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ORIGINAL ARTICLE

Development of functional cakes rich in bioactive compounds extracted from saffron and tomatoes

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Abstract Demand for health-promoting food products rich in bioactive compounds and fibers is increasing. The current study was aimed to evaluate the physicochemical, antioxidant and sensory characteristics of whole wheat flour cakes enriched with tomato powder (TP), crude lycopene (CL) and saffron extracts (SE). Physical characteristics such as loaf weight of cakes containing TP increased significantly ($p < 0.05$) while loaf volume decreased as compared to the control. The color of the crust and crumb of cakes enriched with TP and CL was dark red while cakes containing SE were bright and yellowish. Firmness of the fresh cake samples was found in the range of 7.25–14.53 N. Antioxidant properties were significantly ($p < 0.05$) improved after enrichment of cakes with TP, CL and SE. The storage period increased the water activity while antioxidant activity and concentration of total carotenoids was reduced. Thus, cakes enriched with TP, CL and SE could be successfully developed with improved antioxidant properties, without compromising the sensory quality of the product.

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Keywords Whole wheat · Cakes · Saffron · Lycopene · Antioxidant

Abbreviations

WWF	Whole wheat flour
TP	Tomato powder
CL	Crude lycopene
SE	Saffron extract
TPA	Texture profile analysis
TPC	Total phenolic content
GAE	Gallic acid equivalents
TCA	Trichloroacetic acid
TBA	Thiobarbituric acid
ILP	Inhibition of lipid peroxidation
TCC	Total carotenoids content
BC	Whole wheat flour batter without any supplement
BCL_{50}	Batter with 50 mg CL/100 g WWF
BCL_{100}	Batter with 100 mg CL/100 g WWF
BT_1	Batter with 2 g TP/100 g WWF
BT_2	Batter with 4 g TP/100 g WWF
BS_{50}	Batter with SE of 50 mg saffron/100 g WWF
BS_{100}	Batter with SE of 100 mg saffron/100 g WWF
CkC	Cakes prepared from BC
CkL_{50}	Cakes prepared from BL_{50}
CkL_{100}	Cakes prepared from BL_{100}
CkT_1	Cakes prepared from BT_1
CkT_2	Cakes prepared from BT_2
CkS_{50}	Cakes prepared from BS_{50}
CkS_{100}	Cakes prepared from BS_{100}

Introduction

Bakery products such as cookies and cakes made from wheat flour are the most consumed items by nearly all classes of society. It is mainly because of their ready-to-eat nature, low cost and versatility. Bakery products can therefore be used as a medium for incorporating several health-promoting ingredients of plant origin into their preparations. However, bakery products made from refined wheat flour are deficient in some essential nutrients (Ballester-Sánchez et al. 2019) as compared to whole wheat flour (WWF).

The demand for whole wheat-based foods has increased to a large extent, mainly due to various health benefits associated with them. Whole wheat flour consumption could help to minimize the occurrence of chronic diseases such as diabetes, obesity, cancer and cardiovascular diseases (Bhat et al. 2016). Besides, the development of bakery products enriched with bioactive compounds is an important contribution to a wide range of food products with numerous health benefits. In previous studies, fortification of bakery products like bread and biscuits with spices and herbs has been carried (Agrahar-Murugkar, 2020). In this context, tomato powder, lycopene and saffron extract added to bakery products can play an important role in the human diet.

Tomato (*Lycopesicon esculentum*) is one of the most widely consumed agricultural commodities in the world. In India, it is mainly consumed either as a raw or a processed product. Tomato is a rich source of antioxidants including ascorbic acid, lycopene, flavonoids and phenolics and is regarded as an important source of carotenoids to the human diet (Domínguez et al. 2020). Lycopene has been reported to be protective against cancer and other degenerative diseases induced by free radical chain reactions (Bhat et al. 2020). The waste produced from tomato processing industries, being a rich source of bioactive compounds can be utilized for the development of various food products by incorporating it into their formulations, either as a powder or as an extract.

Saffron (*Crocus sativus*) is a very expensive spice of the world. Its dried stigmas are mainly used as herbal medicine or as a coloring or flavoring agent in foods. The main components of saffron include crocin, picrocrocin and saffranal. Carmona et al. (2006) reported that the antioxidant activity of saffron is chiefly due to crocin and other bioactive components present in it. The objective of our study was to evaluate the effect of incorporation of crude lycopene, tomato powder and saffron extract on the physicochemical, antioxidant and sensory characteristics of cakes during a storage period of 0–15 days. The development of such products with improved antioxidant properties may help in reducing the risk of various lifestyle diseases associated with the consumption of foods containing high amounts fat or sugar.

Material and methods

Sample collection and preparation

Wheat cultivar (SW-1) was collected from Sheri-Kashmir University of Agricultural Sciences & Technology, Kashmir (SKUAST-K), Srinagar, India. Whole wheat flour was obtained by milling the wheat kernels in a laboratory mill (Amar Industries, Amritsar, India) and then passing the flour through a 50 mesh sieve to obtain a flour of smaller particle size.

Saffron stigmas in dried form were purchased from Pampore, Pulwama, the main saffron producing area of Jammu and Kashmir, India.

Tomatoes were purchased from the local farmers of Budgam, Jammu and Kashmir, India. The tomatoes were sorted to remove the spoiled ones, washed in clean running water and then blanched for 2 min in hot water and sliced. The slices were dried in an oven at 40 °C (A.L.O.S.A-2 143, Narang Scientific Works PVT. LTD, India) after removing the seeds. The dried slices were ground using a household grinder. The powdered tomato powder was then packed in laminated pouches and kept under refrigeration (4 °C), till further analysis.

Crude lycopene extraction

The method described by Mayeaux et al. (2006) was used for the extraction of crude lycopene from tomatoes.

Saffron metabolite extraction and analysis

Kumpati et al. (2003) method was used for the extraction of saffron metabolites i.e. crocin, picrocrocin and saffranal. Briefly 1 g (db) of saffron powder was taken in an amber-colored flask and 15 mL of water was added to it. The mixture was then homogenized to increase the extraction of bioactive compounds and was placed on a magnetic stirrer for 24 h in dark. After extraction, the mixture was filtered and kept under frozen storage (– 18 °C) till further analysis.

Crocin, safranal and picrocrocin concentration in saffron was observed as 13,577.92 ± 20.78 µg/g, 3570.79 ± 37.10 µg/g and 7583.57 ± 27.0 µg/g, respectively.

Preparation of cakes

Whole wheat flour was supplemented with tomato powder (2 & 4/100 g of WWF), crude lycopene (50 & 100 mg/100 g of WWF) and saffron extract (extract of 50 & 100 mg saffron powder). Each of the extracts was added to 100 g of the WWF. In brief, WWF enriched with tomato powder (TP), crude lycopene (CL) and saffron extracts (SE) was mixed with shortening, sugar, egg white, salt, baking powder, refined oil and water. Shortening (70 g) was firstly mixed with 100 g of the WWF for 2–3 min in a laboratory mixer. After this, 100 g of sugar, 12 g of skim milk powder, 1.72 g of baking powder, 20 g of egg white, 2 g of salt, 20 mL of refined oil and 20 mL of water was added to it and mixed thoroughly. Before baking, a small amount of batter from each formulation was taken in a laminated pouch for analysis. The samples were labeled as BC (batter without any supplement), BCL_{50} (batter with 50 mg CL/100 g WWF), BCL_{100} (batter with 100 mg CL/100 g WWF), BT_1 (batter with 2 g TP/100 g WWF), BT_2 (batter with 4 g TP/100 g WWF), BS_{50} (batter with SE of 50 mg saffron/100 g WWF) and BS_{100} (batter with SE of 100 mg saffron/100 g WWF). The batter was then transferred to aluminum moulds and baked in an oven at 160 °C for 25 min. The cakes were allowed to cool at room temperature (27 °C) for 2 h and then labeled as CkC, CkL_{50}, CkL_{100}, CkT_1, CkT_2, CkS_{50} and CkS_{100} (prepared from BC, BL_{50}, BL_{100}, BT_1, BT_2, BS_{50} & BS_{100}, respectively).

Physical characteristics of cakes

Loaf weight

Loaf weight of cakes was determined by using the method of Chaiya and Pongsawatmanit (2011). The cake sample was cut into 25 × 25 × 25 mm cubes and the weight of one piece of cake was taken as loaf weight.

Specific volume

The specific volume was determined as the ratio of the volume (V_o) to the weight of cake (W_o)

$$\text{Specific volume} = \frac{V_o}{W_o}$$

Weight and volume

Weight and volume were determined by using the method of Chaiya and Pongsawatmanit (2011).

Texture profile analysis (TPA)

Texture profile analysis of cakes was done by using a Texture analyzer (TA-XT2, Stable Micro System Ltd., Surrey, UK), fitted with a load cell of 50 kg and was connected with a computer to control the instrument and analyze the data. The cake sample was placed centrally on the base plate of the Texture analyzer. TPA was done by making use of an aluminum cylindrical probe of the diameter of 80 mm, to compress the samples to 75% depth, with a trigger force of 5 g, pretest speed of 1 mm s^{-1}, test speed of 5 mm s^{-1} and time interval of 5 s.

Color

Color Flex Spectrocolorimeter (Hunter Lab Colorimeter D-25, Hunter Associates Laboratory, Ruston, USA) was used for the determination of hunter color i.e. '*L*' (lightness), '*a*' (redness) and '*b*' (yellowness) values of the samples. The calibration of the equipment was done by using a standard white paper.

Chemical Characteristics of cakes

Proximate composition of cakes

AOAC (1990) standard procedure was used for estimation of the proximate composition of the samples.

Water activity

The water activity of samples was estimated by using a water activity meter (PRE AQUA LAB, Water activity analyzer, SN: PRE000197).

Total phenolic content (TPC)

The procedure described by Gao et al. (2002) was used for estimation of the TPC of cakes. A sample weight of 200 mg was taken in a centrifuge tube and 4 mL of acidified methanol (HCl/methanol/water, 1:80:10, v/v/v) was added and kept at room temperature for 2 h for extraction. After this, 1.5 mL of freshly prepared (tenfold diluted) Folin-Ciocalteu reagent was added to 200 µL of sample extract. The reagents were then mixed and equilibrated for 5 min and then neutralised with 1.5 mL of sodium carbonate solution (60 g/L). The samples were kept for incubation at room temperature (25 °C) for 90 min. The absorbance of the samples was taken at 725 nm (UV-Spectrophotometer, Model U-2900 2JI-0003, Hitachi, Japan). The TPC of samples was measured by preparing a standard curve of gallic acid and expressed as gallic acid equivalents (GAE) per gram of sample.

Antioxidant properties

DPPH (1, 1-diphenyl-2- picrylhydrazyl) radical scavenging assay The procedure described by Brand-Williams et al. (1995) was used for estimation of the DPPH radical scavenging activity of cake samples. The DPPH scavenging activity was calculated by using the following equation:

DPPH radical scavenging activity (%) = [1- (A of sample t = 30/A of control t = 0)] × 100.

Reducing power The method of Zhao et al. (2008) was used for determining the reducing power of the samples. The reducing power was calculated by preparing the standard curve of ascorbic acid and expressed as ascorbic acid equivalents (AAE) per gram of sample.

Lipid peroxidation Inhibition of lipid peroxidation of the cakes was determined by following the procedure of Wright et al. (1981) with slight modification. A sample extract of 250 µL was transferred to a centrifuge tube and 1 mL of 0.1% (0.1 mL/99.9 mL of ethanol) linoleic acid, 0.2 mL of 20 mM ferric nitrate, 0.2 mL of 200 mM ascorbic acid and 0.2 mL of 30 mM hydrogen peroxide was added, followed by incubation for 1 h in a water bath at 37 °C. After this, 1 mL of 10% (w/v) TCA was added to terminate the reaction, followed by the addition of 1 mL of 1% TBA (w/v). The reaction mixture was then kept in a boiling water bath for 20 min and centrifuged for 10 min at 5000 × g. The absorbance of the samples was read at 535 nm against a blank. Inhibition of lipid peroxidation was calculated by using the following formula:

$$\%\text{Inhibition} = [1 - (\text{A of sample}/\text{A of control})] \times 100$$

Total carotenoids content

The method described by de-Carvalho et al. (2012) was used for the estimation of total carotenoids content (TCC) of cakes. The TCC of whole wheat flour, tomato powder and crude lycopene was found as 1.136 ± 0.45 µg/g, 263.02 ± 12.30 µg/g and 4619.98 ± 75.12 µg/g, respectively.

Sensory evaluation

Sensory analysis of cake samples was done by a total of 25 semi-trained panelists from the Department of Food Science and Technology, University of Kashmir, India. All the samples were differently coded and then presented to panelists. The panelists rinsed their mouths thoroughly with potable water after the analysis of each sample. A 9-point hedonic scale was used to record the organoleptic characteristics like appearance, texture, flavor, aftertaste and overall acceptability.

Statistical analysis

The average values of triplicate observations and mean ± standard deviation were reported. Analysis of variance (ANOVA) was carried out by using a statistical package (SPSS, Inc, Chicago, IL, USA). The test was performed at a 5% level of significance and Duncan's test was selected to calculate the differences between means.

Results and discussion

Physical properties

Loaf weight, specific volume, weight and volume

The physical characteristics of cakes are presented in Table 1. The volume, weight, specific volume, loaf weight and loaf volume were observed in the range of 179.40–180.22 cm^3, 88.11–88.26 g, 2.03–2.04 cm^3/g, 7.99–8.25 g and 12.89–13.25 cm^3, respectively. Cakes with added TP, CL and SE showed a non-significant ($p > 0.05$) variation in volume. However, the loaf weight of the cakes with added TP was found to increase compared to the control. The possible reason could be the increased density of cakes upon the addition of TP. Tomato powder has an increased amount of fiber that may reduce the expansion of cakes (Camire and King 1991) resulting in reduced loaf volume.

Texture profile analysis

Texture profile analysis (TPA) of the fresh and stored (0–15 days) cakes is presented in Table 2. The results revealed that the firmness of fresh cakes decreased significantly ($p < 0.05$) from 12.60 to 7.25 N upon the incorporation of tomato powder, crude lycopene and saffron extracts, except CkT_2 (14.53 N) as compared to control. The possible reason could be the higher water binding ability of the tomato fiber as compared to wheat flour which might have hindered the gluten-protein network formation and less quantity of air retained by the dough resulting in increased firmness of the cakes (Chang et al. 2015). Similar results were reported by Aydogdu et al. (2018) for the hardness of cakes enriched with different fibers. Adhesiveness of the cake samples was observed to increase significantly ($p < 0.05$) from − 1.203 to − 127 after enrichment with TP and SE, indicating that enriched cakes were more adhesive than the control. Adhesiveness is the negative force area between first and second bites by

Table 1 Proximate composition and Physical characteristics of cakes supplemented with tomato powder, crude lycopene and saffron extracts (n = 3)

	CkC	CkL_{50}	CkL_{100}	CkT_1	CkT_2	CkS_{50}	CkS_{100}
Moisture (g/100 g)	33.4 ± 0.10^{b}	34.2 ± 0.04^{bc}	35.4 ± 0.1^{c}	35.1 ± 0.03^{bc}	34.3 ± 0.06^{bc}	30.8 ± 0.20^{a}	36.1 ± 0.11^{c}
Crude protein (g/100 g)	6.57 ± 0.21^{b}	6.55 ± 0.13^{b}	6.49 ± 0.11^{ab}	6.45 ± 0.30^{a}	6.43 ± 0.23^{a}	6.79 ± 0.14^{d}	6.68 ± 0.6^{c}
Crude fat (g/100 g)	30.11 ± 0.10^{a}	30.27 ± 0.22^{cd}	30.32 ± 0.35^{d}	30.18 ± 0.43^{abc}	30.20 ± 0.26^{abc}	30.15 ± 0.31^{ab}	30.21 ± 0.12^{bc}
Ash (g/100 g)	1.77 ± 0.01^{ab}	1.75 ± 0.13^{a}	1.82 ± 0.05^{b}	2.03 ± 0.11^{c}	2.11 ± 0.06^{d}	1.80 ± 0.01^{ab}	1.76 ± 0.02^{ab}
Weight (g)	88.11 ± 0.12	88.20 ± 0.11	88.15 ± 0.56	88.12 ± 0.72	88.26 ± 0.13	88.13 ± 1.0	88.18 ± 1.10
Volume (cm^3)	180.0 ± 1.01^{a}	180.20 ± 1.20^{a}	180.22 ± 2.0^{a}	179.61 ± 0.88^{a}	179.40 ± 2.01^{a}	180.11 ± 2.54^{a}	180.00 ± 1.12^{a}
Specific volume (cm^3/g)	2.04 ± 0.04^{a}	2.04 ± 0.01^{a}	2.04 ± 0.02^{a}	2.04 ± 0.01^{a}	2.03 ± 0.12^{a}	2.04 ± 0.11^{a}	2.04 ± 0.01^{a}
Loaf weight (g)	8.01 ± 0.05^{a}	7.99 ± 0.22^{a}	8.02 ± 0.21^{a}	8.18 ± 0.30^{c}	8.25 ± 0.15^{d}	8.10 ± 0.06^{b}	8.00 ± 0.10^{a}
Loaf volume (cm^3)	13.12 ± 0.46^{c}	13.10 ± 0.04^{c}	13.13 ± 0.11^{cd}	12.97 ± 1.10^{b}	12.89 ± 0.06^{a}	13.25 ± 0.67^{e}	13.19 ± 0.77^{de}

Results are expressed as means (n = 3) ± standard deviation

Values followed by same letter in a row do not differ significantly ($p < 0.05$)

CkC: Cakes without any supplement; CkL_{50}: Cakes with added crude lycopene (50 mg/100 g of flour); CkL_{100}: Cakes with added crude lycopene (100 mg/100 g of flour); CkT_1: Cakes with added tomato powder (2 g/100 g); CkT_2: Cakes with added tomato powder (4 g/100 g); CkS_{50}: Cakes with added SE of 50 mg/100 g of flour; CkS_{100}: Cakes with added SE of 100 mg/100 g of flour

the TPA software. Thus, the samples with high negative values are more adhesive. Cohesiveness depicts the internal resistance of the cake structure. Springiness determines the recovery of a sample between first and second compression cycles by quantifying the elasticity, and resilience gives an indication of the energy recovered after the first compression cycle is relieved. TPA of the enriched cake samples revealed a significant ($p < 0.05$) increase in the cohesiveness, springiness and resilience when compared to the control. The energy required to disintegrate food particles for swallowing is depicted by chewiness and it was found to decrease significantly ($p < 0.05$) in the composite cakes. The changes in the textural properties of enriched cakes particularly those enriched with TP might be due to the dilution of gluten, decrease in the amount of starch and increase in the fiber content upon the incorporation of tomato powder (Sharma and Gujral 2014). Kaack et al. (2006) reported that the bread firmness increased and also its deformation energy and gumminess were badly affected due to the increase in the content of soluble non-starch polysaccharides and insoluble non-starch polysaccharides, which might also be the case in our study.

Storage time of 0–15 days significantly ($p < 0.05$) enhanced the firmness and adhesiveness of all the cake samples, whereas the springiness, cohesiveness, chewiness and resilience were significantly ($p < 0.05$) lowered. The increase in the firmness of samples could be attributed to an increase in retrogradation or ageing rate of cakes with time (Ferng et al. 2016). A similar decrease in the cohesiveness, springiness and resilience of cakes upon storage was reported by Gómez et al. (2010). Other studies have also reported similar results for textural characteristics of bread (Gambaro et al. 2004).

Color

Lightness (*L*) of the crust of freshly prepared cakes was observed to decrease significantly ($p < 0.05$) with the incorporation of TP and CL in comparison to the control (Table 3). However, the cakes containing SE showed increased values for crust lightness (Fig. 1). The highest value for lightness was observed in the case of cake containing SE (CkS_{50}) and the lowest in the cake with added lycopene (CkL_{100}). It depicts that crusts of cakes with added TP and CL were slightly darker in color, while as, those containing SE were bright in color when compared to the control. The crust of cakes containing SE was more yellowish in color as compared to other samples. This might be due to the presence of crocins in the saffron extract that provide golden yellow color to it (Bolhassani et al. 2014). Similarly, the crusts of cakes containing TP and CL were slightly more reddish in color compared to

Table 2 Texture profile analysis of cakes enriched with tomato powder, crude lycopene and saffron extract (n = 3)

Storage (Days)	CkC	CkL_{50}	CkL_{100}	CkT_1	CkT_2	CkS_{50}	CkS_{100}
Firmness (N)							
0	12.60 ± 0.43^{fp}	9.61 ± 0.12^{cp}	7.25 ± 0.23^{ap}	11.11 ± 0.21^{ep}	14.53 ± 0.52^{gp}	10.13 ± 0.18^{dp}	8.55 ± 0.21^{bp}
7	13.29 ± 0.12^{cq}	11.83 ± 0.31^{aq}	13.31 ± 0.10^{dq}	13.47 ± 0.13^{eq}	16.73 ± 0.87^{gq}	12.66 ± 0.40^{bq}	13.54 ± 1.11^{fq}
15	14.22 ± 0.61^{dr}	12.52 ± 0.56^{ar}	16.12 ± 0.65^{fr}	13.59 ± 1.13^{cr}	17.14 ± 1.34^{gr}	13.01 ± 1.22^{br}	15.48 ± 0.21^{er}
Adhesiveness							
0	− 1.203 ± 0.01^{ep}	− 0.002 ± 0.08^{ep}	− 0.292 ± 0.12^{ep}	− 127.11 ± 0.8^{ap}	− 39.56 ± 1.45^{bp}	− 12.23 ± 0.34^{cq}	− 7.33 ± 1.00^{dr}
7	− 15.76 ± 0.03^{dq}	− 96.25 ± 0.34^{cq}	− 4.346 ± 0.1^{eq}	− 422.4 ± 1.1^{bq}	− 471.4 ± 1.67^{aq}	− 0.029 ± 0.02^{fp}	− 1.120 ± 0.20^{fq}
15	− 21.52 ± 0.01^{dr}	− 145.8 ± 0.45^{cr}	− 5.778 ± 0.1^{er}	− 591.8 ± 0.9^{br}	− 662.4 ± 1.22^{ar}	− 0.023 ± 0.01^{fp}	− 0.994 ± 0.06^{fp}
Springiness							
0	0.725 ± 0.21^{ar}	0.792 ± 0.12^{cr}	0.774 ± 0.54^{br}	0.842 ± 0.32^{dq}	0.845 ± 0.32^{dr}	0.728 ± 0.13^{ar}	0.731 ± 0.10^{ar}
7	0.621 ± 0.41^{aq}	0.759 ± 0.45^{dq}	0.697 ± 0.35^{cq}	0.823 ± 0.30^{ep}	0.768 ± 0.25^{dq}	0.610 ± 0.14^{aq}	0.646 ± 0.51^{bq}
15	0.569 ± 0.24^{ap}	0.710 ± 0.67^{dp}	0.645 ± 0.65^{cp}	0.815 ± 0.24^{ep}	0.809 ± 0.31^{ep}	0.551 ± 0.86^{ap}	0.601 ± 0.32^{bp}
Cohesiveness							
0	0.315 ± 0.44^{ar}	0.452 ± 0.11^{cr}	0.463 ± 0.08^{dr}	0.455 ± 0.02^{cdr}	0.489 ± 0.09^{er}	0.400 ± 0.22^{bq}	0.463 ± 0.19^{dp}
7	0.253 ± 0.34^{aq}	0.412 ± 0.27^{cq}	0.372 ± 0.54^{bq}	0.373 ± 0.13^{bq}	0.419 ± 0.10^{cq}	0.379 ± 0.25^{bp}	0.377 ± 0.37^{bq}
15	0.225 ± 0.17^{ap}	0.394 ± 0.31^{ep}	0.337 ± 0.11^{bcp}	0.342 ± 0.12^{cp}	0.393 ± 0.05^{ep}	0.367 ± 0.07^{dp}	0.334 ± 0.32^{br}
Chewiness							
0	4.87 ± 0.55^{gr}	3.45 ± 0.58^{dp}	3.90 ± 1.11^{er}	3.28 ± 0.81^{cp}	3.00 ± 1.21^{bp}	2.32 ± 0.46^{ar}	4.10 ± 0.17^{fr}
7	4.33 ± 0.21^{fq}	3.70 ± 0.39^{cr}	3.54 ± 0.70^{bq}	4.16 ± 0.66^{eq}	4.29 ± 1.43^{fq}	1.96 ± 0.73^{aq}	4.01 ± 0.84^{dq}
15	4.01 ± 0.12^{ep}	3.54 ± 0.14^{dq}	3.31 ± 1.46^{cp}	4.64 ± 0.32^{fr}	4.98 ± 1.14^{gr}	1.81 ± 0.12^{ap}	2.39 ± 1.44^{bp}
Resilience							
0	0.110 ± 0.28^{ar}	0.170 ± 0.08^{cq}	0.172 ± 0.65^{cq}	0.163 ± 0.32^{cr}	0.189 0.07^{dr}	0.142 ± 0.20^{br}	0.172 ± 0.00^{cr}
7	0.089 ± 0.03^{aq}	0.139 ± 0.12^{cp}	0.139 ± 0.16^{cp}	0.125 ± 0.22^{bq}	0.142 ± 0.09^{cq}	0.132 ± 0.05^{bcq}	0.138 ± 0.35^{cq}
15	0.076 ± 0.10^{ap}	0.130 ± 0.16^{efp}	0.134 ± 0.06^{fp}	0.118 ± 0.13^{cp}	0.126 ± 0.11^{dp}	0.127 ± 0.51^{dep}	0.113 ± 0.09^{bp}

Results are expressed as means (n = 3) ± standard deviation

Values followed by same letter in a row & in the column do not differ significantly ($p < 0.05$). The letters 'a, b, c, d…' denote difference within a row and 'p, q, r, s…' within a column

CkC: Cakes without any supplement; CkL_{50}: Cakes with added crude lycopene (50 mg/100 g of flour); CkL_{100}: Cakes with added crude lycopene (100 mg/100 g of flour); CkT_1: Cakes with added tomato powder (2 g/100 g); CkT_2: Cakes with added tomato powder (4 g/100 g); CkS_{50}: Cakes with added SE of 50 mg/100 g of flour; CkS_{100}: Cakes with added SE of 100 mg/100 g of flour other samples due to tomato lycopene present in them (Dehghan-Shoar et al. 2010).

The lightness of the crumb of cakes with added TP, CL and SE varied non-significantly ($p > 0.05$) from the control. However, the redness (*a*) and yellowness (*b*) of the crumb was found to increase significantly ($p < 0.05$) upon addition with TP and CL. In general, the crumb of cakes with added SE appeared slightly bluish in comparison to the control. The crumb of CkT_2 showed the highest redness value whereas, the crumb of CkS_{100} was more yellowish compared to the other samples.

The storage time of 15 days adversely affected the color values of cakes. Hunter color '*a*' and '*b*' values of the cake crusts were observed to decrease non-significantly ($p > 0.05$) with storage, except the control. However, the lightness values of crusts increased with storage. On the other hand, the crumb color of cakes did not show any particular trend. In general, the crumb lightness of cakes was enhanced whereas, redness and yellowness were reduced upon storage. The possible reason may be the degradation of carotenoids upon exposure to light radiations. Hydrolysis of crocin into crocetin might take place in saffron upon storage which might have reduced the coloring strength of cakes enriched with saffron extract (Raina et al. 1996).

Chemical characteristics

Proximate composition

The proximate composition of the cakes containing tomato powder (TP), crude lycopene (CL) and saffron extract (SE) is presented in Table 1. The crude protein content of the cakes was found to decrease significantly ($p < 0.05$) after the addition of TP when compared to control. This could be attributed to the lower protein content of TP as compared to WWF. However, the crude protein content of cakes containing SE was significantly ($p < 0.05$) higher than that of the control. The saffron extract might contain some water-soluble proteins which might have increased the protein content of the composite cakes (Armellini et al. 2018). Cakes with added CL showed an increased crude fat content when compared to the control. Tan et al. (2014) reported that lycopene might form micro globules with fat which may prevent oxidation of fat during baking. This might be the reason for the enhanced fat content of cakes containing CL. The ash content of the cake samples containing CL and SE did not vary significantly ($p < 0.05$) as compared to control, whereas, it increased significantly ($p < 0.05$) with the addition of tomato powder. A similar increase in the ash content of cookies after the addition of tomato powder has been reported by Bhat and Ahsan (2015).

Water activity (a_w)

The Water activity of the samples is shown in Fig. 2. The water activity of the freshly prepared cakes, CkC, CkL_{50}, CkL_{100}, CkT_1, CkT_2, CkS_{50} and CkS_{100} was observed as 0.851, 0.845, 0.796, 0.789, 0.781, 0.822 and 0.823, respectively. Maximum value for water activity was found for CkC and the least was observed for CkT_2. The possible reason could be the presence of more solutes in TP as compared to WWF that might have reduced the amount of free water, thereby decreasing the water activity of cakes.

The water activity increased significantly ($p < 0.05$) in all the samples upon storage (0–15 days). Bhise and Kaur (2014) reported that the water activity of bread increased upon storage at ambient temperature (30 ± 1 °C) which is consistent with the results of the present study.

Total phenolic content

The total phenolic content of the freshly prepared cakes containing CL and SE was found to vary non-significantly ($p > 0.05$) from control, except the samples with added TP (Table 4). It was observed in the range of 0.62–0.87 mg GAE/g. Navarro-González et al. (2011) reported the total phenolic content of tomatoes as 1.58 mg GAE/g, higher than that of WWF (0.74 mg GAE/g). This could be the possible reason for the enhanced phenolic content of the cakes containing TP.

Storage period of 0–15 days resulted in a non-significant ($p > 0.05$) decrease in total phenolic content of cakes except control, where the decrease in the said parameter was significant ($p < 0.05$). This might be due to the high antioxidant activity of TP, CL (Stahl and Sies 2003) and SE (Mashmoul et al. 2013), compared to the WWF that might have prevented the degradation of phenolics during storage.

Antioxidant assays

DPPH radical scavenging assay The DPPH radical scavenging activity of freshly prepared cakes is presented in Table 4. It was observed that DPPH radical scavenging activity increased significantly ($p < 0.05$) upon the incorporation of TP, CL and SE and was found in the range of 10.40–21.40%. The cakes containing tomato powder (CkT_2) showed maximum DPPH radical scavenging activity of 0.87 mg GAE/g while the lowest was observed in the case of control (0.62 mg GAE/g). The increase in DPPH radical scavenging activity might be due to the enhanced ability of lycopene and other carotenoids to scavenge free radicals (Stahl and Sies 2003) compared to WWF. SE has been reported to have higher antioxidant activity as compared to WWF which might be a reason for

Table 3 Colour of cakes supplemented with tomato powder, crude lycopene and saffron extract (n = 3)

Crust colour	Storage (Days)	CkC	CkL_{50}	CkL_{100}	CkT_1	CkT_2	CkS_{50}	CkS_{100}
L	0	43.7 ± 0.40^{bp}	43.5 ± 2.32^{bp}	41.2 ± 0.56^{aq}	41.5 ± 0.42^{ap}	42.9 ± 0.65^{bq}	58.9 ± 2.78^{dp}	50.8 ± 0.38^{cp}
	7	45.2 ± 0.16^{cq}	43.2 ± 1.11^{bp}	37.1 ± 0.18^{ap}	42.6 ± 0.22^{bq}	42.1 ± 0.55^{bp}	58.2 ± 0.76^{dp}	55.7 ± 0.19^{dq}
	15	45.7 ± 0.11^{dq}	43.4 ± 0.61^{cp}	36.5 ± 0.21^{ap}	43.0 ± 0.13^{cq}	42.1 ± 0.17^{bp}	58.3 ± 1.67^{fp}	55.8 ± 1.20^{eq}
A	0	7.38 ± 0.03^{cp}	7.78 ± 0.22^{cp}	7.60 ± 0.32^{cp}	7.67 ± 0.08^{cp}	7.89 ± 0.03^{cq}	0.37 ± 0.12^{ap}	3.21 ± 0.13^{bq}
	7	7.23 ± 0.06^{cp}	7.41 ± 0.10^{cp}	7.50 ± 0.29^{cp}	7.65 ± 0.01^{cp}	7.39 ± 0.08^{cp}	1.52 ± 0.21^{aq}	2.44 ± 0.06^{bp}
	15	6.90 ± 0.02^{cp}	7.70 ± 0.06^{dp}	7.00 ± 0.07^{cp}	7.56 ± 0.01^{dp}	7.52 ± 0.06^{dp}	1.31 ± 0.09^{aq}	2.39 ± 0.03^{bp}
B	0	31.8 ± 2.10^{ap}	41.9 ± 1.03^{dp}	49.3 ± 1.32^{fq}	34.1 ± 0.17^{bp}	45.0 ± 0.18^{ep}	37.0 ± 0.12^{cq}	41.6 ± 0.40^{dp}
	7	36.6 ± 1.12^{aq}	43.9 ± 1.21^{bcp}	36.2 ± 0.97^{ap}	35.1 ± 0.36^{ap}	41.6 ± 0.24^{bp}	34.9 ± 0.71^{apq}	46.9 ± 0.21^{cq}
	15	35.9 ± 0.15^{aq}	44.2 ± 0.54^{cp}	35.8 ± 0.76^{ap}	34.8 ± 0.19^{ap}	41.0 ± 1.13^{bp}	34.6 ± 0.65^{ap}	46.9 ± 0.10^{dq}
Crumb colour	*Storage (Days)*							
L	0	70.3 ± 2.30^{dp}	65.5 ± 0.70^{bp}	65.1 ± 0.42^{bp}	67.8 ± 0.89^{cp}	64.8 ± 1.54^{bp}	68.6 ± 1.15^{cp}	62.9 ± 1.89^{ap}
	7	73.2 ± 1.73^{eq}	67.9 ± 0.32^{cq}	67.5 ± 0.11^{cq}	67.8 ± 0.34^{cp}	65.4 ± 1.10^{bp}	70.6 ± 2.92^{dq}	63.1 ± 1.76^{ap}
	15	73.5 ± 1.23^{eq}	67.9 ± 0.09^{cq}	68.1 ± 0.25^{cq}	68.5 ± 0.26^{cp}	65.6 ± 0.98^{bp}	71.1 ± 0.78^{dq}	63.4 ± 1.67^{ap}
A	0	-1.66 ± 0.02^{ap}	-0.52 ± 0.01^{cq}	-0.39 ± 0.01^{cp}	-0.50 ± 0.18^{cp}	0.07 ± 0.01^{dq}	-2.15 ± 0.12^{bp}	-3.87 ± 0.23^{ap}
	7	-1.14 ± 0.10^{aq}	-0.57 ± 0.06^{cpq}	-0.38 ± 0.01^{cp}	-0.50 ± 0.02^{cp}	0.07 ± 0.00^{dq}	-2.50 ± 0.04^{bp}	-3.37 ± 0.15^{aq}
	15	-1.97 ± 0.01^{bq}	-0.63 ± 0.02^{dp}	-0.42 ± 0.04^{dp}	-0.59 ± 0.09^{dp}	0.06 ± 0.02^{ep}	-2.60 ± 0.11^{cp}	-3.51 ± 0.20^{aq}
B	0	28.1 ± 0.23^{aq}	38.9 ± 1.33^{cq}	32.9 ± 0.12^{bq}	31.6 ± 0.16^{bp}	31.9 ± 0.38^{bp}	32.1 ± 0.44^{bq}	48.1 ± 1.34^{dq}
	7	27.7 ± 0.08^{apq}	36.7 ± 1.10^{cp}	32.0 ± 1.21^{bp}	31.6 ± 0.56^{bp}	42.2 ± 0.43^{dq}	30.8 ± 0.09^{bp}	47.8 ± 1.09^{epq}
	15	26.8 ± 0.64^{ap}	36.5 ± 0.87^{cp}	31.5 ± 1.00^{bp}	31.5 ± 0.66^{bp}	41.4 ± 0.18^{dq}	30.3 ± 0.37^{bp}	47.6 ± 1.69^{ep}

Results are expressed as means (n = 3) ± standard deviation

Values followed by same letter in a row & in the column do not differ significantly ($p < 0.05$). The letters 'a, b, c, d…' denote difference within a row and 'p, q, r, s…' within a column

CkC: Cakes without any supplement; CkL_{50}: Cakes with added crude lycopene (50 mg/100 g of flour); CkL_{100}: Cakes with added crude lycopene (100 mg/100 g of flour); CkT_1: Cakes with added tomato powder (2 g/100 g); CkT_2: Cakes with added tomato powder (4 g/100 g); CkS_{50}: Cakes with added SE of 50 mg/100 g of flour; CkS_{100}: Cakes with added SE of 100 mg/100 g of flour

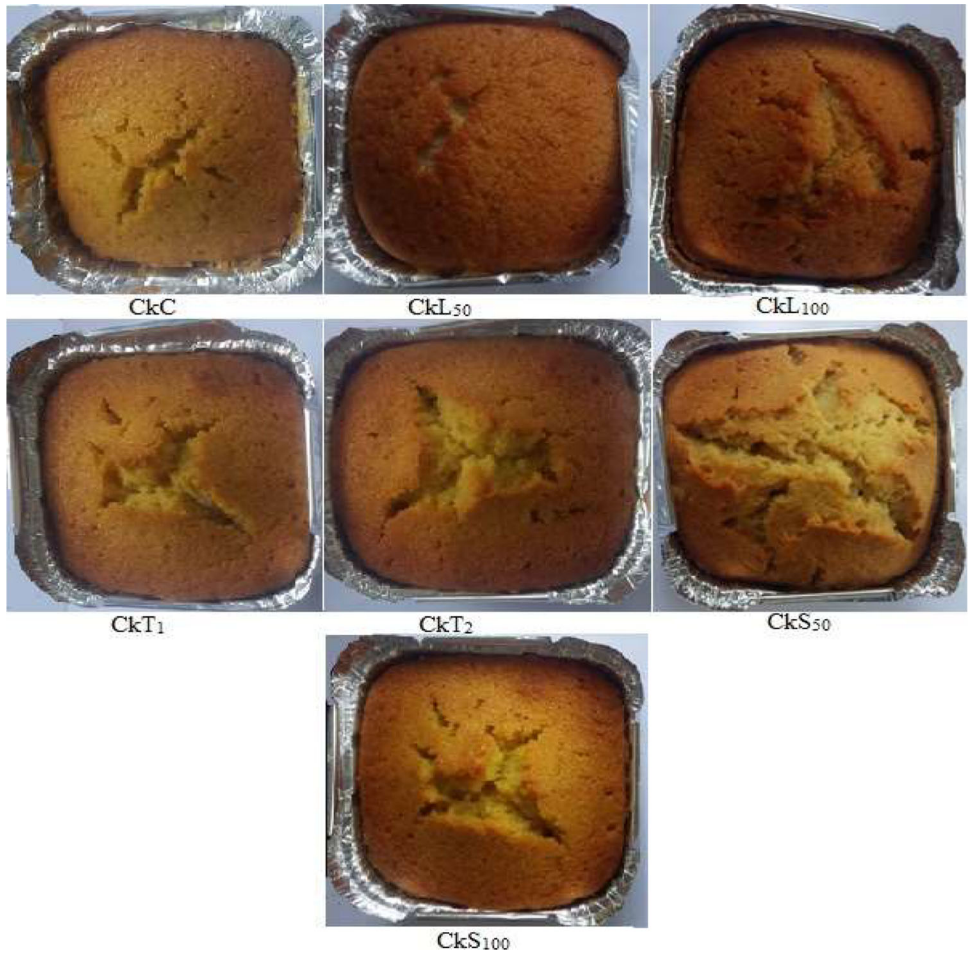

Fig. 1 Images of cakes supplemented with crude lycopene, tomato powder and saffron extract. CkC: Cakes without any supplement; CkL_{50}: Cakes with added crude lycopene (50 mg/100 g of flour); CkL_{100}: Cakes with added crude lycopene (100 mg/100 g of flour); CkT_1: Cakes with added tomato powder (2 g/100 g); CkT_2: Cakes with added tomato powder (4 g/100 g); CkS_{50}: Cakes with added SE of 50 mg/100 g of flour; CkS_{100}: Cakes with added SE of 100 mg/100 g of flour

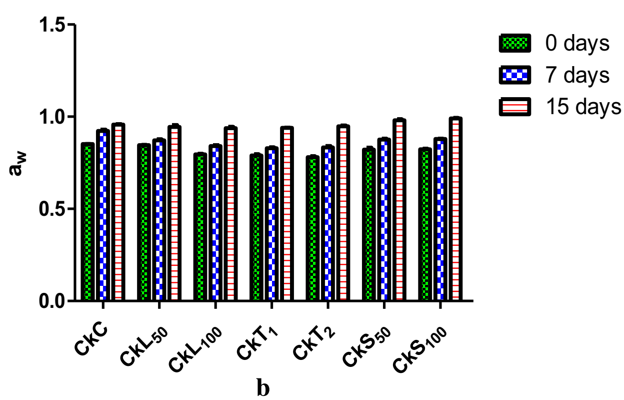

Fig. 2 Water activity of cakes enriched with tomato powder, crude lycopene and saffron extracts (n = 3). CkC: Cakes without any supplement; CkL_{50}: Cakes with added crude lycopene (50 mg/100 g of flour); CkL_{100}: Cakes with added crude lycopene (100 mg/100 g of flour); CkT_1: Cakes with added tomato powder (2 g/100 g); CkT_2: Cakes with added tomato powder (4 g/100 g); CkS_{50}: Cakes with added SE of 50 mg/100 g of flour; CkS_{100}: Cakes with added SE of 100 mg/100 g of flour

the enhanced antioxidant activity of cakes containing SE (Bhat et al. 2018).

The DPPH radical scavenging activity of all the cake samples was observed to decrease non-significantly ($p > 0.05$) upon storage of 0–15 days. However, it remained high in enriched cakes as compared to the control. This predicts the higher antioxidant capacity of TP, CL and SE than the WWF.

Reducing power The reducing power of a compound is based on its capacity to donate electrons and thus break the free radical chain reaction, thereby preventing peroxide formation (Kaur et al. 2017). The reducing power of control and enriched cake samples is presented in Table 4. Addition of TP, CL and SE significantly ($p < 0.05$) increased the reducing power of freshly prepared cakes and was observed in the range of 0.49–0.79 mg AAE/g. The increase in reducing power of enriched cakes may be due to the higher antioxidant ability of TP (Kim and Chin 2016) and saffron (Baba et al. 2015) as compared to the WWF.

In general, the reducing power of samples i.e. CkC, CkL_{50}, CkL_{100}, CkS_{50} and CkS_{100}, was significantly

Table 4 Total phenolic content and antioxidant properties of cakes supplemented with tomato powder, crude lycopene and saffron extracts (n = 3)

	Total phenolic content (mg GAE/g)			DPPH scavenging assay (%)			Reducing power (mg AAE/g)			Lipid peroxidation (% inhibition)		
	Storage (Days)			Storage (Days)			Storage (Days)			Storage (Days)		
	0	7	15	0	7	15	0	7	15	0	7	15
CkC	0.62 ± 0.10^{bp}	0.61 ± 0.02^{bp}	0.52 ± 0.00^{ap}	10.4 ± 1.14^{ap}	10.4 ± 0.04^{ap}	10.3 ± 0.05^{ap}	0.49 ± 0.00^{cp}	0.38 ± 0.07^{bp}	0.28 ± 0.02^{ap}	14.7 ± 0.14^{ap}	14.2 ± 0.12^{ap}	14.0 ± 0.01^{ap}
CkL_{50}	0.66 ± 0.01^{apq}	0.64 ± 0.01^{apq}	0.63 ± 0.01^{aq}	16.7 ± 1.2^{aqr}	16.7 ± 0.05^{ar}	16.7 ± 0.04^{ar}	0.71 ± 0.03^{brs}	0.66 ± 0.04^{br}	0.54 ± 0.01^{as}	21.3 ± 0.22^{ars}	21.0 ± 0.21^{at}	20.9 ± 0.13^{at}
CkL_{100}	0.69 ± 0.03^{bpqr}	0.68 ± 0.03^{abqr}	0.66 ± 0.02^{ar}	18.5 ± 0.40^{ar}	18.4 ± 0.12^{at}	18.3 ± 0.03^{at}	0.77 ± 0.04^{bs}	0.73 ± 0.04^{bs}	0.68 ± 0.08^{at}	24.5 ± 1.30^{as}	24.0 ± 0.33^{av}	23.6 ± 0.07^{av}
CkT_1	0.85 ± 0.02^{ar}	0.83 ± 0.01^{at}	0.83 ± 0.05^{at}	18.6 ± 0.77^{ar}	18.5 ± 0.15^{at}	18.4 ± 0.11^{at}	0.58 ± 0.01^{aqs}	0.56 ± 0.06^{aq}	0.47 ± 0.02^{ar}	17.0 ± 2.10^{apq}	16.7 ± 0.10^{aq}	16.3 ± 0.09^{aq}
CkT_2	0.87 ± 0.01^{ar}	0.86 ± 0.12^{at}	0.85 ± 0.06^{at}	21.3 ± 0.61^{as}	21.4 ± 0.13^{au}	21.3 ± 0.07^{au}	0.79 ± 0.05^{as}	0.78 ± 0.01^{as}	0.73 ± 0.06^{at}	22.8 ± 1.11^{ars}	22.4 ± 0.08^{au}	22.1 ± 0.14^{au}
CkS_{50}	0.73 ± 0.01^{bpqr}	0.69 ± 0.11^{abr}	0.66 ± 0.01^{ar}	16.1 ± 1.04^{aq}	15.9 ± 0.06^{aq}	15.8 ± 0.01^{aq}	0.64 ± 0.08^{bqr}	0.59 ± 0.07^{bq}	0.42 ± 0.10^{aq}	19.1 ± 0.09^{aqr}	18.9 ± 0.11^{ar}	18.7 ± 0.15^{ar}
CkS_{100}	0.74 ± 0.04^{apqr}	0.75 ± 0.03^{as}	0.73 ± 0.10^{as}	17.9 ± 1.56^{aqr}	17.8 ± 0.13^{as}	17.6 ± 0.02^{as}	0.73 ± 0.02^{cs}	0.68 ± 0.12^{br}	0.56 ± 0.21^{as}	19.6 ± 0.07^{aqr}	19.3 ± 0.05^{as}	19.2 ± 0.13^{as}

Results are expressed as means (n = 3) ± standard deviation

Values followed by same letter in a row & the column do not differ significantly ($p < 0.05$). The letters 'a, b, c, d…' denote difference within a row and 'p, q, r, s…' within a column

CkC: Cakes without any supplement; CkL_{50}: Cakes with added crude lycopene (50 mg/100 g of flour); CkL_{100}: Cakes with added crude lycopene (100 mg/100 g of flour); CkT_1: Cakes with added tomato powder (2 g/100 g); CkT_2: Cakes with added tomato powder (4 g/100 g); CkS_{50}: Cakes with added SE of 50 mg/100 g of flour; CkS_{100}: Cakes with added SE of 100 mg/100 g of flour

($p < 0.05$) reduced from 0.49–0.38, 0.71–0.54, 0.77–0.68, 0.64–0.42 and 0.73–0.56 mg AAE/g respectively, with storage (0–15 days) except CkT_1 & CkT_2, where the reduction was non-significant ($p > 0.05$). The increase in water activity upon storage (Fig. 2) may result in dilution of antioxidants which might be a reason for decreased reducing power of all the cake samples.

Lipid peroxidation Inhibition of lipid peroxidation (ILP) by cake samples increased significantly ($p < 0.05$) from 14.5 to 24.05% with the addition of TP, CL and SE (Table 4). The highest ILP was found in cakes containing lycopene (CkL_{100}) and the lowest in the case of control (CkC). TP, CL and SE due to their higher antioxidant activity than WWF might have more ability to prevent the oxidation of lipids (Alshatwia et al. 2010).

Storage period of 0–15 days resulted in a non-significant ($p > 0.05$) decrease in ILP. However, it remained high in cakes containing tomato powder, lycopene and saffron extracts when compared to the control. The decrease in the ILP values of cakes could be due to an increase in the oxidation of lipids upon storage (Butt et al. 2004).

Total carotenoids content (TCC)

TCC of the batter samples was found in the range of 0.98–7.97 μg/g. Baking resulted in a non-significant ($p > 0.05$) reduction in carotenoid content from 0.98 to 0.87, 6.62 to 6.14, 7.97 to 7.83, 4.34 to 4.08 and 7.00 to 6.87 μg/g for BC, BL_{50}, BL_{100}, BT_1 and BT_2, respectively. However, it increased significantly ($p < 0.05$) in freshly prepared cake samples after the addition of TP and CL as compared to control (Fig. 3). The highest TCC was found

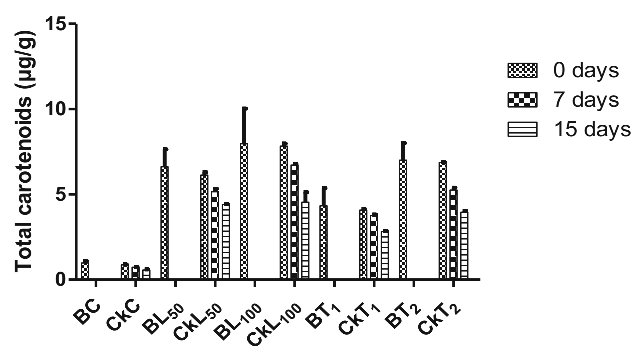

Fig. 3 Total carotenoid content of batter and cakes supplemented with tomato powder and crude lycopene (n = 3). BC: Batter without any supplement; CkC: Control cakes without any supplement; BL_{50}: Batter with added crude lycopene (50 mg/100 g of flour); BL_{100}: Batter with added crude lycopene (100 mg/100 g of flour); CkL_{50}: Cakes prepared from BL_{50}; CkL_{100}: Cakes prepared from BL_{100}; BT_1: Batter with added tomato powder (2 g/100 g); BT_2: Batter with added tomato powder (4 g/100 g); CkT_1: Cakes made from BT_1; CkT_2: Cakes made from BT_2

Table 5 Sensory properties of cakes supplemented with tomato powder, crude lycopene and saffron extracts (n = 3)

Storage (Months)	CkC	CkL_{50}	CkL_{100}	CkT_1	CkT_2	CkS_{50}	CkS_{100}
Appearance							
0	8.25 ± 0.41^{aq}	9.00 ± 0.21^{cq}	8.50 ± 0.43^{bq}	9.00 ± 0.11^{cp}	8.60 ± 0.63^{bs}	9.01 ± 1.0^{cp}	9.32 ± 0.23^{dp}
7	8.34 ± 0.31^{fr}	8.81 ± 0.63^{cpq}	8.27 ± 0.21^{ap}	8.85 ± 0.19^{cdq}	8.41 ± 0.10^{br}	8.89 ± 0.23^{dp}	9.21 ± 0.03^{eq}
15	8.10 ± 0.12^{ap}	8.62 ± 0.15^{dp}	8.22 ± 0.31^{bp}	8.52 ± 0.10^{cq}	8.20 ± 0.56^{bq}	8.92 ± 0.42^{eq}	9.00 ± 0.11^{fq}
Texture							
0	7.75 ± 0.78^{ar}	9.75 ± 0.32^{gr}	8.00 ± 0.42^{bp}	8.50 ± 0.87^{er}	8.80 ± 0.54^{fr}	8.23 ± 0.21^{cr}	8.34 ± 0.54^{dr}
7	7.10 ± 0.31^{abq}	7.36 ± 0.23^{abcq}	6.84 ± 0.23^{abcp}	7.82 ± 0.13^{bcp}	6.71 ± 0.30^{aq}	8.10 ± 0.33^{cq}	8.00 ± 0.22^{cq}
15	6.00 ± 0.56^{ap}	6.50 ± 0.67^{cp}	6.80 ± 0.31^{dp}	6.79 ± 0.12^{dq}	6.36 ± 0.31^{bp}	8.02 ± 0.11^{fp}	7.69 ± 0.35^{ep}
Flavour							
0	8.68 ± 0.02^{fr}	8.25 ± 0.41^{dr}	8.50 ± 0.12^{er}	8.75 ± 0.30^{gr}	7.01 ± 0.55^{br}	8.12 ± 0.33^{cq}	7.09 ± 0.32^{aq}
7	7.66 ± 0.19^{ep}	7.25 ± 0.31^{dq}	7.25 ± 0.51^{dp}	6.71 ± 0.66^{bq}	6.78 ± 0.72^{aq}	8.13 ± 0.20^{fq}	7.00 ± 0.07^{cq}
15	7.77 ± 0.81^{fq}	7.15 ± 0.32^{dp}	7.66 ± 0.45^{eq}	6.00 ± 0.44^{bp}	5.99 ± 0.49^{ap}	7.88 ± 0.12^{gp}	6.53 ± 0.81^{cp}
Aftertaste							
0	8.50 ± 1.01^{er}	8.41 ± 0.22^{dq}	8.00 ± 0.27^{cp}	7.56 ± 0.60^{bq}	6.50 ± 0.15^{ar}	8.01 ± 0.22^{cq}	6.56 ± 0.45^{ar}
7	8.30 ± 0.32^{fq}	8.75 ± 0.75^{br}	8.51 ± 0.66^{eq}	7.18 ± 0.33^{dp}	6.03 ± 0.83^{aq}	8.12 ± 0.10^{gr}	6.00 ± 0.22^{cq}
15	8.21 ± 0.33^{cp}	7.80 ± 0.46^{dp}	8.55 ± 0.72^{eq}	7.11 ± 0.10^{bp}	5.01 ± 0.77^{ap}	7.80 ± 0.40^{fp}	5.43 ± 0.35^{bp}
Overall acceptability							
0	8.29 ± 0.11^{cr}	8.85 ± 0.43^{fr}	8.25 ± 0.19^{cr}	8.45 ± 0.34^{er}	7.98 ± 0.18^{br}	8.34 ± 0.45^{dq}	7.83 ± 0.26^{ar}
7	7.85 ± 0.68^{fq}	7.04 ± 0.45^{bp}	7.72 ± 0.31^{ep}	7.64 ± 0.10^{dq}	6.73 ± 0.23^{aq}	8.31 ± 0.21^{gq}	7.55 ± 0.10^{cq}
15	7.52 ± 0.23^{cp}	7.62 ± 0.15^{dq}	7.81 ± 0.78^{eq}	7.12 ± 0.21^{bp}	6.14 ± 0.43^{ap}	8.16 ± 0.34^{fp}	7.16 ± 0.36^{bp}

Results are expressed as means (n = 3) ± standard deviation. Values followed by same letter in a row do not differ significantly ($p < 0.05$)

Values followed by same letter in a row & in the column do not differ significantly ($p < 0.05$). The letters 'a, b, c, d…' denote difference within a row and 'p, q, r, s…' within a column

CkC: Cakes without any supplement; CkL_{50}: Cakes with added crude lycopene (50 mg/100 g of flour); CkL_{100}: Cakes with added crude lycopene (100 mg/100 g of flour); CkT_1: Cakes with added tomato powder (2 g/100 g); CkT_2: Cakes with added tomato powder (4 g/100 g); CkS_{50}: Cakes with added SE of 50 mg/100 g of flour; CkS_{100}: Cakes with added SE of 100 mg/100 g of flour

in CkL_{100} (7.83 µg/g) while as, the lowest was observed in the control (0.87 µg/g). This is due to the higher TCC of crude lycopene (4619.98 µg/g) than the WWF (1.136 µg/g).

TCC of all the cake samples reduced significantly ($p < 0.05$) upon storage (0–15 days). The possible reason for the reduction in carotenoid content could be the degradation of carotenoids with storage. It has been reported by Mellado-Ortega and Hornero-Méndez (2016) that the total TCC of WWF decreased upon storage, which is consistent with the results of the present study.

Quantification of saffron metabolites, crocin, safranal and picrocrocin

Saffron metabolites crocin, safranal and picrocrocin were found in the range of 20.14–29.54 µg/g, 41.34–53.13 µg/g and 87.67–98.56, respectively for BS_{50} and BS_{100} batter samples (Supplementary Table 1). The saffron metabolite concentration of all the samples was observed to decrease significantly ($p < 0.05$) upon baking. The degradation of saffron metabolites has been reported to be temperature-dependent which might be a reason of their decreased concentration upon baking (Tsimidou 1997). In freshly prepared cakes the content of crocin, safranal and picrocrocin was observed in the range of 6.32–9.78 µg/g, 15.84–26.11 µg/g and 45.09–64.14 µg/g, respectively for CkS_{50} and CSk_{100}.

Storage time of 0–15 days resulted in a significant ($p < 0.05$) decrease in the concentration of crocins, safranal and picrocrocin from 6.32 to 5.10, 15.84 to 15.07 and 45.09 to 44.31 µg/g respectively, in CkS_{50} and from 9.78 to 8.22, 26.11 to 25.93 and 64.14 to 64.05 µg/g, respectively in CkS_{100}. The increase in water activity of the cake samples (Fig. 1) might have enhanced the deterioration of saffron metabolites during storage (Raina et al. 1996).

Sensory analysis

Sensory parameters of cakes evaluated include appearance, texture, flavor, aftertaste and overall acceptability. The appearance and texture of the freshly prepared cakes enriched with TP, CL and SE were given maximum scores by the panelists as compared to control (Table 5). The flavor and aftertaste of the composite cakes were comparable with that of control. However, the cakes containing an increased amount of TP (CkT_2) and SE (CSk_{100}) were rated low for flavor and aftertaste as compared to the control. In general, the sensory characteristics of enriched cakes were desirable, indicating that TP, CL and SE can be utilized to develop products with improved antioxidant properties, without compromising the sensory quality of the product.

Although the storage time of 0–15 days significantly ($p < 0.05$) reduced the sensory scores of all cakes, the appearance of the cakes was still 'liked very much' by the panelists as per the 9-point hedonic scale. However, the aftertaste and flavor of CkT_2 and CSk_{100} cakes were rated as 'dislike slightly' on the 9-point hedonic scale after the end of storage period (15 days). The overall acceptability of the cakes was good after the storage period of 15 days. Thus, the cakes could be easily stored for 15 days without any adverse changes in their organoleptic properties.

Conclusion

It can be concluded from the study that the addition of TP, CL and SE significantly affected the physicochemical properties of cakes. Cakes enriched with TP had increased loaf weight while as, their loaf volume was reduced. Enriched cakes had increased antioxidant properties, total carotenoid content and the ability to inhibit lipid peroxidation. The cakes showed excellent sensory properties comparable to that of control. In general, the overall quality of the cakes was improved to a great extent. Thus, health-promoting cakes can be prepared by adding fruits, vegetables and spices either in the form of extract or powder that are a rich source of bioactive compounds, without adversely affecting their sensory properties.

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Declarations

Conflict of interest The author declare that the work described has not been published before (except in the form of an abstract, a published lecture or academic thesis). It is not under consideration for publication elsewhere. Its submission to JFST publication has been approved by all authors as well as the responsible authorities–tacitly or explicitly–at the institute where the work has been carried out. If accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright holder, and JFST will not be held legally responsible should there be any claims for compensation or dispute on authorship.

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