Quality and antioxidant properties of yellow layer cake containing Korean turmeric (*Curcuma longa* L.) powder

HO SOO LIM – KASHIF GHAFOOR – SO HEE PARK – SUNG YEON HWANG – JIYONG PARK

Summary

Turmeric (*Curcuma longa* L.) is a widely used food ingredient containing curcuminoids, which are important biologically active compounds. The antioxidant and anti-inflammatory properties of turmeric are well documented. We used turmeric powder in yellow layer cakes to study its effects on physico-chemical, sensory and overall product qualities. The viscosity of cake batter, cake volume, crumb color *a* and *b* values, crude fibre, curcuminoids content and total phenolic contents of baked yellow layer cakes increased with the addition of turmeric powder. The specific gravity in cake batter, crumb color *L* value, density, water activity and hardness of cakes decreased with the addition of turmeric powder. No significant differences were found among all the sensory parameters of control cakes and those with up to 6% turmeric substitution. However, cake that contained 8% turmeric was rated comparatively lower in crumb color, sweetness, flavour and overall acceptability. Turmeric yellow layer cakes showed good antioxidant activity, ferric (Fe^{3+}) ion reducing power, scavenging ability for 1,1-diphenyl-2-picrylhydrazyl (DPPH) radicals and chelating ability on ferrous (Fe^{2+}) ions. These results suggest that yellow layer cake can be developed as functional food with the addition of turmeric powder, which imparts improved physico-chemical and higher antioxidant properties to these cakes.

Keywords

yellow layer cake; turmeric powder; curcuminoid; total phenols; antioxidant; sensory analysis

Bakery products are consumed all over the world. Fat is an important ingredient in bakery products and its major functions are to tenderize the product and soften the texture, add moistness and richness, prolong shelf-life, add flavour and assist in leavening when used as creaming agents or when used to give flakiness to puff pastry, pie, dough and similar products [1]. However, fat has a disadvantage of getting oxidized rapidly upon exposure to air, moisture and sunlight, giving rise to an unacceptable flavour. Antioxidants are used as food additives in order to prevent the oxidative deterioration of fats and oils in processed food products. Since some of synthetic antioxidants might be toxic, mutagenic and/or carcinogenic, and some natural antioxidants were found to be effective in enhancing the shelf-life of bakery products, though less effective than synthetic antioxidants, there is a great demand for new natural antioxidants for use in foods, in particular in bakery products [2]. The demand for natural antioxidants such as β-carotene, α-tocopherol, ascorbic acid, phenols or terpenoids is increasing especially for health foods. Antioxidants impart to food components protection against oxidation. The level of antioxidant is critical in preserving fat-containing foods in particular in bakery products to minimize the development of objectionable odours and flavours due to rancidity, and to prevent or reduce the formation of decomposed products that may be toxic [3]. The development of rancidity involves degradation of vitamins (A, C, D, E and folate), essential fatty acids (linoleic acid) and essential amino acids (methionine, cystine, histidine, lysine and tryptophan) resulting in the loss of nutritional value, which can be prevented by the use of antioxidants[4]. Hence, natural antioxidants can play an important role in enhancing the shelf-life and preserving the nutritional and organoleptic qualities of bakery products.

Ho Soo Lim, Jiyong Park, Department of Biotechnology, Yonsei University, 134 Sinchon-dong, Seodaemun-gu, Seoul 120-749, Republic of Korea.
Kashif Ghafoor, Department of Food and Nutrition Sciences, King Saud University, Riyadh 11451, Kingdom of Saudi Arabia.
So Hee Park, Food Research Center, Han Sung Co., 222-69 Nae-dong, Ojeung-gu, Bucheon, Gyeonggi-do 421-160, Republic of Korea.
Sung Yeon Hwang, Department of Food Biotechnology, Hankyong National University, 67 Seokjung-dong, Anseong, Gyeonggi-do 456-749, Republic of Korea.

Correspondence author:
Jiyong Park, e-mail: foodpro@yonsei.ac.kr, tel.: +82-2-21232888, fax: +82-2-3627265

Studies have been carried out to find potential sources of natural additives in bakery products. VERGARA-VALENCIA et al. [5] characterized mango dietary fibre (MDF) with antioxidant capacity, using the unripe fruit. Cookies and bread with added MDF showed higher total dietary fibre than respective controls and these products also maintained a significant antioxidant capacity associated with their extractable polyphenol content. LIN et al. [6] found that buckwheat could be incorporated into wheat bread to get better functional composition and improved antioxidant properties of bread. In another study, apple fibre and cellulose were added to wheat flour to improve its physical and functional characteristics [7]. Turmeric colorant is also documented as a viable alternative for tartrazine in extruded products [8].

Turmeric (*Curcuma longa* L.) is one of the most popular spices and natural colorants in the world and its consumption is increasing recently. The powdered rhizome of turmeric has been widely used as a colouring agent and spice in many food items. It is considered as a traditional remedy for centuries in several Asian countries [9]. Turmeric may contain volatile (essential) and non-volatile oils, proteins, lipids, minerals and saccharides. The aromatic properties of turmeric are thought to be attributable to its volatile oils, its colouring characteristics may be largely due to its non-volatile oils, particularly the curcuminoids [10]. Three major colouring substances, as components of non-volatile oil from turmeric, are curcumin, demethoxycurcumin and bis-demethoxycurcumin [11]. Turmeric bioactives are extensively reported to have high antioxidant activities, such as 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical-scavenging and metal-chelating properties [12]. Recently, some new curcuminoids have been isolated and identified from turmeric, such as cyclocurcumin or curcumin IV [13]. Turmeric is reported to possess anti-oxidative, anti-inflammatory and anti-carcinogenic properties [14]. Curcuminoids in turmeric extracts were shown to have anti-arthritic effects and similar activities of essential oils from turmeric have been recently reported in rats [15]. This plant is therefore potentially a good source of natural antioxidants for functional foods.

The objectives of this research were to prepare yellow layer cakes by incorporation of turmeric powder, and to evaluate its influence as a natural additive on physico-chemical, sensory and antioxidant properties of these cakes.

Tab. 1. Formulation of yellow layer cakes prepared with turmeric powder replacement for cake flour.

Ingredients [g]	Control	T2	T4	T6	T8
Cake flour	494	484.2	474.3	464.4	454.5
Turmeric powder	0	9.8	19.7	29.6	39.5
Saccharose	518	518	518	518	518
Whole egg	822	822	822	822	822
Butter	78	78	78	78	78
Emulsifier	39	39	39	39	39
Salt	7	7	7	7	7
Baking powder	12	12	12	12	12
Distilled Water	73	73	73	73	73

Control, T2, T4, T6 and T8, prepared with 0%, 2%, 4%, 6%, and 8% replacement of cake flour with turmeric powder, respectively.

MATERIALS AND METHODS

Materials

Korean turmeric rhizomes were harvested in fall from Jindo, Chonnam, South Korea. They were washed, cleaned, cut into small pieces, dried using forced air drying oven at 40 °C for 2 days, ground to a powder form using blender (KMF-360, Daewoo, Seoul, South Korea) and passed through a 150 μm sieve. The final moisture percentage of dried turmeric powder was 14.8 ± 0.12 (w/w). Wheat flour containing 9.7% protein and saccharose were purchased from Cheiljedang (Incheon, South Korea). Emulsifier, butter and baking powder were purchased from Seoul Dairy (Seoul, South Korea). Salt and fresh eggs were purchased from the local market. Gallic acid, Folin-Ciocalteu reagent and curcumin standards were obtained from Sigma-Aldrich (St. Louis, Missouri, USA). All other chemicals were of analytical grade and were purchased from Merck (Darmstadt, Germany).

Cake making

Five formulations of yellow layer cakes, containing different levels of turmeric powder, are shown in Tab. 1. A single-bowl mixing procedure was used to mix all the ingredients using a professional mixer (K5SS; KitchenAid, St. Joseph, Michigan, USA) at speed 6 for 12 min. Approximately 400 g of cake batter was poured into a cake pan (20.3 cm in diameter and 7 cm high) and baked at 195 °C for 30 min in a pre-heated baking oven. Baked cakes were allowed to cool down for 2 h, removed from pans and packed in polypropylene bags for physico-chemical and sensory analysis. The yellow layer cake samples were prepared randomly using 0%, 2%, 4%, 6% and 8% turmeric

powder, as replacement of cake flour, and were designated as control, T2, T4, T6 and T8, respectively.

Proximate analysis

The moisture, crude protein, crude fat, ash and total dietary fibre contents of flour, turmeric powder and cakes were determined according to approved methods [16]. The nitrogen conversion factor used for crude protein calculation was 6.25. The saccharide content (%) of cake was calculated by subtracting crude protein, fat, ash and moisture contents (%) from 100. Approximate contents of cake and turmeric powder were expressed on a wet basis and dry basis, respectively.

Determination of physical characteristics

In order to measure viscosity, 500 ml of cake batter was immediately after mixing poured into a 600 ml beaker and viscosity was measured at a spindle speed of 45 × *g* using rotational viscometer (RVDR-1; Brookfield Engineering Labs, Middleboro, Indiana, USA). The specific gravity of each type of cake batter was determined by an approved method [16]. Cake volume was measured using rapeseed displacement method. Cake density was also calculated and expressed as $g \cdot cm^{-3}$. Water activity of the cake was measured using a water activity meter (BT-RS1; Rotronic Instrument, Bassersdorf, Switzerland).

The texture profile analysis (TPA) of samples (3 × 3 × 3 cm) taken from the midsection of cakes, with no crust, was carried out using a texture analyser (Compac-100; Sun Scientific, Tokyo, Japan). A 35 mm diameter aluminium cylinder probe was used to measure the required compression force. The optimal test conditions were 30–60% deformation, 0.1–2 $mm \cdot s^{-1}$ cross-head speed and variance coefficient of plunger compressing a sample to 50% of its original height at a speed of 0.8 $mm \cdot s^{-1}$. The texture parameters recorded were hardness, cohesiveness and springiness.

Colour determinations of crumb samples (3 × 3 × 3 cm), taken from the cake midsection, were carried out using Color-Eye 7000 spectrophotometer (Gretag-Macbeth, Richmond, Virginia, USA). In this method, colour of a sample is denoted by dimensions *L*, *a* and *b*. The *L* value gives a measure of the lightness of the product colour, 100 being for perfect white and zero for black. The redness/greenness and yellowness/blueness are denoted by *a* and *b* values, respectively.

Determination of curcuminoid contents

Samples for HPLC analysis were prepared by mixing 1 g powdered cake in 40 ml ethanol using a vortex mixer. This was followed by extraction at 50 °C in an ultrasonic water bath for 3 h. A volume of 2 ml of the filtered extracted solution was diluted with 8 ml distilled water and passed through a Sep-Pak C-18 cartridge (Waters, Milford, Massachusetts, USA). The cartridge was washed with 10 ml distilled water and turmeric dye from the cartridge was eluted using 20 ml ethanol. The collected solution was concentrated under vacuum at 40 °C and filtered through a 0.45 μm Nylon-66 filter disk. Standard solution was prepared by dissolving 0.05 g of curcumin in 100 ml ethanol and it was further diluted with ethanol to give a final concentration of 0.1 $mg \cdot ml^{-1}$. This solution was also filtered through a 0.45 μm Nylon-66 filter disk prior to HPLC analysis.

A modified method [17] was used to quantify curcumionoids (curcumin, demethoxycurcumin and bis-demethoxycurcumin) levels of yellow layer cake. An Agilent Series 1100 HPLC instrument (Agilent Technologies, Santa Clara, California, USA) equipped with a photodiode array detector, a quaternary pump and a manual sample injector was used. A C-18 column (5 μm C18, 250 × 4.6 mm I.D.) from Supelco (Bellefonte, Pennsylvania, USA) was used for separation. The mobile phase for elution consisted of acetonitrile-water-acetic acid (50 : 49 : 1 v/v/v). A volume of 20 μl of the sample or standard solutions was injected into HPLC and the flow rate was 1 $ml \cdot min^{-1}$. The isocratic elution was monitored at a wavelength of 425 nm for 25 min. The determination of curcumin, demethoxycurcumin and bis-demethoxycurcumin content involved calculations using concentrations of the standard and the samples, the purity of commercial curcumin and peak areas of curcumin, demethoxycurcumin and bis-demethoxycurcumin. The concentrations were expressed as $mg \cdot kg^{-1}$.

Determination of total phenolic contents

Total phenolics were determined using the Folin-Ciocalteu method [18]. An amount of 1 g powdered cake sample was homogenized in 80% ethanol at room temperature, centrifuged at 10 000 × *g* for 15 min and the supernatant was saved. The residue was extracted two times again with 80% ethanol and supernatants were pooled. Extract was evaporated at room temperature until dry. Residue was dissolved in 5 ml distilled water. A volume of 100 μl of this extract was diluted to 3 ml using distilled water and mixed with 0.5 ml Folin-Ciocalteu reagent. After 3 min, 2 ml of 20% sodium carbonate was added, followed by thorough mixing. Solutions were heated in a 40 °C water bath for 30 min. Absorbance was measured at 765 nm using spectrophotometer (Optima

2000DV; Perkin Elmer, Waltham, Massachusetts, USA). Gallic acid was used as a standard and results were expressed as milligram of gallic acid equivalent per gram.

Determination of antioxidant properties

Preparation of ethanol extracts

Cakes were freeze-dried, ground in a mill and screened through a 0.5 mm sieve. An amount of 10 g of cake powder was extracted with 100 ml ethanol at 25 °C for 24 h along with stirring followed by filtration using Whatman No. 1 filter paper. The residues were re-extracted twice as described above. The combined ethanolic extracts were evaporated at 40 °C under vacuum until dry. The yields of extracts were expressed as percentages of dry matter.

Antioxidant activity

The antioxidant activity was determined by the conjugated diene method [19]. Each extract (0.5–20 mg·ml^{-1}) in ethanol (100 μl) was mixed in test tubes with 2 ml 10 mmol·l^{-1} linoleic acid (emulsion in 0.2 mol·l^{-1} sodium phosphate buffer, pH 6.6) and placed to darkness at 37 °C in order to accelerate oxidation. After incubation for 15 h, 100 μl samples from each tube were mixed with 7 ml 80% methanol and absorbance (A) was recorded at 234 nm against a blank. The control solution consisted of ethanol and reagent solution without ethanolic extracts and prepared by following the same procedure as described above. The antioxidant activity (AA) was calculated as follows:

$$AA\ [\%] = \frac{(\Delta A_{234\ \text{control}} - \Delta A_{234\ \text{sample}})}{\Delta A_{234\ \text{control}}} \times 100 \quad (1)$$

A value of 100% indicates the strongest antioxidant activity. EC_{50} value (mg·ml^{-1}) was considered as the effective concentration at which the antioxidant activity was 50% and it was obtained by interpolation using linear regression analysis.

Ferric (Fe^{3+}) ions reducing power

The ferric ion reducing power was determined according to the method described by Oyaizu [20]. Each extract (0.5–20 mg·ml^{-1}) in ethanol (2.5 ml) was mixed with 2.5 ml 200 mmol·l^{-1} sodium phosphate buffer (pH 6.6) and 2.5 ml 1% potassium ferricyanide. The mixture was incubated at 50 °C for 20 min. Afterwards, 2.5 ml 10% trichloroacetic acid was added to the mixture and centrifuged at 200 × g for 10 min. A volume of 5 ml of the supernatant was mixed with 5 ml deionized water along with 1 ml of 0.1% ferric chloride and absorbance was recorded at 700 nm against a blank. A higher absorbance indicated a higher Fe^{3+} reducing power. EC_{50} value (mg·ml^{-1}) was also calculated. It was regarded as the effective concentration at which the absorbance was 0.5 for Fe^{3+} reducing power.

Scavenging ability for DPPH radicals

Each extract (0.5–20 mg·ml^{-1}) in ethanol (4 ml) was mixed with 1 ml of methanolic solution containing DPPH radicals, resulting in a final concentration of 0.2 mmol·l^{-1} DPPH. Following vigorous shaking, the mixture was left for 30 min in the dark and absorbance (A) was recorded at 517 nm against a blank [21]. The control consisting of ethanol and reagent solution without ethanolic extracts was prepared as described before. The scavenging ability (SA) was calculated as follows:

$$SA\ [\%] = \frac{(\Delta A_{517\ \text{control}} - \Delta A_{517\ \text{sample}})}{\Delta A_{517\ \text{control}}} \times 100 \quad (2)$$

EC_{50} value (mg·ml^{-1}) was the effective concentration at which 50% DPPH radicals were scavenged.

Chelating ability for ferrous (Fe^{2+}) ions

The chelating ability for ferrous ions was determined according to the method of Larrauri et al. [22]. Each extract (0.5–20 mg·ml^{-1}) in ethanol (2.5 ml) was mixed with 1 ml 50 mmol·l^{-1} phosphate buffer, pH 7.0, 0.4 ml deionized water, 0.5 ml methanol and 0.5 ml 2.5% linoleate. A volume of 100 μl of methanol was used to replace cake extract in the control solution. The mixture was incubated at 50 °C and analyzed every 24 h. A volume of 50 μl of the incubated mixture was thoroughly mixed with 9.7 ml 70% ethanol and 0.1 ml 30% thiocyanate. These solutions were allowed to stand for 3 min at room temperature and 0.1 ml 20 mmol·l^{-1} ferric chloride was then added to each. The absorbance was measured at 500 nm.

Sensory evaluation

Sensory evaluation was carried out by 80 persons selected among students, staff and faculty members of Hankyung University, Korea. Each evaluator was given five cake samples (3 × 3 × 3 cm) randomly numbered and asked to rate them, based on the degree of liking on a nine-point hedonic scale (1 – dislike extremely, 5 – neither like nor dislike, 9 – like extremely). Panelists evaluated the samples in a sensory testing area and they were instructed to rinse their mouths with water during the evaluation in order to minimize any cross-residual effects among different samples.

Statistical analysis

Each manufacturing treatment and physicochemical measurement was carried out in triplicate. The experimental data was subjected to statistical analysis using analysis of variance (ANOVA) for a completely random design using statistical analysis system software (SAS Institute, Cary, North Carolina, USA). Duncan's multiple range tests were used to determine the differences among means. Significance was defined at $P < 0.05$.

RESULTS AND DISCUSSION

Approximate composition of yellow layer cakes

Approximate composition of yellow layer cakes is presented in Tab. 2. The crude protein, crude fat, crude fibre, crude ash, saccharide and water contents of turmeric powder were 3.9, 1.5, 1.6, 1.8, 76.4 and 14.8%, respectively whereas those for cake flour were 8.0, 1.2, 2.4, 0.4, 73.1 and 14.9%, respectively. There were non-significant differences among the moisture, saccharides, crude protein and crude fat contents of control and turmeric-containing yellow layer cakes. However, crude fibre and ash contents varied significantly, being the lowest in control and increased with turmeric powder contents. A 6% replacement of wheat flour in cake with turmeric powder resulted in 1.3% and 0.3% increase in crude fibre and ash contents of cakes, respectively. Dietary fibre plays an important role in human health and high-fibre diets are associated with the prevention, reduction and treatment of some diseases, such as diverticular and coronary heart diseases [23]. Higher ash contents reflect possibly more minerals in cake, which may have positive role for health [24].

Physical properties of cake batter and yellow layer cake containing turmeric powder

Tab. 3 shows physical properties of cake batters and yellow layer cakes. A significant increase in viscosity and decrease in specific gravity of cake batter was observed with increasing turmeric powder level. LOEWE [25] found that viscosity is an essential property of batter, as it helps to suspend ingredients that are insoluble at ambient temperature. MILLER and HOSNEY [26] reported similar useful increase in batter viscosity and de-

Tab. 2. Approximate composition of cake flour, turmeric powder and yellow layer cakes prepared with turmeric powder replacement for cake flour.

Component [%]	Cake flour	Turmeric powder	Control	T2	T4	T6	T8
Moisture	14.9 ± 0.01	14.8 ± 0.12	32.1 ± 0.53^{a}	32.4 ± 0.90^{a}	32.7 ± 0.97^{a}	32.8 ± 0.86^{a}	32.5 ± 0.72^{a}
Carbohydrate	73.1 ± 0.43	76.4 ± 0.36	51.2 ± 1.71^{a}	51.3 ± 2.30^{a}	51.0 ± 1.35^{a}	51.1 ± 1.56^{a}	51.3 ± 2.66^{a}
Crude protein	8.0 ± 0.02	3.9 ± 0.03	7.0 ± 0.02^{a}	7.2 ± 0.06^{a}	7.3 ± 0.03^{a}	7.5 ± 0.07^{a}	7.7 ± 0.12^{a}
Crude fat	1.2 ± 0.01	1.5 ± 0.01	10.2 ± 0.21^{a}	10.2 ± 0.36^{a}	10.2 ± 0.28^{a}	10.3 ± 0.23^{a}	10.2 ± 0.39^{a}
Crude fibre	2.4 ± 0.02	1.6 ± 0.04	0.6 ± 0.04^{e}	1.2 ± 0.02^{d}	1.6 ± 0.01^{c}	1.9 ± 0.05^{b}	2.3 ± 0.08^{a}
Crude ash	0.4 ± 0.01	1.8 ± 0.03	0.8 ± 0.02^{e}	0.9 ± 0.01^{d}	1.0 ± 0.03^{c}	1.1 ± 0.02^{b}	1.2 ± 0.01^{a}

Control, T2, T4, T6 and T8, prepared with 0%, 2%, 4%, 6%, and 8% replacement of cake flour with turmeric powder, respectively. Values are the mean ± standard deviation ($n = 3$). Means (Control, T2, T4, T6 and T8) within same rows with different superscript letters are significantly different ($P < 0.05$).

Tab. 3. Physical properties of cake batter and yellow layer cakes prepared with turmeric powder.

Sample	Batter		Cake	
	Viscosity [Pa·s]	Specific gravity [g·cm^{-3}]	Volume [cm^{3}]	Density [g·cm^{-3}]
Control	5.10 ± 0.03^{e}	0.96 ± 0.02^{a}	606 ± 13^{e}	0.58^{a}
T2	5.62 ± 0.06^{d}	0.88 ± 0.01^{b}	726 ± 14^{d}	0.48^{b}
T4	6.11 ± 0.01^{c}	0.86 ± 0.01^{c}	757 ± 16^{c}	0.46^{c}
T6	6.84 ± 0.03^{b}	0.84 ± 0.01^{d}	796 ± 12^{b}	0.44^{d}
T8	7.21 ± 0.02^{a}	0.81 ± 0.01^{e}	814 ± 10^{a}	0.43^{e}

Control, T2, T4, T6 and T8, prepared with 0%, 2%, 4%, 6%, and 8% replacement of cake flour with turmeric powder, respectively. Values except density are the mean ± standard deviation ($n = 3$). Means within same columns with different letter superscripts are significantly different ($P < 0.05$).

Tab. 4. Water activity of yellow layer cakes prepared with turmeric powder replacement for cake flour during storage at 20 °C.

Storage [d]	Control	T2	T4	T6	T8
1	0.901 ± 0.003^{aA}	0.884 ± 0.002^{bA}	0.883 ± 0.001^{bA}	0.879 ± 0.001^{cA}	0.870 ± 0.003^{dA}
3	0.886 ± 0.001^{aB}	0.875 ± 0.002^{bB}	0.871 ± 0.001^{cB}	0.865 ± 0.003^{dB}	0.860 ± 0.02^{eB}
5	0.882 ± 0.001^{aC}	0.870 ± 0.003^{bC}	0.861 ± 0.002^{cC}	0.855 ± 0.001^{dC}	0.848 ± 0.004^{eC}
7	0.872 ± 0.004^{aD}	0.858 ± 0.001^{bD}	0.846 ± 0.001^{cD}	0.840 ± 0.002^{dD}	0.837 ± 0.001^{eD}

Control, T2, T4, T6 and T8, prepared with 0%, 2%, 4%, 6%, and 8% replacement of cake flour with turmeric powder, respectively.
Each value is expressed as mean ± standard deviation (n = 3).
Means within same rows with different superscript small letters are significantly different ($P < 0.05$).
Means within same columns with different superscript capital letters are significantly different ($P < 0.05$).

Tab. 5. Texture parameters of yellow layer cakes prepared with turmeric powder replacement for cake flour during storage at 20 °C.

Properties	Storage [d]	Control	T2	T4	T6	T8
Hardness [g·cm^{-2}]	1	470.7 ± 12.1^{aD}	314.0 ± 14.6^{bD}	249.5 ± 15.5^{cD}	195.3 ± 10.4^{dD}	171.8 ± 17.7^{eD}
	3	523.5 ± 19.2^{aC}	332.7 ± 20.3^{bC}	265.3 ± 21.5^{cC}	239.2 ± 16.7^{dC}	193.6 ± 14.6^{eC}
	5	550.5 ± 11.9^{aB}	365.6 ± 11.7^{bB}	301.2 ± 17.6^{cB}	269.7 ± 11.0^{dB}	213.5 ± 12.4^{eB}
	7	653.6 ± 15.4^{aA}	413.9 ± 14.6^{bA}	343.5 ± 19.1^{cA}	298.6 ± 14.4^{dA}	255.7 ± 18.8^{eA}
Cohesiveness [%]	1	62.4 ± 1.0^{bA}	64.9 ± 0.9^{aA}	65.1 ± 0.7^{aA}	65.4 ± 1.6^{aA}	65.8 ± 1.2^{aA}
	3	59.4 ± 1.7^{bB}	62.3 ± 2.4^{aB}	62.6 ± 2.9^{aB}	62.8 ± 1.5^{aB}	62.9 ± 1.1^{aB}
	5	58.9 ± 1.2^{bB}	62.1 ± 1.4^{aB}	62.0 ± 1.4^{aB}	62.4 ± 1.3^{aB}	62.1 ± 0.8^{aB}
	7	58.5 ± 1.0^{bB}	61.1 ± 1.1^{aB}	61.6 ± 2.1^{aB}	62.1 ± 1.9^{aB}	62.3 ± 1.9^{aB}

Control, T2, T4, T6 and T8, prepared with 0%, 2%, 4%, 6%, and 8% replacement of cake flour with turmeric powder, respectively.
Each value is expressed as mean ± standard deviation (n = 3).
Means within same rows with different superscript small letters are significantly different ($P < 0.05$).
Means within same columns with different superscript capital letters are significantly different ($P < 0.05$).

crease in specific gravity when xanthan gum was replaced with cake flour in white layer cakes. The weight of yellow layer cakes was not affected significantly however there was a significant increase in cake volume from 606 cm^3 to 814 cm^3 by increasing turmeric contents from 0% to 8%. Cake volume varies due to granule size, gelatinization temperature and water requirement of the starch. Generally, a greater contact and interaction between starch and water result in a higher cake volume. Similarly, higher viscosity of cake batter provides more capacity to retain expanding air nuclei and thereby lead to the desired product volume [27]. In general, a good cake batter must retain sufficient viscosity to prevent the incorporated air bubbles from rising to the surface and being lost during initial heating. The increase in cake volume with turmeric powder might be due to the facts that addition of turmeric powder increased the viscosity of dough, which resulted in increased formation of air bubbles as a result of more air entrapment in the dough, and sustained expansion during baking. The density of cake decreased from 0.58 to 0.43 with increasing the turmeric powder level. These results show that the turmeric powder had beneficial effects on the physical properties of batter and cake.

Water activity, texture properties and crumb colour of yellow layer cake containing turmeric powder

A significant decrease in water activity (A_w) of yellow layer cakes was observed at increasing turmeric powder contents. A similar decrease in A_w was also noted for storing cakes for up to 7 days at 20 °C (Tab. 4). The reason for the decrease in A_w with increasing the storage period is the migration of moisture from the crumb toward the crust, which subsequently evaporates from the surface of the cake [28]. A similar decrease in A_w was reported in rice cake during storage at room temperature [29]. The reasons for lower A_w in cakes containing turmeric powder might be that the higher cake volume with increased pore size facilitated moisture migration during baking and storage, and probable lower moisture absorption by turmeric powder as compared to wheat flour [30]. Water is

an important substance present in all foods which contributes to food texture, structure and storage stability [31].

Results for hardness, cohesiveness and springiness as major textural parameters are shown in Tab. 5. The data on hardness show that the cake became softer with increasing the amount of turmeric powder. However, hardness increased with increasing storage time from 1 to 7 days. KAMEL and RASPER [32] pointed out that the hardness of cakes is directly related to the cake density which is in agreement with our finding as the cake density (Tab. 3) and hardness decreased with increasing turmeric powder contents. There was no significant difference observed in the weight of cakes. Thus, the increased hardness was mainly related to lower cake volume. Cakes prepared with turmeric powder had higher cohesiveness than the control. Cohesiveness values decreased significantly from day 1 to day 3 and remained at similar levels afterwards. The effects of treatment and storage time on springiness of the cake were not significant (data not shown).

Effects of turmeric powder during storage at 20 °C on crumb colour (lightness, redness and yellowness) of yellow layer cake were evaluated in different cakes during 1–7 days. The crumb color was significantly affected by the use of turmeric powder, however, the effect of storage period was not significant. In case of crumb color, the *L* value decreased significantly ($P < 0.05$) with increasing the turmeric powder contents in cakes. *L* value decreased from 85.5 in control to 69.3 in T8 containing 8% turmeric powder after 7 days storage. However, *a* and *b* values increased significantly ($P < 0.05$) from 6.3 in control to 8.8 in T8 and from 30.4 in control to 48.9 in T8, respectively. There was a significant increase in *a* and *b* values of crumb colour with increasing contents of turmeric powder in cakes, irrespective of the storage period. This indicated that turmeric powder substitution resulted in darker, redder and more yellow crumb of cakes. The colour change of baked cakes might be related to the fact that turmeric pigments, curcuminoids and polyphenol compounds underwent oxidation reaction and saccharides participated in caramelization during baking. Maillard reaction, which is the cause of undesirable colour changes in foods, results in the formation of pyrolysates, some of which are mutagens and carcinogens. These play an important role in the development and progression of diabetes and age-related degenerative diseases and also destroy important essential amino acids. Turmeric, an important ingredient in the food preparation, blocks the formation of hazardous Maillard reaction products and their mutagenic activity [33]. Hence it is recommendable to be used in foods including bakery products, as a preferred food colorant [8].

Functional components of yellow layer cakes containing turmeric powder

The major curcuminoid compounds present in turmeric are curcumin, demethoxycurcumin and bis-demethoxycurcumin. These are phenolic compounds possessing broad spectrum of biological activities, which have been widely documented both in vivo an in vitro studies [34]. The contents of these curcuminoids in cake samples significantly increased by increasing turmeric powder contents (Tab. 6) and curcumin was found as the most abundant amongst them. Antioxidant activities of curcuminoids are found to be in the order of curcumin having the highest activity followed by demethoxycurcumin and bis-demethoxycurcumin [35]. Curcumin is an effective antioxidant, scavenging superoxide radicals, hydrogen peroxide and nitric oxide from activated macrophages [36]. It is reported that some types of curcumins, such as ferulic acid, vanillic acid and vanillin, are degraded when subjected to cooking or baking [37]. However, PRATHAPAN et al. [38] reported that turmeric curcuminoids have better stability and heating does not affect the concentration of

Tab. 6. Contents of curcuminoids of yellow layer cakes prepared with turmeric powder replacement for cake flour at the first storage day.

Curcuminoid [mg·kg^{-1}]	Control	T2	T4	T6	T8
Bis-demethoxycurcumin	ND	9.0 ± 0.1^{d}	18.4 ± 0.2^{c}	26.7 ± 0.8^{b}	38.3 ± 0.6^{a}
Demethoxycurcumin	ND	16.1 ± 1.2^{d}	34.7 ± 2.1^{c}	102.0 ± 6.0^{b}	128.0 ± 9.7^{a}
Curcumin	ND	53.0 ± 0.9^{d}	100.3 ± 8.2^{c}	147.1 ± 1.5^{b}	203.2 ± 2.7^{a}
Total curcuminoids	ND	78.1 ± 6.3^{d}	153.4 ± 8.8^{c}	275.8 ± 9.3^{b}	369.5 ± 12.2^{a}

Control, T2, T4, T6 and T8, prepared with 0%, 2%, 4%, 6%, and 8% replacement of cake flour with turmeric powder, respectively. Values are the mean ± standard deviation ($n = 3$). Means (Control, T2, T4, T6 and T8) within same rows with different superscript letters are significantly different ($P < 0.05$). ND – not detected.

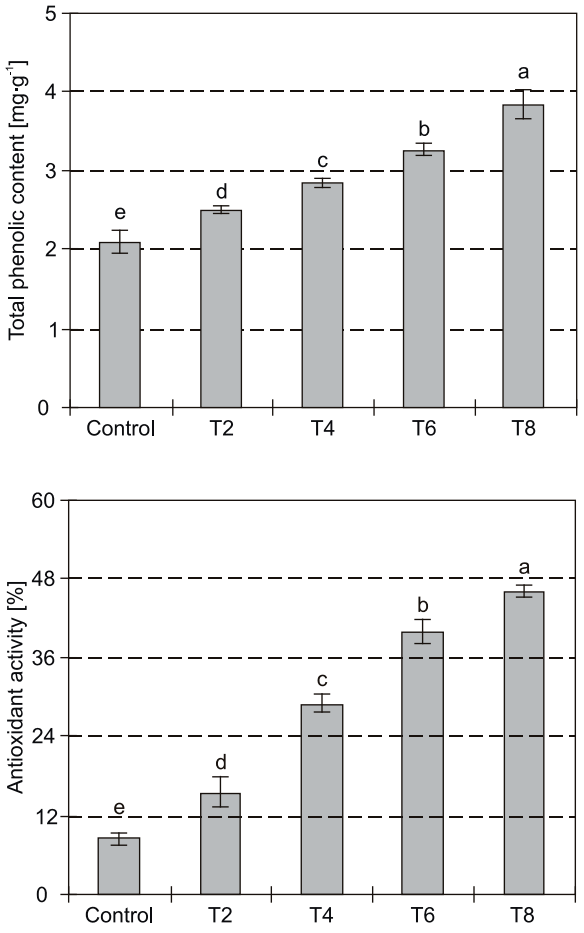

Fig. 1. Total phenolic content and antioxidant activity (carotene-linoleate system) of yellow layer cake extracts at first storage day.

Control, T2, T4, T6 and T8: prepared with 0%, 2%, 4%, 6%, and 8% replacement of cake flour with turmeric powder, respectively. Values are the mean ± standard deviation (n = 3). Bars with different letters show significant ($P < 0.05$) difference among values. Total phenolic contents are expressed in milligrams of gallic acid equivalent per gram.

individual curcuminoids. Turmeric is one of the highly recommended sources of functional food components such as curcumin [39] and its use in yellow layer cake would be beneficial in improving functional properties. The turmeric curcuminoids were stable during baking and their high contents remained in cakes. These curcuminoids were not detected in the control cake samples containing no turmeric powder.

Total phenolic contents and antioxidant properties of yellow layer cakes containing turmeric powder

The total phenolic content and antioxidant activity of yellow layer cake is shown in Fig. 1. Total phenolic contents and antioxidant activities of cakes increased with increasing contents of the turmeric powder. A direct correlation was observed between antioxidant activities and phenolic contents. These types of correlations among different functional properties and phenolic compounds have been reported in other studies [40, 41]. We observed that all turmeric-containing yellow layer cakes had significantly higher contents of total phenolic compounds than the control, which demonstrates the importance of turmeric as a food ingredient for incorporation of biologically important compounds in health foods.

Different antioxidant properties of ethanolic extracts obtained from yellow layer cakes are presented in Tab. 7. The results were expressed in terms of EC_{50} for comparison among different properties. The antioxidant effectiveness inversely correlated with EC_{50} values. The effectiveness, including antioxidant activity, ferric ion reducing power, scavenging ability for DPPH radicals and chelating ability for ferrous ions, decreased in the order of T8 > T6 > T4 > T2 > control. The results showed that addition of turmeric powder significantly improved these properties in yellow

Tab. 7. EC_{50} values of ethanolic extracts from yellow layer cakes for antioxidant properties at the first storage day.

Property	EC_{50} value [mg·ml^{-1}]				
	Control	T2	T4	T6	T8
Antioxidant activity	8.12 ± 0.21^{a}	6.02 ± 1.16^{b}	4.67 ± 0.17^{c}	3.66 ± 0.16^{d}	2.67 ± 0.08^{e}
Ferric (Fe^{3+}) ion reducing power	45.10 ± 2.21^{a}	34.40 ± 0.07^{b}	24.53 ± 0.02^{c}	13.60 ± 0.01^{d}	3.20 ± 0.01^{e}
Scavenging ability for DPPH radicals	37.20 ± 3.55^{a}	28.10 ± 1.06^{b}	19.67 ± 0.42^{c}	10.92 ± 0.15^{d}	2.09 ± 0.11^{e}
Chelating ability for ferrous (Fe^{2+}) ions	38.40 ± 1.71^{a}	36.35 ± 1.16^{b}	34.36 ± 0.44^{c}	30.65 ± 1.20^{d}	28.96 ± 1.08^{e}

Control, T2, T4, T6 and T8, prepared with 0%, 2%, 4%, 6%, and 8% replacement of cake flour with turmeric powder, respectively. Each value is expressed as mean ± standard deviation (n = 3).
Means within same rows with different superscript small letters are significantly different ($P < 0.05$).
EC_{50} value – the effective concentration at which the antioxidant activity was 50%; the absorbance was 0.5 for reducing power; DPPH radicals were scavenged by 50%; and ferrous ions were chelated by 50%, respectively.

layer cakes. The improved antioxidant properties of yellow layer cake are due to the incorporation of phenolic compounds, mainly curcuminoids [35]. Curcumin, which is chemically diferuoyl methane, is a major phenolic component of turmeric that can be used in food and pharmaceutical industries due to its excellent antioxidant properties. In a study carried out by TUBA and ILHAMI [42], it was observed that 20 mmol·l^{-1} solution of curcumin inhibited 97.3% lipid peroxidation of 15 μg·ml^{-1} linoleic acid emulsion. At the same time, butylated hydroxyanisole (BHA, 123 mmol·l^{-1}), butylated hydroxytoluene (BHT, 102 mmol·l^{-1}), α-tocopherol (51 mmol·l^{-1}) and Trolox (90 mmol·l^{-1}) as standard antioxidants showed 95.4, 99.7, 84.6 and 95.6% inhibition of 45 μg.ml^{-1} linoleic acid emulsion peroxidation, respectively. It was also pointed out that curcumin had DPPH scavenging, superoxide anion radical-scavenging, hydrogen peroxide scavenging, ferric ions (Fe^{3+}) reducing power and ferrous ions (Fe^{2+}) chelating activities comparable with BHA, BHT, α-tocopherol and trolox. BHA and α-tocopherol possess antioxidant activity, Fe^{3+}-reducing power and DPPH-scavenging ability. However, their use is restricted and emphasis is currently being laid down on the use of bioactives from natural sources. Turmeric is an excellent source of bioactive compounds and our study proved that yellow layer cake added with turmeric powder had significantly higher amounts of curcuminoids. These phenolic compounds imparted important antioxidant properties to the cakes, demonstrating possible application of the turmeric powder in bakery products.

Sensory evaluation of yellow layer cakes containing turmeric powder

Effects of adding turmeric powder at different levels on the sensory properties of yellow layer cakes were evaluated by scoring crust and crumb colour, sweetness, flavour, texture and overall acceptability of cakes on a 9-point hedonic scale. No statistically significant differences were observed in the sensory score for crumb colour, sweetness, flavour and overall acceptability of control, T2, T4 and T6. The crust colour and texture scores showed no significant variation among all samples. The scores for crumb colour, sweetness, flavour and overall acceptability of T8 were lower than those of the other cakes. The scores for overall acceptability of control, T2, T4 and T6 ranged between 7.4 and 7.8 and they were significantly ($P < 0.05$) higher than those for T8 which scored 5.3. It showed that the cakes containing up to 6% turmeric powder had a good overall sensory quality. It is known that turmeric has a pungent flavour, which is mainly due to ketones and sesquiterpene alcohols such as turmerone, ar-turmerone, α and β-zingiberene, 8-cineol, α-phelandrene, sabinene and borneol [43]. This flavour dominated sensory characters of yellow layer cake when prepared by replacing 8% of cake flour with turmeric powder in T8. The remarkable colour differences, determined by instrumental methods, were not recognized in sensory evaluation. The sensory values of the control, T2, T4 and T6 were in the range of 7.0–7.9, indicating that these four cake types had good consumer acceptability for crust and crumb colour, sweetness, flavour and texture of yellow layer cakes. Hence, partial replacement of cake flour with up to 6% turmeric powder in yellow layer cakes is possible without affecting the sensory quality.

Recently consumers are demanding for healthy nutritious foods having not only a balanced calorific content but also carrying additional health-promoting functions, i.e. functional foods [44]. The addition of turmeric powder was found to have profound effects on the quality of yellow layer cake with a significant improvement in its texture, contents of biologically active compounds and functional properties. Use of turmeric powder in bakery products may play an important role in the development of foods with additional health benefits. The sensory acceptability levels may also be improved by using techniques such as hydrodistillation for deodorization of turmeric [43]. Turmeric is a potential source of important bioactives having different therapeutic activities [45] and the addition of these bioactive into food matrices is an effective method for decreasing disease risks. The scientific community should develop innovative functional foods with the potential to produce physiological benefits or reduce the long-term risk of developing diseases [46].

CONCLUSION

A novel formulation of yellow layer cake was developed successfully using turmeric powder. Turmeric is a good source of curcuminoids and yellow pigments. Yellow layer cake formulated with partial replacement of cake flour with up to 8% turmeric powder increased the cake volume and decreased its hardness. These cakes possessed lesser lightness and more redness and yellowness than the control. They contained significantly more phenolic compounds and curcuminoids than the control, and showed excellent antioxidant activity, Fe^{3+} reducing power, radical scavenging and Fe^{2+} chelation. No statistically significant

differences were found in all sensory parameters of yellow layer cakes while formulated using up to 6% turmeric powder. Considering these findings, Korean turmeric may be effectively incorporated in yellow layer cakes to impart improved texture, higher contents of biologically active compounds and improved antioxidant properties in cakes.

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