Functional low-fat frozen yoghurt with carrot puree and orange juice

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Abstract: The effects of adding mix of carrot puree solids (CPS) and orange juice solids (OJS) as a dietary fiber source as well as natural antioxidants on the physiochemical, rheological, chemical, sensory properties, and production cost of low-fat frozen yoghurt were studied. The CPS and OJS contained total solids (7.75, 11.90%), antioxidant scavenging activity (5.79, 26.40 mg TE 100 g^{-1}), total carotene (69.76,11.20 mg 100 g^{-1}), crude fibers (10.41,0.22 mg 100g^{-1}), vitamin C (16.66, 34.00 mg 100 g^{-1}) and total phenol contents (4.52, 64.93 mg GAE 100g^{-1}), respectively. Low fat frozen yoghurt containing CPS and OJS showed significantly ($p < 0.05$) higher specific gravity, weight per gall, apparent viscosity, total phenol content and antioxidant scavenging activity along with an increase in added mixture of CPS and OJS. Adding CPS and OJS to frozen yoghurt improves the overrun (%) and stimulates the LAB growth of low-fat frozen yoghurt. LAB count decreases slightly during frozen storage period at -18 ± 1ºC but remains at levels above >7 log cfu g^{-1} until 45 days. Adding 3 % of CPS and OJS increase of overall acceptability score for low fat frozen yoghurt with increased antioxidant scavenging activity, total phenol content and reduced production cost.

Keywords: functional dairy, frozen yoghurt, antioxidant, low fat

INTRODUCTION

Carrots (*Dascus carota* L.) are good source of carbohydrate, calcium, iron, phosphorous, copper, potassium, manganese, sulphur and can improve the colour, body and texture of the food products than its flavour (Agarwal and Prasad, 2013). It is recommended to use a different mixture of fruits and vegetables to overcome the lack of flavour when using only some vegetables. Orange (*Citrus cinensis*) is widely consumed fruit for its fresh flavour, vitamin C, and its natural antioxidants source having health benefits. Blending juices is one of the best methods to improve the nutritional quality of the frozen yoghurt through enhancing its vitamins, mineral contents, phenolic compounds and antioxidants depending on the kind and quality of used fruits and vegetables (Jan and Masih, 2012).

Carrot puree solids have a pronounced effect on colour, body and texture of reduced fat frozen yoghurt than its flavour enhancement. While orange juice used as a flavour source than as body and texture improving. Using mixture of both will develop frozen yoghurt colour, body, texture and flavour as well as the health benefits of the resultant reduced fat yoghurt. The aim of this study is replacing different ratios of milk fat by the same ratios of carrot puree solids and orange juice solids mix (1:1) to improve the sensory and functional characteristics of frozen yoghurt.

MATERIALS AND METHODS

-Materials:

Milk: low heat full cream (27% fat and 70% solid non-fat) and low heat skim (97% T.S) milk powder (Dairy Miro™, Sweden) were purchased from the local market, Cairo, Egypt.

Starter cultures: Direct vat starter (DVS) culture containing *Streptococcus thermophilus* and *Lactobacillus delbreuckii* subsp. *bulgaricus* (YC-X11) was purchased from Chr. Hansen's Laboratories, Denmark. The culture was stored at -18 ±1˚C.

Other materials: Commercial sugar (sucrose) was purchased from the local market. Sodium carboxy methyl cellulose (CMC) was purchased from Misr Food Additives – MIFAD – Cairo, Egypt. Fresh carrot and orange were obtained from the local market, Ismailia, Egypt.

-Methods:

Carrot puree solids preparation: Carrot roots were washed with warm water after removing top, bottom and surface layers by sharp knife and soaked in hot water to inactivate pectinase and peroxidase enzymes and to tenderize it and cut into sticks (1×3×1 cm). The sticks were then soaked for 15 min in boiling water with a ratio of 1: 0.5 (w/v) carrot: water. The sticks along with soaked water were blended by Braun Power Max MX 2000 Blender (Germany) for 6 min to get fine paste. The puree was homogenized at 6000 rpm min^{-1} for 5 min using Ultra Turrax Homogenizer (Germany) and kept in polyethylene bags at -18±1˚C until used.

Orange juice solids preparation: Fresh orange was washed and cut with a sharp knife into two half and extraction by Braun MPZ22 Citromatic Deluxe Citrus Juicer (Germany) and homogenized at 6000 rpm min^{-1} for 5 min and cooling to 5˚C until used (freshly prepared).

Frozen yoghurt preparation: A mixture of CPS and OJS (1:1) was used to replace milk fat contents (1, 2 and 3 %) at the same ratios. Frozen yoghurt mixes were prepared according to the standard method described by Marshall and Arbuckle (1996). Five treatments of frozen yoghurt were carried out according to the formulation

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given in Table (1). The control full fat frozen yoghurt (T1) was standardized (4% fat, 11% SNF, 15% sugar and 0.25% CMC). Other four reduced fat frozen yoghurt treatments (11% SNF, 15% sugar and 0.25% CMC) with gradual decrease of milk fat by 3, 2, 1 and 1% with adding 1, 2, 3 and 0% (CPS + OJS), for T2, T3, T4 and T5 treatments, respectively. All treatments of frozen yoghurt were prepared in three replicates. Each treatment was analyzed for physiochemical, chemical, rheological, bacteriological and organoleptic characteristics when fresh (1 day) and after 15, 30 and 45 days of freezing storage at -18±1°C.

Analysis of carrot pure solids and orange juice solids: The levels of total solids, crude fiber contents and acidity % were determined according to AOAC, (2000) methods. Total carotenoids content was determined according to Moore et al. (2005), vitamin C as described by Elgailani et al. (2017) and pH values using (Jenway pH meter with Jenway spear electrode No. 3505, Jenway limited, Dunmow, England). The total soluble solids content was measured as degree °Brix (%) using with an ATAGO type refractometer (Schmidt Haensch, Germany).

Colour measurement: The colour of carrot puree solids, orange juice solids and resultant frozen yoghurt samples were measured using Hunter colorimeter (Hunter Ultra Scan XE, France). The L (lightness), + a (redness) and + b (yellowness) were measured according to Commission Internationale de I'Eclairage, CIE (1976). 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.

Determination of total phenol contents and antioxidant scavenging activity: One hundred grams from each sample was mixed with 100 ml methanol (Methanex, Egypt) and homogenized at 2000 rpm for 5 min. The homogenates were kept at 4 °C for 12 h and then centrifuged using ICE PR-7000 centrifuge (International Equipment Company, UK) at 10,000 rpm for 20 min. The supernatants were recovered and stored at -20 °C until analyzed.

The total phenol content was determined using the Folin-Ciocalteu (procedure Sigma-Aldrich, Germany) according to Zilic et al. (2012). The absorbance was measured by using a spectrophotometer UV-VIS Double Beam Model UVD-3500 (Labomed, Inc. USA) at 725 nm. The total phenol content was determined by means of a calibration curve prepared with gallic acid (Euromedex, France). The results were expressed as mg of gallic acid equivalent (mg GAE) per 100 g of sample.

The antioxidants scavenging activity was determined by 2, 2-Diphenyl-1-picrylhydrazyl (DPPH) according to Hwang and Do Thi (2014). The absorbance was measured at 517 nm against a blank of pure methanol after 60 min of incubation in a dark condition. Percent inhibition of the DPPH free radical was calculated by the following equation:

Inhibition (%) = [(Acontrol-Asample)/Acontrol] × 100

The standard curve was prepared using Trolox. Results were expressed as mg Trolox equivalents (TE) 100 g^{-1} sample.

HPLC analysis of the phenolic compounds: Sample (5 g) was placed in quick fit conical flask, 10 ml of 2 M NaOH were added, flushed with N2 and then closed. The flask contents were shaked for 4 h at room temperature, pH was adjusted to 2 with 6 M HCl (Adwic, Egypt), centrifuged at 5000 rpm for 10 min and the supernatant was collected. The supernatant was extracted twice with 25 ml of mixed (1:1) ethyl ether and ethyl acetate (SDFCL, Mumbai, India). The organic phase was separated and evaporated at 45°C and the residue was re-dissolved in 1 ml methanol (Methanex, Egypt) as described by Kim et al. (2006). HPLC analysis of the extracted phenolic compounds was carried out using Agilent Technologies 1100 series liquid chromatograph (Tedia company lnc, Ohio, USA) equipped with an auto sampler and a diode-array detector (Thermo FisherTM, USA). The analytical column was an Eclipse XDB-C18 (150 X 4.6 μm; 5 μm) with a C18 guard column (Phenomenex, Torrance, CA). The mobile phase consisted of acetonitrile HPLC grade, (Sigma-Aldrich, Germany, solvent A) and 2% acetic acid (Almasria for Chemicals, Egypt) in water (v/v, solvent B). The flow rate was kept at 0.8 ml min^{-1} for a total run time of 65 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 10 min. The injection volume was 50 μl and peaks were monitored simultaneously at 280 and 320 nm for the benzoic acid and cinnamic acid derivatives, respectively. All samples were filtered through a 0.45 μm syringe filter (Sigma-Aldrich, Germany) before injection. Peaks were identified by congruent retention times and UV spectra and compared with those of the standards.

Analysis of the (CPS + OJS) frozen yoghurt mix and resultant frozen yoghurt: All measurements of frozen yoghurt mixes were done in triplicates. The specific gravity of both of mixes and resultant frozen yoghurt was analysed as described by Winton (1958). Weight per gallon was determined according to Burke (1947). Freezing point and over run of frozen yoghurt were determined according to Marshall and Arbuckle (1996). The melting rate of resultant frozen yoghurt was determined according to Segall and Goff (2002), and colour was measured by Hunter colorimeter.

The apparent viscosity (centipoise, c.p) of all mixes of frozen yoghurt samples was measured using (Ametek Brookfield model LV rotary viscometer, DV-lllTM, USA) with spindle 03 at 50 rpm for different treatments. Viscosity was measured using 200 ml of frozen yoghurt mix at 20˚C. Measurements were taken every 3 min of spindle operation and at least 3 replicates performed.

Crude fiber content, total carotenoids, vitamin C, antioxidant scavenging activity, total phenolic compounds and phenolic compounds as described before under carrot puree solids and orange juice solids.

Total viable lactic acid bacteria: Eillker agar medium (Eillker et al., 1956) was used for the enumeration of total viable lactic acid bacteria after incubation (Memmert, Germany) at 37˚C for 48 h under aerobic condition.

The sensory properties: Sensory properties for the control and other treatments of frozen yoghurt were evaluated when fresh (1 day) and after 15, 30 and 45 days of cold storage at -18±1˚C by 10 staff members of the dairy department, faculty of agriculture, suez canal university, Egypt for flavour (45 points), body & texture (35 points) colour & appearance (10 points), melting resistance (10 points) and overall acceptability (100 points) as described by Salama (2004).

Cost of production: The cost of production the different mixes were calculated according to Khalil and Blassey (2019). The available prices (L.E) of raw materials used in frozen yoghurt making in the Egyptian market were shown in Table (2).

Statistical analysis: Data were analyzed statistically by using CoStat program 2005, Version 6.311.

Table (1) Composition (Kg 100 Kg^{-1}) of frozen yoghurt mixes containing different levels of carrot puree and orange juice solids

Ingredients	Treatments				
	T_1	T_2	T_3	T_4	T_5
Sugar (Kg)	15.00	15.00	15.00	15.00	15.00
Stabilizer (Kg)	0.250	00.25	0.250	0.250	0.250
Skim milk powder (Kg)	1.320	03.82	06.30	8.830	8.800
Full milk powder (Kg)	14.28	10.71	7.140	3.570	3.500
Water (l)	69.15	59.55	49.92	40.23	72.45
Carrot puree solids (Kg)	-	6.450	12.90	19.35	-
Orange juice solids (Kg)	-	4.270	8.540	12.82	-
Total	100	100	100	100	100

T_1: Full fat (4% fat) frozen yoghurt (FY) without adding of (CPS+ OJS, $control_1$).
T_2: Treatment with 3% fat FY with adding of 1% (CPS+OJS at equal ratio).
T_3: Treatment with 2% fat FY with adding of 2% (CPS+OJS at equal ratio).
T_4: Treatment with 1% fat FY with adding of 3% (CPS+OJS at equal ratio).
T_5: Treatment with 1% fat FY without adding of (CPS+ OJS, $control_2$).

Table (2) Price (L.E) of ingredients used for production of carrot-orange frozen yoghurt

Raw materials	Full milk powder	Skim milk powder	Sugar	CMC	Water	Carrot	Orange
Price (L.E) Kg^{-1}	230	180	30	140	1	10	12

RESULTS AND DISCUSSION

Chemical properties of carrot puree and orange juice: Carrot is an inexpensive and highly nutritious vegetable, since it contains appreciable amounts of vitamins, folic acid, β-carotene, carbohydrate, calcium, phosphorous, iron, potassium, magnesium, copper, manganese and sulphur, besides having potent antioxidant property (Agarwal and Prasad, 2013). Thus, carrot puree was found to be suitable for incorporation in the production of nutritionally rich yoghurt food. Orange is a good source antioxidant including ascorbic acid (vitamin C), rich a variety of phenolic compounds, including hesperidin and ferulic acid. They offer a wide range of health and nutrition benefits (Sadecka et al., 2014). Carrot puree contented high levels of total carotene (69.76 mg 100 g^{-1}) as shown in Table (3). Carrot puree had attractive orange colour. Carrot puree contained high levels of ρ-hydroxybenzoic (1115.04 µg 100 g^{-1}, Table 4). The orange juice solids contained high levels of antioxidant scavenging activity (26.40 mg TE 100 g^{-1}), total phenol (64.93 mg GAE 100 g^{-1}) and total carotene contents (11.20 mg 100 g^{-1}, Table 3). Orange juice contained high levels of cateachin (3125.58 µg 100 g^{-1}, Table 4). These findings concur with Kelebek et al. (2009).

Physicochemical properties of carrot-orange frozen yoghurt mixes: Specific gravity of carrot-orange frozen yoghurt (COFY) mixes was significantly increased ($p<0.05$) when solids content in the mix increased owing to the addition of vegetables and fruits. Meanwhile, the weight per gallon in kilograms of all mixes was found to be closely related to their specific gravity (Table 5). These results might be due to the higher specific gravity of (CPS+OJS). These results are in agreements with Hussein and Aumara (2006).

The initial and gradual development of the average size of the ice crystals formed, as well as their inherent thermodynamic instability, are all affected by freezing point depression, which is a critical stage in the production of ice cream (Hartel, 2001). Freezing point of COFY mixes (T2, T3 and T4) treatments lowered significantly ($p <0.05$) with adding (CPS+OJS) as a milk fat replacer might be due to high fiber contents of carrot puree (Table 3). Soukoulis et al. (2009) reported that addition of wheat and apple fibers in the ice cream manufacture decrease significantly the freezing point temperature. El-Kholy (2018) stated that when fat removed from frozen yoghurt and replaced with non-fat milk solids or other dissolved substances, the freezing point was decreased.

Apparent viscosity of COFY mixes was significantly increased ($p<0.05$) with the increase of (CPS+OJS) addition as a milk fat replacer, whereas control (T1 and T5) treatments showed the lowest viscosity (Table 5). The increase in the apparent viscosity of frozen yoghurt containing (CPS+OJS) may be due to its high content of fiber characterized by its high-water retention capacity. These findings concur with El-kholy (2015).

Lactic acid bacteria count of carrot-orange frozen yoghurt mixes: The total viable LAB in COFY mixes decreased significantly ($p<0.05$) by addition of 1, 2 and 3% of carrot puree and orange juice solids to COFY T2, T3 and T4 treatments (Table 5). These findings concur with Matter et al. (2016) who explain the reduction of lactic acid bacteria counts by low pH of citrus fruits. Furthermore, the high content of phytochemicals may affect negatively on LAB counts (Leong and Shui, 2002).

Physicochemical properties of carrot-orange frozen yoghurt: Control of COFY (T5) recorded lowest specific gravity values and weight per gallon compared with all treatments (Table 6). However, the specific gravity increased as total solids content in the COFY was increased owing to the addition of carrot and orange. Specific gravity and weight per gallon of COFY increased with increase of (CPS+OJS) levels in the mix, this may be because of (CPS+OJS) higher specific gravity. These findings concur with Hassan and Hussein (2010) and El-kholy (2015) who stated that, the increase in specific gravity is dependent on the formula component and the mixing ability to contain the air bubbles and the overrun percent in the resulting ice cream and frozen yogurt.

The overrun % of COFY made by using different levels of (CPS+ OJS) for T2, T3, and T4 treatments significantly ($p<0.05$) were less than control (T1) full fat (Table 6). This may be due to the reduction in fat and the addition of a fat replacer. The low-fat control frozen yoghurt (T5) recorded the lowest overrun % compared with all treatments. . These findings concur with Chang and Hartel (2002) who indicated that the addition of carbohydrate-based fat replacers, since they exhibited a viscous behavior, may decrease ice cream whipping capacity. Similar results were obtained by Crizel et al. (2014) which found that the use of carbohydrate as a fat replacer in ice cream mix decrease the overrun due to the higher viscous component, which could have prevented air incorporation. Also, Akalın et al. (2008) indicated a positive relation between high overrun and high viscosity in ice cream. On the other hand, Akalın et al. (2018) found that addition of orange fiber (as a fat replacer) caused lower significantly overrun values in ice cream (compared with control).

Melting rate % of COFY made with addition of different ratios of (CPS+OJS) significantly decreased ($p<0.05$) in comparison with control treatments (T1 and T5) as shown in Fig. (1). T4 treatment recorded the lowest melting rate. Crizel et al. (2014) reported that ice cream contains orange fiber had low melting rate % than control full fat ice cream. Rossa et al. (2012) stated that the ice cream supplemented with low concentrations of orange fiber (1.0 %) had lower resistance values than that of the control ice cream.

Table (3) Physiochemical composition of carrot puree and orange juice

Components	Carrot puree			Orange juice		
Moisture	92.25			88.10		
T.S (%)	7.75			11.90		
T.S.S (%)	6.85			11.70		
pH value	0.82			4.22		
Antioxidant scavenging activity (mg TE 100 g^{-1})	5.79			26.40		
Total phenol (mg GAE 100 g^{-1})	4.52			64.93		
Total carotene contents (mg 100 g^{-1})	69.76			11.20		
Crud fiber (mg 100 g^{-1})	10.41			0.22		
Vitamin C (mg 100 g^{-1})	16.66			34.00		
Colour	*L**	*a**	*b**	*L**	*a**	*b**
	50.75	32.69	50.69	51.55	8.40	55.04

Table (4) Phenolic acid compounds (µg 100 g^{-1}) of carrot puree and orange juice determined by HPLC

Compounds	Retention time (min)	Concentration (µg 100 g^{-1})	
		Carrot puree	Orange juice
ρ-Hydroxybenzoic	12.082	1115.04	54.90
Catechin	14.672	86.89	3125.58
Syringic	20.108	30.78	6.85
Vanillic	28.008	171.77	1046.85
Ferulic	31.703	72.61	1332.06
Sinapic	33.301	30.22	582.54
ρ-Coumaric	35.782	47.91	18.66
Hesperidin	37.911	ND	227.40
Apigenin-7-glucoside	41.234	33.79	4.36
Rosmarinic	49.968	7.26	5.81
Cinnamic	51.755	30.81	30.21

Table (5) Effect of using different percentages of carrot puree and orange juice solids on the specific gravity, weight per gallon, freezing point, viscosity and total viable lactic acid bacteria of carrot frozen yoghurt mix

Physicochemical properties	Treatments				
	T_1	T_2	T_3	T_4	T_5
Specific gravity	$1.087^d \pm 0.00$	$1.117^c \pm 0.00$	$1.135^b \pm 0.00$	$1.155^a \pm 0.00$	$1.078^e \pm 0.00$
Weight per gallon (kg)	$4.944^d \pm 0.00$	$5.077^c \pm 0.00$	$5.159^b \pm 0.00$	$5.251^a \pm 0.00$	$4.900^e \pm 0.00$
Freezing point ˚C	$-1.77^d \pm 0.00$	$-1.88^c \pm 0.01$	$-2.04^b \pm 0.00$	$-2.59^a \pm 0.00$	$-1.62^e \pm 0.01$
Viscosity (Cp)	$779^d \pm 1.00$	$786^c \pm 2.64$	$1257^b \pm 2.51$	$1553^a \pm 2.51$	$602^e \pm 2.64$
LAB (log cfu g^{-1})	$7.98^a \pm 0.08$	$7.40^b \pm 0.05$	$7.21^c \pm 0.03$	$6.74^d \pm 0.12$	$7.95^a \pm 0.02$

T_1: Full fat (4% fat) frozen yoghurt (FY) without adding of (CPS+ OJS, $control_1$).
T_2: Treatment with 3% fat FY with adding of 1% (CPS+OJS at equal ratio).
T_3: Treatment with 2% fat FY with adding of 2% (CPS+OJS at equal ratio).
T_4: Treatment with 1% fat FY with adding of 3% (CPS+OJS at equal ratio).
T_5: Treatment with 1% fat FY without adding of (CPS+ OJS, $control_2$).
Values are means ± standard deviations of triplicate determinations.
Means with the same row with different superscript (a, b, c…) are significantly different ($p<0.05$).

Table (6) Effect of using different percentages of carrot puree and orange juice solids on specific gravity, weight per gallon and overrun of carrot-orange frozen yoghurt

Physicochemical properties	Treatments				
	T_1	T_2	T_3	T_4	T_5
Specific gravity	$0.653^d \pm 0.00$	$0.684^c \pm 0.00$	$0.705^b \pm 0.00$	$0.733^a \pm 0.00$	$0.228^e \pm 0.00$
Weight per gallon (kg)	$2.968^d \pm 0.00$	$3.108^c \pm 0.01$	$3.204^b \pm 0.00$	$3.332^a \pm 0.00$	$1.035^e \pm 0.01$
Overrun (%)	$66.32^a \pm 1.02$	$64.08^b \pm 0.60$	$60.84^c \pm 0.45$	$57.46^d \pm 0.49$	$42.45^e \pm 0.75$

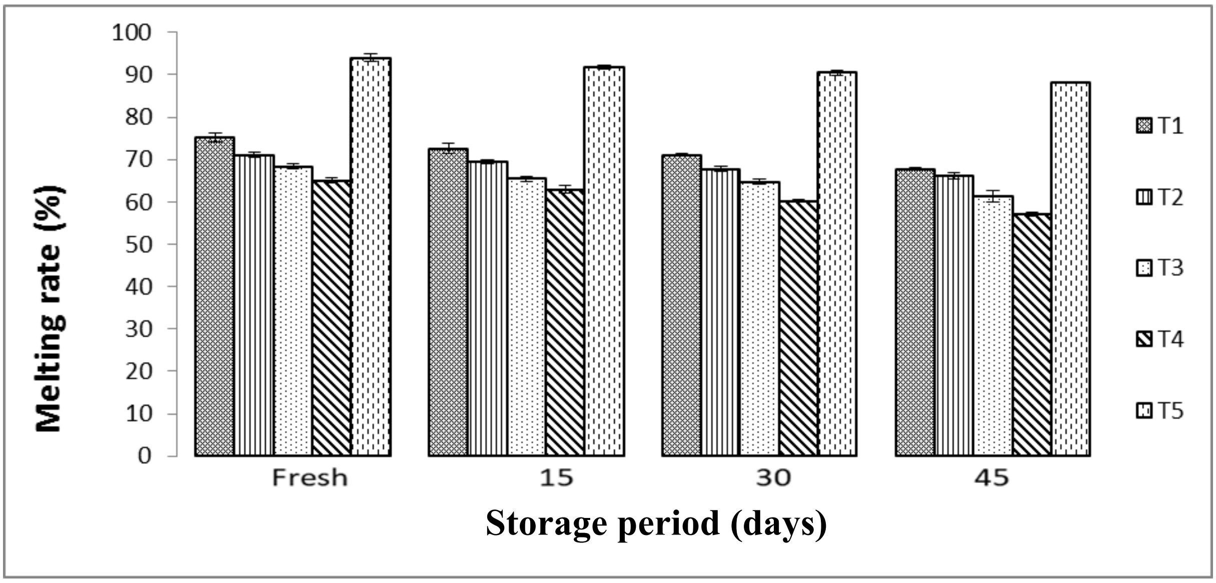

Fig. (1) Effect of using different percentages of carrot puree and orange juice solids on the melting rate of carrot-orange frozen yoghurt

T_1: Full fat (4% fat) frozen yoghurt (FY) without adding of (CPS+ OJS, $control_1$).
T_2: Treatment with 3% fat FY with adding of 1% (CPS+OJS at equal ratio).
T_3: Treatment with 2% fat FY with adding of 2% (CPS+OJS at equal ratio).
T_4: Treatment with 1% fat FY with adding of 3% (CPS+OJS at equal ratio).
T_5: Treatment with 1% fat FY without adding of (CPS+ OJS, $control_2$).

These findings concur with Akalın et al. (2008) who indicated that the full fat ice cream should melt more slowly than the low-fat ice cream due to slow heat transfer rate of milk fat through the ice cream.

Colour plays a significant role in food quality as it is linked to freshness, maturity, and taste and safety of food. It's often the first thing people think about when they make a purchase. Frozen yoghurt treatments supplemented with CPS and OJS (T2, T3 and T4) recorded high L* value (Fig. 2 a and b). Crizel et al. (2014) found that, the lightness values (L*) of the ice cream decreased as the fat content increased. Addition of (CPS+OJS) in the manufacture of frozen yoghurt influenced L*, a* and b* values. L* value was decreased gradually in COFY T2, T3 and T4 treatments but yellow b* and red *a values of COFY treatments were increased gradually. The COFY T4 treatment recorded the highest b* and a* values compared with all treatments. These increases depending on the concentration of CPS+OJS were added to COFY.

Addition of CPS+OJS to frozen yoghurt affected the values of b* and a* during freezing storage period (-18±1˚C). It is noticeable that the b* and a* values decreased gradually from fresh (1 day) to 45 days of freezing storage. These findings concur with El-Samahy et al. (2015).

Chemical analysis of carrot-orange frozen yoghurt: The total carotene content of frozen yoghurt manufacture with addition of (CPS+OJS) significantly increased ($p<0.05$) as (CPS+OJS) ratio increased in comparison with control (T1 and T5) treatments as shown in Fig. (3). These results are in agreement with Agarwal (2014) stated that β-carotene contents and colour intensity were increased in the yoghurt dependence of carrot-juice concentrations.

The total carotene content of the COFY manufacture by addition (CPS+OJS) decreased significantly ($p<0.05$) during freezing storage period. These findings concur with Dutta et al. (2005).Vitamin C content of COFY significantly increased ($p<0.05$) as (CPS+OJS) ratios increased in T2, T3 and T4 treatments compared with frozen yoghurt controls (T1 and T5) as shown in Fig. (4). Vitamin C content of COFY decreased significantly ($p<0.05$) until the end of storage period in all treatments. This is most likely because that, ascorbic acid is sensitive to oxygen, light and heat. In the presence of oxygen, it was oxidized by both an enzyme-based catalyst and an un-enzymatic catalyst (Jan and Masih, 2012). Maximum ascorbic acid was recorded in T4 treatment (20.61 mg 100 g^{-1}). These findings are in conformity with the study of Sadecka et al. (2014).

Crude fiber content in frozen yoghurt treatments fortified with (CPS+OJS) was significantly increased ($p<0.05$) as (CPS +OJS) ratios increased in T2, T3 and T4 treatments which recorded 1.28, 2.34 and 3.52 mg 100 g^{-1}, respectively (Fig. 5). The value of crude fiber was stable until the end of storage period in all treatments. These findings are in conformity with Khalil and Blassy (2011).

On the other hand, Akalın et al. (2018) stated that the soluble and insoluble nature of the orange fiber resulted in a more significant impact on the increase of a parameter such as viscosityCitrus fruits (like oranges) are rich in soluble and insoluble fiber, as well as high levels of pectin in the soluble material.The antioxidant scavenging activity and total phenol content were significantly increased ($p<0.05$) with increase the addition of (CPS+OJS) to frozen yoghurt as a fat replacer (Fig. 6 a and b). T4 treatment had the highest levels of antioxidant scavenging activity and total phenol content. Thus, using (CPS+OJS) could improve the antioxidant scavenging activity and total phenol content of the frozen yoghurt. These findings are in conformity with Hsu et al. (2006). The antioxidant scavenging activity and total phenol content of all COFY treatments was decreased significantly during storage period.

Phenolic acid compound contents: Orange juice has low concentration of ρ-hydroxybenzoic acid (Kelebek et al., 2009). The addition of orange juice to carrot puree improved the nutritional and health values of COFY. Generally, T4 treatment was recorded highest phenolic acid compounds content in all treatments (Table 7). The plant cell wall contains a large amount ρ-Hydroxybenzoic. It was the main phenolic acid. ρ-Hydroxybenzoic content was 39.63, 57.40, 82.88, 141.63 and 29.95 μg100g^{-1} in T1, T2, T3, T4 and T5 treatments, respectively. The highest ratio was noticed in T4 treatment. It potential to decrease cardiovascular problems related to aging (such as hypertension, atherosclerosis and dyslipidemia, Juurlink et al., 2014). It is also the main bioactive ingredient in the prevention of urinary tract infections as it stops Escherichia coli from colonising the urinary tract (Vattem et al., 2005). The highest ratio of catechin was recorded in T4 treatment. Functional activity of catechin refers to the prevention of certain diseases such as: cancer, obesity, diabetic, cardiovascular, Alzheimer`s disease, infection (like influenza), improved antiviral activities, hepatoprotective and neuroprotective effects. Catechin is known to have dual actions in relation to reactive oxygen species as an antioxidant and a pro-oxidant (Isemura, 2019).

Syringic acid is one of the most effective compounds for the treatment of various diseases (diabetes, brain ischemia, decreased the blood pressure, neuro and liver damage It also increases the levels of non-enzyme antioxidants (vitamins C and E), stimulates the brain to send signals to immune cells to reduce inflammation, and increases insulin secretion (Srinivasulu et al., 2018). Vanillic acid is also referred to

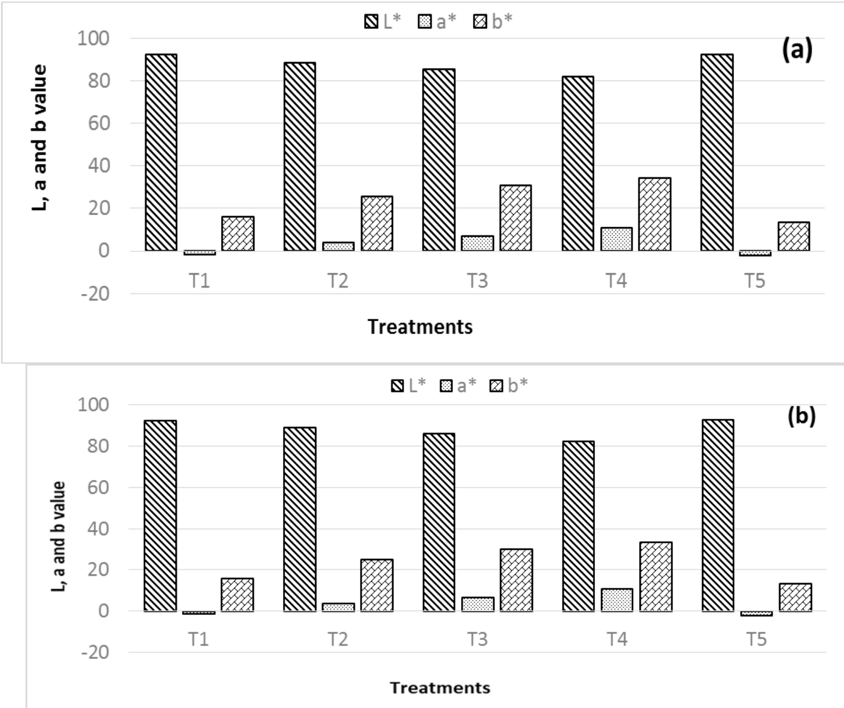

Fig. (2 a, b) Effect of using different percentages of carrot puree and orange juice solids on colour parameters (L*, a* and b*) when fresh (1 day) [a] and after 45 days of freezing storage period (b) of carrot-orange frozen yoghurt

T_1: Full fat (4% fat) frozen yoghurt (FY) without adding of (CPS+ OJS, $control_1$).
T_2: Treatment with 3% fat FY with adding of 1% (CPS+OJS at equal ratio).
T_3: Treatment with 2% fat FY with adding of 2% (CPS+OJS at equal ratio).
T_4: Treatment with 1% fat FY with adding of 3% (CPS+OJS at equal ratio).
T_5: Treatment with 1% fat FY without adding of (CPS+ OJS, $control_2$).

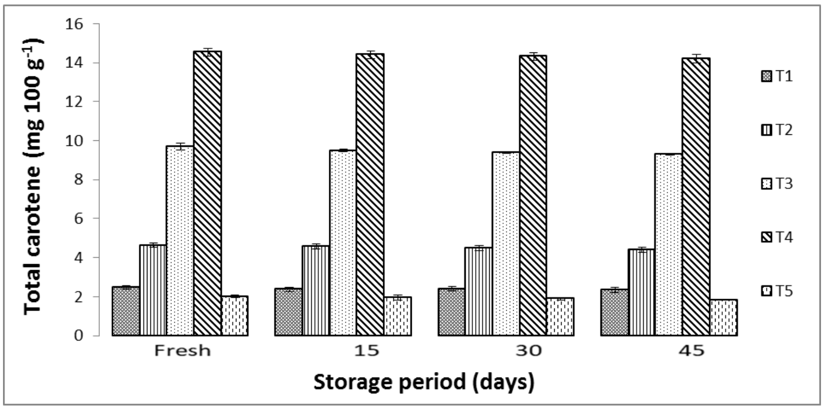

Fig. (3) Effect of using different percentages of carrot puree and orange juice solids on the total carotene (mg 100 g^{-1}) of carrot-orange frozen yoghurt

T_1: Full fat (4% fat) frozen yoghurt (FY) without adding of (CPS+ OJS, $control_1$).
T_2: Treatment with 3% fat FY with adding of 1% (CPS+OJS at equal ratio).
T_3: Treatment with 2% fat FY with adding of 2% (CPS+OJS at equal ratio).
T_4: Treatment with 1% fat FY with adding of 3% (CPS+OJS at equal ratio).
T_5: Treatment with 1% fat FY without adding of (CPS+ OJS, $control_2$).

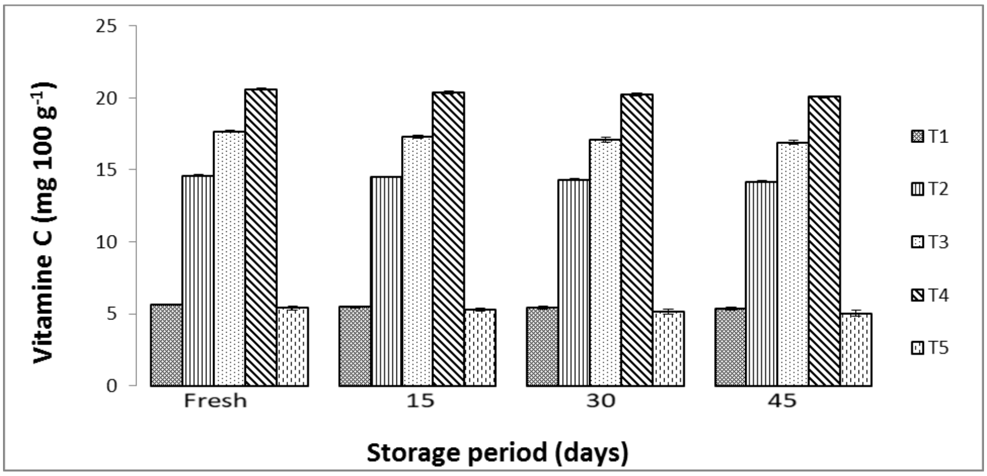

Fig. (4) Effect of using different percentages of carrot puree and orange juice solids on vitamin C (mg 100 g^{-1}) of carrot-orange frozen yoghurt

T_1: Full fat (4% fat) frozen yoghurt (FY) without adding of (CPS+ OJS, $control_1$).
T_2: Treatment with 3% fat FY with adding of 1% (CPS+OJS at equal ratio).
T_3: Treatment with 2% fat FY with adding of 2% (CPS+OJS at equal ratio).
T_4: Treatment with 1% fat FY with adding of 3% (CPS+OJS at equal ratio).
T_5: Treatment with 1% fat FY without adding of (CPS+ OJS, $control_2$).

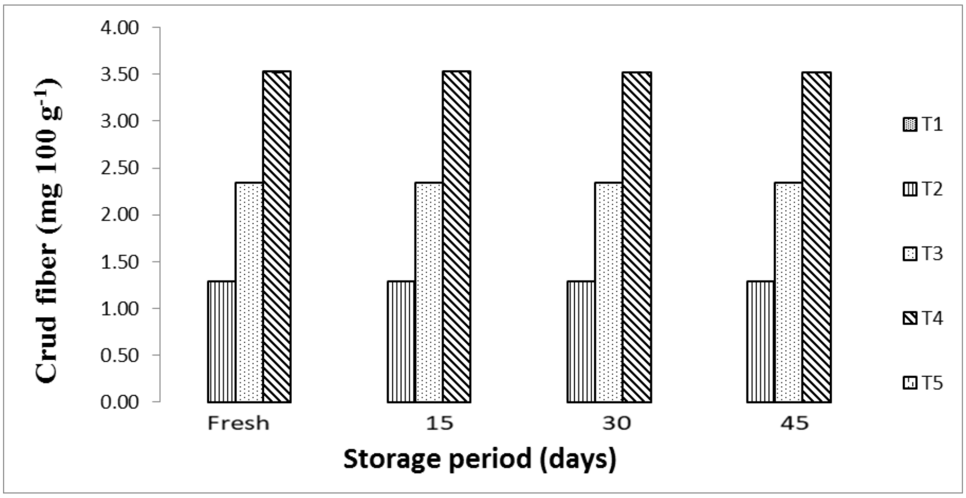

Fig. (5) Effect of using different percentages of carrot puree and orange juice solids on crude fiber (mg 100 g^{-1}) of carrot-orange frozen yoghurt

T1: Full fat (4% fat) frozen yoghurt (FY) without adding of (CPS+ OJS, control1).
T2: Treatment with 3% fat FY with adding of 1% (CPS+OJS at equal ratio).
T3: Treatment with 2% fat FY with adding of 2% (CPS+OJS at equal ratio).
T4: Treatment with 1% fat FY with adding of 3% (CPS+OJS at equal ratio).
T5: Treatment with 1% fat FY without adding of (CPS+ OJS, control2).

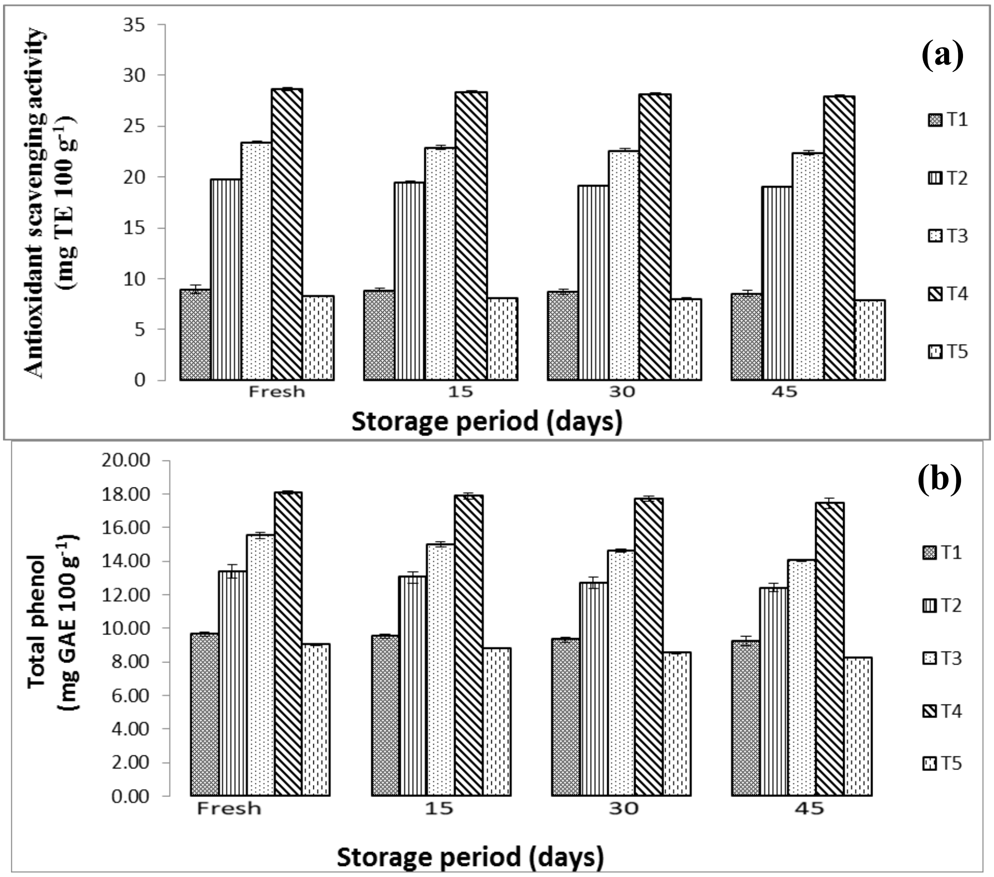

Fig. (6 a, b) Effect of using different percentages of carrot puree and orange juice solids on (a) the antioxidant scavenging activity and (b) total phenol of carrot-orange frozen yoghurt during storage period

T1: Full fat (4% fat) frozen yoghurt (FY) without adding of (CPS+ OJS, $control_1$).
T2: Treatment with 3% fat FY with adding of 1% (CPS+OJS at equal ratio).
T3: Treatment with 2% fat FY with adding of 2% (CPS+OJS at equal ratio).
T4: Treatment with 1% fat FY with adding of 3% (CPS+OJS at equal ratio).
T5: Treatment with 1% fat FY without adding of (CPS+ OJS, $control_2$).

Table (7) Concentration of phenolic acid compounds content in COFY after 45 days of freezing storage period

Compounds	Retention time (min)	Treatments(µg 100 g^{-1})				
		T_1	T_2	T_3	T_4	T_5
ρ-Hydroxybenzoic	12.082	39.63	57.40	82.88	141.63	29.95
Catechin	14.672	21.85	97.01	114.02	123.72	15.63
Syringic	20.108	0.78	19.00	25.29	19.37	ND
Vanillic	28.008	ND	15.46	35.58	52.20	ND
Ferulic	31.703	ND	34.57	72.03	115.99	ND
Sinapic	33.301	ND	6.75	17.26	20.04	ND
ρ-Coumaric	35.782	ND	4.77	4.44	4.12	ND
Hesperidin	37.911	ND	42.25	51.63	73.43	ND
Apigenin-7-glucoside	41.234	ND	12.29	11.36	20.08	ND
Rosmarinic	49.968	ND	0.51	0.73	0.89	ND
Cinnamic	51.755	ND	2.07	6.75	10.66	ND

T1: Full fat (4% fat) frozen yoghurt (FY) without adding of (CPS+ OJS, $control_1$).
T2: Treatment with 3% fat FY with adding of 1% (CPS+OJS at equal ratio).
T3: Treatment with 2% fat FY with adding of 2% (CPS+OJS at equal ratio).
T4: Treatment with 1% fat FY with adding of 3% (CPS+OJS at equal ratio).
T5: Treatment with 1% fat FY without adding of (CPS+ OJS, $control_2$).
ND: not detected.

as Chinese medicine. It is a benzoic acid derivative that is used as a flavoring agent. It is an oxidized form of vanillin. Vanallic acid prevent the harmful effects of chronic stress on cognitive function and activation memory, reduced colitis, regulation of chronic intestinal inflammation, enhanced the of activity lymphocyte and improve function of immune system in human and protective of liver inflammation (Kim et al., 2010 and Singh et al., 2015).

The highest ratio of ferulic acid was recorded in T4 treatment. Ferulic acid (4-hydroxy-3-methoxy cinnamic acid) is a phenolic compound, it contains carboxylic acid group which it binds to the lipid bilayer to provide some protection against lipid peroxidation. Ferulic acid exhibits anticarcinogenic effect especially colon and skin carcinogenesis by polycyclic aromatic hydrocarbon (Srinivasan et al., 2007 and Batista, 2014).

The highest ratio of sinapic acid was recorded in T4 treatment. It was not detected in T1 and T5 treatments. Sinapic acid (3,5-dimethoxy-4-hydroxycinnamic acid) is a bioactive phenolic acid and has the potential to attenuate various chemically induced toxicities and widespread in the plant kingdom (citrus and berry fruits, vegetables, cereal grains, oilseed crops, and some spices and medicinal plants) and as such is common in the human diet. It is known to exhibit antioxidant, anti-inflammatory, anticancer, antimutagenic, antiglycemic, neuroprotective, anti-anxiety activity and antibacterial activities. In another study, sinapic acid was reported to have the potential to selectively kill the pathogenic bacteria leaving beneficial lactic acid bacteria alive. For these reasons they have been suggested this compound for potential use in food processing, cosmetics and the pharmaceutical industry (Nićiforović and Abramovič, 2014 and Chen, 2016). ρ-Coumaric was recorded 4.77, 4.44 and 4.12 μg 100 g-1 in T2, T3 and T4 treatments, respectively.

The functional of ρ-coumaric acid are reducing oxidative stress and inflammatory reactions. It has good potential to be used as a skin-lightening active ingredient in cosmetics (Boo, 2019). Chinese medicine is used ρ-coumaric as medication to treat patients with rheumatoid arthritis (Zhu et al., 2018). Also, it prevents hepatotoxicity and nephrotoxicity by increased antioxidant enzymes and prevent cancer disease by reduce the free radical (Ekinci Akdemir et al., 2017). The highest ratio of hesperidin in T4 treatment. It was not detected in T1 and T5 treatments. Hesperidin is a bioflavonoid, with high concentration in citrus fruits, it increases following pasteurization of citrus juice at 90°C for 20 seconds. Hesperidin well-known multiple benefits like cardiovascular function, wound healing, UV protection because it can reduce epidermal pigmentation in both normal and UV-B challenged skin, anti-inflammation because it decrease the concentration of nitrite levels, antimicrobial including the common pathogens in the cutaneous infections such as *Staphylococcus aureus*, *Candida albicans*, *Candida tropicalis* and *Streptococcus pyogenes*, anti-skin cancer because it can prevent the development of skin tumor and skin lightening. In addition, hesperidin enhances epidermal permeability barrier homeostasis in both normal young and aged skin (Man et al., 2019).

The highest ratio of apigenin-7-glucoside was recorded in T4 treatment. It was not detected in T1 and T5 treatments. Apigenin (4,5,7-trihydroxyflavone) is one of the most widely distributed in the plant kingdom and one of the most studied phenolics. Apigenin is present principally as glycosylated in significant amount in vegetables (parsley, celery and onions), fruit (orange), herbs (chamomile, thyme, oregano and basil) and plant-based beverages (tea). It is effects in diabetes, amnesia and Alzheimer's disease, obesity disease Parkinson's disease, depression and insomnia, anti-inflammatory and antioxidant function (Hadrich and Sayadi, 2018 and Salehi et al., 2019). The highest ratio of rosmarinic acid was recorded in T4 treatment. It was not detected in T1 and T5 treatments. Friedman (2015), Alagawany et al. (2017) and Taram et al. (2018) stated that rosmarinic acid is an ester of caffeic acid and 3,4-dihydroxyphenylactic acid and has a number of beneficial biological activities, commonly used as an herbal spice in food and it had a positive effect treatment on headaches, stomach problems, antimicrobial, immunomodulatory, anti-diabetic, anti-allergic, anti-inflammatory, hepato- and renal protectant, Alzheimer's disease, anti-viral, anti-mutagenic, Parkinson's disease and beneficial effects during skin affections.

The highest ratio of cinnamic acid in T4 treatment. It was not detected in T1 and T5 treatments. Cinnamic acid is antimicrobial natural preparations involving cinnamon. Cinnamic molecules related with medicinal application, for example on anticancer, antituberculosis, antimalarial, antifungal, antimicrobial, antiatherogenic and antioxidant activities and it was found to be much more active against Mycobacterium tuberculosis the tuberculosis causing bacterium (Guzman, 2014).

Lactic acid bacterial counts: Viable LAB counts decreased significantly ($p<0.05$) with increase of CPS+OJS ratios added in the T2, T3 and T4 treatments (Fig. 7). T4 COFY treatment was recorded the highest decrease compared with all treatments; may be due to the low pH and high acid content orange juice which added to frozen yoghurt. These findings are in conformity with Kaur et al. (2016) who indicated that the culture fortified orange juice should be able to at least survive at low pH and high acid content. On the other hand, protein and dietary fiber could protect cells from acidic stress (Kohajdova et al, 2006).

In comparison with the LAB counts of mix (Table 5), the viability of LAB of all treatments decreased from 6.74 -

7.98 to 6.82 - 5.53 log cfu g^{-1} for control (T1 and T5 treatments) and CPS+OJS of COFY treatments (Fig. 7). LAB counts in all COFY treatments were decreased significantly ($p<0.05$) until 45 days of storage period. As mentioned before, this could be a result of the destructive of low temperature of bacterial cells and the effect of residual oxygen from the air incorporated during overrun process (Ordonez et al., 2000 and El-Kholy, 2018).

Sensory properties of carrot-orange frozen yoghurt: The flavor of COFY was improved by the addition of (OJS+CPS) mix. Whereas, the controls (T1 and T5) had lower flavor scores compared with all treatments of COFY as shown in Table (8). Generally, flavor and overall acceptability of resultant frozen yoghurt increased with the increasing the percentage of added (OJS+CPS) mix. The best flavor of COFY was reported for T3 and T4 treatments. However, T2 replacement ratio gave quite acid taste. The best body and texture were for T4 treatment. T4 recorded the highest overall acceptability compared with all treatments followed by T3, T2, T1 and T5, respectively. These findings are in conformity with El-Kholy (2018) who reported that the fruit additives are the better options for increasing flavored value of low-fat frozen yoghurt its quality and acceptability. A gradual decrease significantly ($p<0.05$) was noticed in all COFY treatments during freezing storage period. The addition of fruits in frozen yoghurt preparation improved composition properties and enhanced taste, make delicious pleasing flavor product that contains refreshing flavor of fruit and beneficial effect of frozen yoghurt.

Carrot-orange frozen yoghurt cost production: Full fat frozen yogurt was the most expensive to produce. The cost production was decreased by decreasing fat content by 1%. Addition (CPS+OJS) at ratio 1 (T1), 2 (T2) and 3 (T3) % in low fat frozen yoghurt reduce the cost production with 6.50, 13.09 and 19.46 %, respectively compared with T1, control full fat (Table-9).

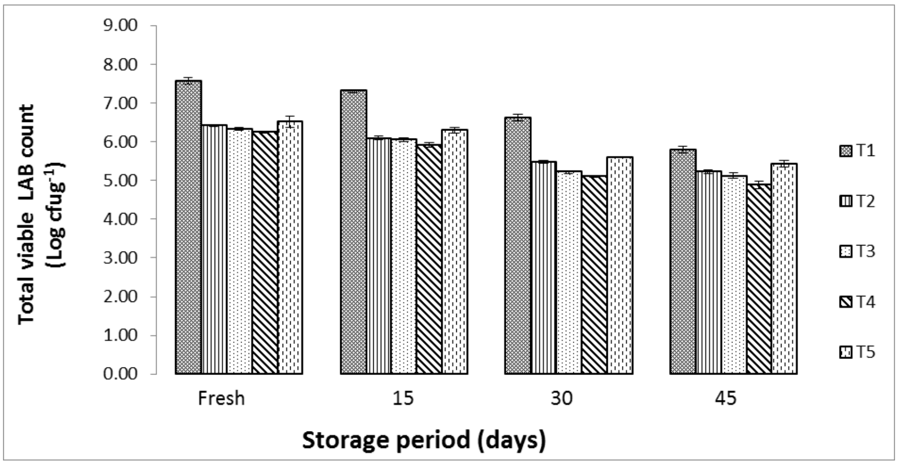

Fig. (7) Effect of using different percentages of carrot puree and orange juice solids on LAB counts of carrot-orange frozen yoghurt

T1: Full fat (4% fat) frozen yoghurt (FY) without adding of (CPS+ OJS, $control_1$).
T2: Treatment with 3% fat FY with adding of 1% (CPS+OJS at equal ratio).
T3: Treatment with 2% fat FY with adding of 2% (CPS+OJS at equal ratio).
T4: Treatment with 1% fat FY with adding of 3% (CPS+OJS at equal ratio).
T5: Treatment with 1% fat FY without adding of (CPS+ OJS, $control_2$).

Table (8) Effect of using different percentages of CPS+ OJS in the organoleptic characteristic of carrot-orange frozen yoghurt

Treatments	Storage period (days)				Mean
	Fresh	15	30	45	
Flavour (45)					
T_1	36± 0.57	35± 1.52	35± 0.57	35± 1.73	35.33^d
T_2	40± 0.57	39± 1.00	38± 0.57	36± 0.57	38.16^c
T_3	42± 0.57	41± 1.00	39± 0.57	39± 1.15	40.16^b
T_4	44± 1.00	44± 1.00	42±0.57	40±0.57	42.66^a
T_5	30± 0.57	30±2.08	27±0.57	26± 1.00	28.16^e
Mean	38.4^a	47.73^a	36.2^b	35.26^c	
Body and texture (35)					
T_1	27± 0.57	26± 0.57	27± 0.57	26± 0.57	26.5^d
T_2	30± 0.57	30± 0.57	29± 0.57	29± 0.57	29.5^c
T_3	32± 0.57	32± 1.15	33± 0.57	33± 0.57	32.5^b
T_4	34± 0.57	35±0.57	34±0.57	35±0.57	34.5^a
T_5	21± 1.00	21±1.00	21±0.57	21± 1.15	21.00^e
Mean	28.80^a	28.80^a	28.70^a	28.86	
Colour and appearance (10)					
T_1	5± 0.57	4±0.57	5± 0.57	4± 0.57	4.5^d
T_2	7± 0.57	6± 0.57	6± 0.57	6± 0.57	6.41^c
T_3	9± 0.57	9± 0.57	9± 0.57	8± 0.57	8.58^b
T_4	10± 0.00	10±0.57	10±0.57	10±0.57	9.75^a
T_5	4±0.57	3±0.57	3±0.57	4± 0.57	3.50^e
Mean	6.73^a	6.46^a	6.53^a	6.46^a	
Melting resistance (10)					
T_1	4± 0.57	4± 0.57	5± 0.00	4± 0.57	4.50^a
T_2	7± 0.57	6± 0.57	7± 0.57	6± 0.57	6.50^b
T3	8± 0.57	9± 0.00	9± 0.57	8± 0.57	8.58^c
T4	10± 0.57	10± 0.57	10±0.57	9± 0.57	9.58^d
T5	3± 0.57	4± 0.57	4± 0.57	3±0.57	3.58^e
Mean	6.46^a	6.60^a	6.73^a	6.40^a	
Overall acceptability (100)					
T_1	72± 1.00	70± 1.52	72± 0.57	70± 1.00	70.83^d
T_2	83± 1.52	81± 0.57	80± 0.00	78± 1.15	80.58^c
T_3	93± 1.52	95± 1.15	92± 1.00	90± 0.57	92.33^b
T_4	96± 1.15	95± 0.00	93± 1.73	92± 1.52	94.00^a
T_5	58± 0.57	58± 2.08	54± 1.15	55± 3.21	56.25^e
Mean	80.40^a	79.60^a	78.20^b	77.00^c	

T1: Full fat (4% fat) frozen yoghurt (FY) without adding of (CPS+ OJS, $control_1$).
T2: Treatment with 3% fat FY with adding of 1% (CPS+OJS at equal ratio).
T3: Treatment with 2% fat FY with adding of 2% (CPS+OJS at equal ratio).
T4: Treatment with 1% fat FY with adding of 3% (CPS+OJS at equal ratio).
T5: Treatment with 1% fat FY without adding of (CPS+ OJS, $control_2$).
Values are means ± standard deviations of triplicate determinations.
Means with the same row with different superscript (a, b, c…) are significantly different ($p \leq 0.05$).

Table (9) Effect of using different ratios of CPS+OJS in the cost production of carrot-orange frozen yoghurt

Items	Treatments

	T_1	T_2	T_3	T_4	T_5
Cost of production (L.E) 100 Kg^{-1}	4076.15	3811.19	3542.60	3283.07	2946.45
% Reduction of cost as compared to full fat one	-----	6.50	13.09	19.46	27.71

T1: Full fat (4% fat) frozen yoghurt (FY) without adding of (CPS+ OJS, $control_1$).
T2: Treatment with 3% fat FY with adding of 1% (CPS+OJS at equal ratio).
T3: Treatment with 2% fat FY with adding of 2% (CPS+OJS at equal ratio).
T4: Treatment with 1% fat FY with adding of 3% (CPS+OJS at equal ratio).
T5: Treatment with 1% fat FY without adding of (CPS+ OJS, $control_2$).

CONCLUSION

Frozen yoghurt can be made with puree of carrots and orange juice. It is flavourful, naturally scavenges antioxidants, has fibers in addition to the nutritive component and has health-promoting properties. Carrots and oranges have unique characteristics and beautiful colour which makes it suitable for use in frozen yogurt making. In addition, CPS+OJS enhanced the rheological properties, antioxidant scavenging properties and overall acceptability of low-fat frozen yogurt. (CPS + OJS) can therefore be used effectively to create functional low fat frozen yogurt with acceptable sensory characteristics comparable to that of full fat frozen yogurt. CPS+OJS at the ratio of 3% can be recommended in the manufacture of low-fat frozen yoghurt with enhanced acceptability comparable to full fat frozen yoghurt.

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اليوغورت المجمد الوظيفي منخفض الدسم مع اضافه الجزر والبرتقال

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تم دراسة تأثير إضافة جوامد الجزر الكلية مع جوامد عصير البرتقال الكلية بنسب متساوية على الخواص الفيزيائية والكيميائية والمركبات الفينولية الكلية ونشاط المواد المضادة للأكسدة والخصائص الحسية وعدد بكتريا حامض اللاكتيك وتكلفة إنتاج اللبن الزبادى المجمد منخفض الدهن. تتميز الخضر والفاكهة بأنهما مصدر للألياف الغذائية الغنية بالمواد المضادة للأكسدة الطبيعية مما يشجع علي استخدامهما في تدعيم الزبادى المجمد منخفض الدهن. وقد وجد إن إضافة جوامد الجزر الكلية مع جوامد عصير البرتقال الكلية بنسب متساوية أدت إلى زيادة كلاً من الوزن النوعى، الوزن بالجالون، اللزوجة الظاهرية، المقاومة للإنصهار، قيم الأس الهيدروجينى، المركبات الفينولية الكلية ونشاط المواد المضادة للأكسدة فى المنتج مقارنة بعينة الكنترول كاملة الدهن ومنخفضة الدهن. كما أظهرت إنخفاض فى كلاً من نقطة التجمد والريع. أيضا وجد أن إضافة جوامد الجزر الكلية مع جوامد عصير البرتقال الكلية بنسب متساوية عملت على خفض العدد الكلى لبكتريا حمض اللاكتيك فى الزبادى خلال التخزين بالتجميد. وقد أظهرت نتائج التقييم الحسى أن معدل الإستبدال بمخلوط كلا من جوامد الجزر الكلية مع جوامد عصير البرتقال الكلية (1:1) بنسبة 3 % أعطت أفضل النتائج في الصفات الطبيعية والكيميائية والريولوجية مع خفض تكلفة الإنتاج.