بالجزر البرتقالي هما بارا هيدروكسي بنزويك أسيد (٢٢,٣٥٦ مجم/ ١٠٠ جم وزن طازج)، والكافيك أسيد (١٨,٣٧١ مجم/ ١٠٠ جم وزن طازج). وجاء ترتيب الكاروتينويدات على النحو التالي: بيتا كاروتين (٨,٢١±٠,٠٤ مجم/١٠٠جم وزن طازج)، ثم ألفا كاروتين (٣,٣٨±٠,٠٩ مجم/١٠٠جم وزن طازج) ثم ليوتين (٠,٤٦٥±٠,٠٥ مجم/١٠٠جم وزن طازج). وأخيرًا ليكوبين (٠,٢١±٠,٠١ مجم/١٠٠جم وزن طازج). إنَّ إضافة مسحوق الكركم كمكون من مكونات مربى الجزر قد حسَّن الاحتفاظ بالكاروتينات والفينولات، كما حسَّن نشاط تضاد الأكسدة؛ فضلًا عن أنَّه يُحسّن من التقبل الحسي للمربّى حتى مستوى إضافة ٤جم مسحوق كركم لكل ١٠٠٠ جم جزر خام.