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Quality and antioxidant property of green tea sponge cake

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ABSTRACT

Green tea powder was used to substitute 0%, 10%, 20%, and 30% of wheat flour to make sponge cakes, called the control, GT10, GT20, and GT30, respectively. The viscosity and specific gravity in cake batter, and hardness, gumminess, chewiness, crumb *a* value, protein, total dietary fibre, ash, and various catechin content of baked cakes increased with increasing green tea levels whereas the volume, cohesiveness, adhesiveness, springiness, resilience, crust *L*, *a*, *b* and crumb *L*, *b* values of samples showed a reverse trend. No differences were found in all hedonic sensory results for control, GT10, and GT20 whereas GT30 were rated lower in all sensory results. Green tea cake contained a greater variety of catechins, and had good antioxidant activity, reducing power, scavenging ability on 1,1-diphenyl-2-picrylhydrazyl radicals and chelating ability on ferrous ions. Overall, green tea cake could be developed as a food with more effective antioxidant properties.

1. Introduction

Bakery products are consumed all over the world. Fat is an important ingredient in bakery products and its major functions are to tenderise the product and soften the texture, add moistness and richness, increase keeping quality, add flavour, and to assist in leavening when used as creaming agents or when used to give flakiness to puff pastry, pie, dough, and similar products (Gisslen, 1994). However, fat has a disadvantage of getting oxidised 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. Since some of synthetic antioxidants had toxigenic, mutagenic, and carcinogenic effects (Nanditha & Prabhasankar, 2009) and some natural antioxidants were effective in enhancing the shelf life of bakery products but less effective than synthetic antioxidants, there is a great demand for the use of new natural antioxidants in food, especially in bakery products.

Some studies have disclosed the potential sources of natural antioxidants on the bakery products. For example, the rye bread showed better antioxidant properties and higher antioxidant contents when compared to wheat roll (Michalska et al., 2007). Toyosaki and Koketsu (2007) studied the antioxidant effects of the water-soluble fraction from baked sponge cake and found that the use of silky fowl eggs could improve the quality and oxidative stability of baked cakes as compared to cake made with White Leghorn eggs. Vergara-Valencia et al. (2007) characterised a mango dietary fibre (MDF) with antioxidant capacity, using the unripe fruit. Both types of bakery products (cookie and bread) with added MDF showed higher total dietary fibre than respective controls, and the products maintained a significant antioxidant capacity associated to their extractable polyphenol content. In addition, Lin, Liu, Yu, Lin, and Mau (2009) found that the buckwheat could be incorporated into bread and provide buckwheat enhanced wheat bread with more functional components and more effective antioxidant properties.

Tea is one of the most popular drinks in the world, and its consumption is nearly as great as coffee. Tea has been used for centuries by ancient cultures for its medicinal properties and is popularly consumed in unfermented (green tea), semifermented (oolong), and fermented (black tea) forms. Black tea is commonly consumed in the West whereas the consumption of green tea is especially popular in Asia, mainly for its health benefits. Several studies have reported that green tea extract has antioxidant, antibacterial, antiviral, anticarcinogenic, and antimutagenic functions (Higdon & Frei, 2003; Lin, Liu, & Mau, 2008). Green tea contains considerable amounts of catechins, which contribute most to its antioxidant properties. Besides, green tea is also reported to reduce serum cholesterol levels and inhibit hypertension in several experiments (Hodgson, Puddey, Burke, Beilin, & Jordan, 1999; Muramatsu, Fukuyo, & Hara, 1986).

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In addition to its bioactive components, green tea is a rich source of dietary fibre. Dietary fibre is the edible part of plants or analogous carbohydrates resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fibre includes the polysaccharides, oligosaccharides, lignin, and associated plant substances (Anonymous, 2001). The lack of dietary fibre in the diet has been associated with constipation, diverticulosis, cardiovascular disease, and cancer (Kritchevsky, 2001). Many forms of dietary fibre are often added to foods to lower the incidence of these disorders and dilute calories.

Natural antioxidants may inhibit lipid peroxidation in food and improve food quality and safety. Green tea contains antioxidants such as catechins and, added to food as a supplement, can provide beneficial health effects and prevent food from oxidation during processing. Baked food products are enjoyed by consumers all over the world. Because of their high consumption, they are potential carriers of bioactive compounds and dietary fibre. Thus, it would be beneficial to develop a novel formulation of cake production with green tea. The objectives of this research were to make sponge cakes with 0%, 10%, 20%, and 30% replacement of cake flour with green tea powder, to evaluate the influence of green tea powder on sponge cake quality and contents of the functional component as a result of supplementation. The antioxidant properties of sponge cakes were also determined.

2. Materials and methods

2.1. Materials

The ingredients used in the formula of sponge cakes were cake flour (Chiafha Enterprise Co., Taichung, Taiwan), sucrose (Taiwan Sugar Co., Tainan, Taiwan), sodium chloride (Taiyen Industrial Co., Tainan, Taiwan), soybean oil (Fwusow Industrial Co., Taichung, Taiwan), fresh eggs (local market, Taichung, Taiwan), and nonfat dry milk powder (Fonterra Ltd, Auckland, New Zealand). The parching green tea was made from the leaves of *Camellia sinensis* L. (cultivar Shy-Jih-Chun) in the spring season picked from the tea farm in Mingjian, Nantou County, Taiwan. For parching green tea, young leaves were subjected to blanching (280–300 °C, 5–6 min), rolling and drying. The dried tea leaves were ground in a mill (RT-30HS, Rong Tsong Precision Technology Co., Taichung, Taiwan), and screened through a 0.5 mm sieve.

Methanol, ethanol, acetonitrile, hydrochloric acid, and polyoxyethylene 20 sorbitan monolaurate were purchased from Mallinckrodt Baker, Inc. (New Jersey, USA). Linoleic acid, potassium ferricyanide, 1,1-diphenyl-2-picrylhydrazyl (DPPH), ferrous chloride tetrahydrate, ferrozine, trichloroacetic acid, ferric chloride hexahydrate, trifluoroacetic anhydride, catechin, epicatechin (EC), gallocatechin (GC), epigallocatechin (EGC), epicatechin gallate (ECG), gallocatechin gallate (GCG), and epigallocatechin gallate (EGCG) were purchased from Sigma Chemical Co. (St. Louis, MO). Sodium phosphate and potassium phosphate were purchased from Wako Pure Chemical Industries, Ltd. (Tokyo, Japan).

2.2. Sponge cake preparation

The traditional sponge cake formula in this study was adapted from the work of Lee, Wang, and Lin (2008). The formulae of sponge cakes at four different green tea powder levels were shown in Table 1. Green tea powder was infused with boiling water for 5 min in a bowl and cooled to 24–26 °C. Whole egg and egg yolk were poured into a bowl, and mixed by hand with an eggbeater. Sucrose and sodium chloride were added to the bowl, and then warmed to ≈40 °C over a hot water bath. The reason for this step is the foam will attain greater volume if warm. The egg and sugar mixtures were then mixed with a whisk attachment in a mixer (K5SS, Kitchen Aid Inc., St. Joseph, MI) on speed 8 setting for 3 min. The sifted cake flour was gradually poured into the mixer on speed 2 setting for 30 s. The foam was poured into a bowl containing soybean oil, nonfat dry milk, and hydrated tea. Ingredients were mixed by hand with a plastic scraper until smooth. The cake batter was immediately deposited into cake pans.

Table 1
Formulation of sponge cakes.

Ingredient (g)	Control[a]	GT10	GT20	GT30
Cake flour	189	170.1	151.2	132.3
Green tea powder	0	18.9	37.8	56.7
Sucrose	258	258	258	258
Whole egg	258	258	258	258
Egg yolk	57	57	57	57
Sodium chloride	3	3	3	3
Soybean oil	38	38	38	38
Nonfat dry milk	4	4	4	4
Water	84	84	84	84

[a] Control, GT10, GT20, and GT30: prepared with 0%, 10%, 20%, and 30% replacement of cake flour with green tea powder, respectively.

For each cake, 400 g of cake batter was poured into a cake pan (20.3 cm in diameter × 7 cm in height) and baked at 160 °C for 40 min in a preheated oven (Sing Mine International, Taichung, Taiwan). The cakes were allowed to cool for 2 h, and then were removed from the pans. The cooled cakes were packed in polypropylene bags at room temperature before physico-chemical and sensory evaluation analyses. The test sponge cake samples prepared with 0%, 10%, 20%, and 30% replacement of cake flour with green tea powder were designated as the control, GT10, GT20, and GT30, respectively. All treatments were randomly produced. Eighteen sponge cakes were prepared from each cake batter. Ten sponge cakes from the same batter were used for physico-chemical characteristic measurements, and eight sponge cakes were used for sensory evaluation.

2.3. Physical characteristics of cake batter

The physical characteristics of cake batters including moisture, viscosity, and specific gravity were measured in quadruplicate for the same cake batter. The moisture content of cake batters were determined by Approved Methods 44-40 (AACC, 2000). Immediately after mixing, 500 ml of cake batter was poured into a 600 ml beaker and the viscosity was measured at 30 rpm with a spindle L4 on a rotational viscometer (Visco Basic Plus L, Fungilab S.A., GR Scientific, Spain). The specific gravity of each type of cake batter was determined by dividing the weight of the 240 ml of cake batter by the weight of 240 ml of water.

2.4. Proximate composition of sponge cake

The proximate compositions of sponge cakes, including moisture, crude protein, crude fat, ash and total dietary fibre, were determined by Approved Methods 44-40, 46-11A, 30-10, 08-01, and 32-07, respectively (AACC, 2000). The nitrogen conversion factor used for crude protein calculation was 6.25. The carbohydrate content (%) was calculated by subtracting the contents of crude protein, fat, ash, and moisture from 100% of cakes. The proximate compositions of sponge cakes were averaged from four replications. Results were expressed on a wet basis.

2.5. Physical characteristics of sponge cake

The water activity of the sponge cake was measured by the chilled mirror technique using an AquaLab CX-2 water activity metre (Decagon Devices, Pullman, WA). The water activity of sponge cake was averaged from four replications. The volume of the sponge cake was determined by the rapeseed displacement method. The empty cake pan was filled with rapeseed. The empty cake pan volume (*V*1) was calculated based on the volume of rapeseed as determined by a graduated cylinder. After baking, the rest of the volume of the cake pan (*V*2) was filled with rapeseeds, and the volume of rapeseed was determined by graduated cylinder. The cake volume was calculated as *V*1–*V*2. The volume of sponge cake was averaged from four replications.

The texture profile analysis (TPA) of cake samples (3 × 3 × 3 cm) from the midsection of the cakes were measured using a texture analyser (TA-XT2, 25 kg model, Stable Micro Systems, Surrey, UK). The crust of cake samples was removed in cake texture determination. A double cycle was programmed and the texture profile was determined using Xrad software (Stable Micro Systems). To select the optimal test conditions, various combinations of tests (deformation 30–60%, cross-head speed 0.1–2 mm/s) were made. The variance coefficient of a plunger (P/50, 5.08 cm diameter) compressing a sample to 50% of its original height at 0.8 mm/s speed is the minimum. These were the optimal conditions in this study. The texture parameters recorded were hardness, cohesiveness, adhesiveness, springiness, resilience, gumminess, and chewiness, and the texture parameter of cake was averaged from 10 replications.

The colour determinations of cake samples (3 × 3 × 3 cm, crumb only or including top crust) from the midsection of the cakes were measured using a colour measurement spectrophotometer (ColourFlex-Diffuse, Hunter Associates Laboratory, Inc., Reston, VA, USA) set for Hunter *L*, *a*, and *b* values with a D65 illuminant at 10°. The results of Hunter *L*, *a*, and *b* values were averaged from 10 replications.

2.6. Determination of various catechin contents of sponge cake

The catechins were determined according to the method of Goto, Yoshida, Kiso, and Nagashima (1996) with modification. Defatted samples (20 g) were homogenised in 70 ml of boiled deionised water using a stomacher (Laboratory Blender Stomacher 400, London, UK), and were extracted on a water bath at 80 °C for 20 min. After cooling, the homogenised sample was transferred to a centrifuge bottle, and centrifuged at 7000 rpm for 10 min. The supernatant from the centrifuge bottle was filtered with Whatman No. 1 filter, the volume was adjusted to 100 ml using deionised water. The derivative was filtered using a PVDF syringe filter (13 mm × 0.45 μm) before injection into an HPLC system consisting of a Hitachi L-2130 pump, a Hitachi L-2400 UV detector, and a reverse-phase column (300 mm × 4.6 mm × 5 μm, Phenomenex, Torrance, CA). The mobile phase was 0.1% trifluoroacetic anhydride/acetonitrile, 86:14 (v/v) at a flow rate of 1.0 ml/min, and UV detection was at 280 nm. The contents of various catechins were calculated based on of the calibration curve of each catechin, EC, GC, EGC, ECG, GCG, and EGCG. The results of various catechins were averaged from four replications.

2.7. Preparation of ethanol extracts

Sponge cakes were freeze-dried and then ground in a mill and screened through a 0.5 mm sieve. For ethanolic extraction, each cake powder (10 g) was extracted with 100 ml of ethanol at 25 °C in a shaking bath (SB302, Kansin Instruments Co., Kaohsiung, Taiwan) at 100 rpm for 24 h and then filtered through Whatman No. 1 filter paper. The residue was then extracted with two extra 100 ml portions of ethanol as described above. The combined ethanolic extracts were then rotary evaporated at 40 °C and then freeze-dried. Dry extracts thus obtained were stored at −20 °C before use.

2.8. Determination of antioxidant properties

The antioxidant activity of each extract (0.05–20.00 mg/ml in methanol) was determined by the conjugated diene method (Lingnert, Vallentin, & Eriksson, 1979). Reducing power of each extract was determined according to the method of Oyaizu (1986). Scavenging ability of each extract on DPPH radicals was determined on the basis of the method of Shimada, Fujikawa, Yahara, and Nakamura (1992). Chelating ability on ferrous ions of each extract was determined according to the method of Dinis, Madeira, and Almeida (1994).

EC_{50} value (mg extract/ml) is 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%. EC_{50} value was obtained by interpolation from linear regression analysis. Each antioxidant attribute of ethanolic extracts from sponge cakes was averaged from four replications.

2.9. Sensory evaluation

The hedonic test was used to determine the degree of overall liking for the sponge cakes. For this study, untrained consumers were recruited from the students, staff and faculty at Hungkuang University. All consumers were interested volunteers and informed that they would be evaluating sponge cakes. For the sponge cake manufacturing study, 86 consumers (27 males and 59 females, 19–41 years) received four samples (3 × 3 × 3 cm) and were asked to rate them based on degree of liking on a seven-point hedonic scale (1 = dislike extremely, 4 = neither like nor dislike, 7 = like extremely). They received samples held at room temperature from the midsection of the cakes. Samples were placed on white plates and identified with random three-digit numbers. Panelists evaluated the samples in a testing area and were instructed to rinse their mouths with water between samples to minimise any residual effect.

2.10. Statistical analysis

Each measurement was conducted in quadruplicate, except for the hardness ($n = 10$), Hunter *L*, *a*, and *b* values ($n = 10$), and sensory evaluation ($n = 86$). The experimental data were subjected to an analysis of variance (ANOVA) for a completely random design using a statistical analysis system (SAS Institute, Inc., Cary, NC, 2000). Duncan's multiple range tests were used to determine the difference among means at the level of 0.05.

3. Results and discussion

3.1. Physical characteristics of cake batter and proximate composition of sponge cake

Changes in cake batter characteristics with added green tea powder are shown in Table 2. The moisture contents of cake batters were not significantly different. The viscosity of cake batters increased significantly with the increasing green tea powder level. De Fouw, Zabik, Uebersa, and Aguilera (1982) reported an increase in batter viscosity when 15% flour was replaced with either unheated or roasted navy bean hulls. Masood, Sharma, and Chauhan (2002) also reported that batter viscosity increased with increasing apple pomace level and decreasing particle size. In this study, the total dietary fibre contents in green tea powder and cake flour

Table 2
Physical characteristics of cake batters and sponge cakes prepared with green tea powder replacement for cake flour.

	Control[a]	GT10	GT20	GT30
Cake batter				
Moisture (%)	36.04 ± 0.15A[b]	36.15 ± 0.38A	36.00 ± 0.08A	35.92 ± 0.07A
Viscosity (cp)	5308 ± 132D	7670 ± 140C	15130 ± 475B	22206 ± 997A
Specific gravity	0.453 ± 0.010D	0.456 ± 0.004C	0.504 ± 0.007B	0.585 ± 0.019A
Sponge cake				
Moisture (%)	30.63 ± 0.82A	30.50 ± 0.87A	30.79 ± 0.67A	30.34 ± 0.98A
Protein (%)	7.01 ± 0.15C	7.42 ± 0.11B	7.65 ± 0.09B	7.99 ± 0.12A
Fat (%)	10.21 ± 0.07A	10.32 ± 0.12A	10.22 ± 0.21A	10.19 ± 0.35A
Carbohydrate (%)	51.28 ± 1.06A	50.77 ± 0.63A	50.25 ± 0.59A	50.31 ± 0.44A
Total dietary fibre (%)	0.65 ± 0.03D	1.18 ± 0.04C	1.74 ± 0.08B	2.51 ± 0.06A
Ash (%)	0.87 ± 0.04C	0.99 ± 0.03B	1.05 ± 0.02B	1.17 ± 0.06A

[a] Control, GT10, GT20, and GT30: prepared with 0%, 10%, 20%, and 30% replacement of cake flour with green tea powder, respectively.
[b] Each value is expressed as mean ± SD ($n = 4$). Means with different capital letter within a row are significantly different ($P < 0.05$).

were 32.54% and 2.65%, respectively. Thus, the higher viscosity of green tea powder-incorporated batters might be due to the water absorption by fibre. There was a significant increase in specific gravity of cake batter with increasing green tea powder level. Brys and Zabik (1976) found an increase in specific gravity of cake batter with increasing levels of microcrystalline cellulose. Thus, the increase in specific gravity of cake batter should be due to the total dietary fibre of green tea.

Different proximate compositions were found among sponge cakes (Table 2). Protein, total dietary fibre and ash contents were found in the descending order of GT30 > GT20 > GT10 > control whereas moisture, fat and carbohydrate contents showed no significant variation. The protein, fat, carbohydrate, total dietary fibre, and ash contents of green tea powder were 22.84, 1.13, 67.01, 32.54, and 4.62 g/100 g, respectively whereas those of cake flour were 7.87, 1.16, 79.04, 2.65, and 0.43 g/100 g, respectively. Because 0–30% of cake flour in the sponge cake formula was substituted with green tea powder, the proximate composition, especially protein, total dietary fibre and ash contents was accordingly affected.

3.2. Physical characteristics of sponge cake

Changes in sponge cake characteristics with added green tea powder are shown in Table 3. The water activity and cake weight of sponge cakes were not significantly different. A significant decrease in cake volume was noted with an increase in the green tea powder level. The control sample had an average cake volume of 1872 ml, decreasing to 1660, 1443, and 1158 ml for GT10, GT20, and GT30, respectively. Masood et al. (2002) also reported a cake volume decreased with increasing apple pomace levels. Some investigations (Ngo & Taranto, 1986; Paton, Larocque, & Holme, 1981) found 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 cake setting must be timed so the air bubbles can be properly expanded by the carbon dioxide gas and water vapour before the cake sets. Thus, the resulting cake structure is highly aerated and has a more defined structure. In the study, the cake batter viscosities of GT10, GT20, and GT30 were higher than that of the control but their volumes showed a reverse trend. Thus, the results of the cake volume in the study may be due to increased replacement of flour with cellulose, which has been reported to weaken the gluten matrix responsible for retaining gases in baked foods (Baldi, Little, & Hester, 1965; Donelson & Wilson, 1960).

In texture profile analysis, the hardness of samples measured showed that the cake became harder with increasing levels of green tea powder (Table 3). The results are in agreement with the findings of our previous study (Lee & Lin, 2008), which reported an increase in chiffon cake hardness with the increase of GABA (γ-aminobutyric acid) tea. Kamel and Rasper (1988) pointed out that the firmness of cakes was directly related to the density of the tested materials (indirectly to its volume). The weight of samples was not significantly different among any of the cakes in this study. Thus, the increase in hardness was mainly related to the volume of these cakes. Cohesiveness quantifies the internal resistance of food structure. Briefly, cohesiveness is the ability of a material to stick to itself. TPA results showed a decrease in the cake cohesiveness with an increased level of green tea powder. In a typical TPA graph, adhesiveness is the adherence of the cake to the probe and the stage after the first compression. Adhesiveness is the negative force area between the first and second bite. Since adhesiveness is expressed as a negative area by the TPA software, numbers of greater negative value are more adhesive. Furthermore, TPA results showed a decrease in the cake adhesiveness with an increased level of green tea powder.

Springiness measures elasticity by determining the extent of recovery between the first and second compression. Resilience is the ratio of recoverable energy as the first compression is relieved. TPA results showed a decrease in the cake springiness and resilience with increased level of green tea powder. Gumminess is determined by hardness multiplied by cohesiveness. Chewiness is determined by gumminess multiplied by springiness, and represents the amount of energy needed to disintegrate a food for swallowing. TPA results showed an increase in the cake gumminess and chewiness with increased level of green tea powder. Overall, as the percentage of green tea powder increased, hardness, gumminess, and chewiness increased whereas cohesiveness, springiness, and resilience decreased.

All colour data were expressed by Hunter L, a, and b values corresponding to lightness, redness, and yellowness, respectively. The crust colour of samples was affected by the replacement of cake flour with green tea powder (Table 3). In general, as green tea powder level increased, the crust colour became darker as measured by the colorimeter. The crust of the control was lighter and more yellow than any of the other cakes. For crumb colour, as the level of green tea powder increased, the L and b values decreased but the a value increased, indicating that a darker, redder, and less yellow crumb was obtained as a result of green tea powder substitution. It was observed that baked cakes elaborated with green tea powder were darker than the control. The colour change of baked cakes might be related to the fact that tea pigments and polyphenol compounds underwent oxidation reaction, and sucrose also participated in caramelisation during baking.

3.3. Functional components

As expected, catechins were found in green tea sponge cakes (Table 4). Higher catechin content was found in GT30, which was

Table 3
Physical characteristics of sponge cakes prepared with green tea powder replacement for cake flour.

	Control[a]	GT10	GT20	GT30
Water activity	0.907 ± 0.008A[b]	0.900 ± 0.008A	0.907 ± 0.007A	0.906 ± 0.009A
Weight (g)	347 ± 1A	346 ± 2A	347 ± 3A	346 ± 2A
Volume (ml)	1872 ± 52A	1660 ± 48B	1443 ± 42C	1158 ± 52D
TPA parameters				
Hardness (g)	173.7 ± 6.1D	187.3 ± 4.2C	221.3 ± 8.6B	327.3 ± 4.6A
Cohesiveness	0.79 ± 0.01A	0.76 ± 0.02B	0.71 ± 0.03C	0.62 ± 0.03D
Adhesiveness (g/s)	−3.70 ± 0.15D	−3.47 ± 0.06C	−2.78 ± 0.08B	−1.89 ± 0.11A
Springiness	0.92 ± 0.02A	0.89 ± 0.03A	0.83 ± 0.02B	0.71 ± 0.04C
Resilience	0.32 ± 0.02A	0.30 ± 0.02B	0.26 ± 0.01C	0.21 ± 0.02D
Gumminess (g)	137.3 ± 6.9 C	142.4 ± 6.2C	157.3 ± 11.2B	205.2 ± 12.3A
Chewiness (g)	126.3 ± 6.7B	127.5 ± 7.6B	130.5 ± 7.8B	145.4 ± 8.1A
Crust colour				
L	49.02 ± 2.31A	45.17 ± 1.87B	43.04 ± 1.94C	42.98 ± 2.20C
a	11.68 ± 0.88A	10.00 ± 0.31B	6.89 ± 0.67C	5.60 ± 0.76D
b	17.62 ± 1.64A	16.79 ± 0.56B	14.74 ± 0.42C	14.60 ± 0.48C
Crumb colour				
L	71.32 ± 1.99A	49.00 ± 0.92B	40.56 ± 1.48C	35.71 ± 1.17D
a	−1.18 ± 0.14D	2.14 ± 0.15C	2.25 ± 0.21B	2.39 ± 0.14A
b	18.09 ± 0.35A	17.32 ± 0.61B	16.81 ± 0.53C	15.45 ± 0.59D

[a] Control, GT10, GT20, and GT30: prepared with 0%, 10%, 20%, and 30% replacement of cake flour with green tea powder, respectively.
[b] Each value is expressed as mean ± SD (n = 10 for *L*, *a*, *b* values and TPA parameters; n = 4 for other characteristics). Means with different capital letter within a row are significantly different ($P < 0.05$).

prepared with 30% replacement of cake flour with green tea powder. The major catechins present in tea leaves are catechin, EC, GC, EGC, ECG, EGCG, and GCG. Seven catechin contents of cake samples significantly increased with the increasing levels of green tea powder, and EGCG is the most abundant green tea catechin. The antioxidant properties of catechins were found to be: EGC ≅ EGCG ≫ ECG = EC > catechin (Luczaj & Skrzydlewska, 2005). Since the green tea leaf is a good source of functional components, substituting cake flour in the sponge cake formula with green tea powder would be an alternative and successful green tea leaves product. After baking, substantial amounts of catechins remaining in the green tea sponge cake would be beneficial and provide consumers with the alleged physiological properties.

3.4. Antioxidant properties

Using ethanol as the extractant, the yields were in the descending order of control (29.93 ± 1.71% dry matter) > GT10 (28.36 ± 0.74%) > GT20 (25.61 ± 0.40%) > GT30 (22.71 ± 0.98%). The antioxidant properties assayed herein were summarised in Table 5 and the results were expressed as EC_{50} values (milligram dry weight of various extracts per millilitre) for comparison. The effectiveness of antioxidant properties was inversely correlated with their EC_{50} values. Overall, the effectiveness in antioxidant properties, including antioxidant activity, reducing power, scavenging ability on DPPH radicals, and chelating ability on ferrous ions, were in the descending order: GT30 > GT20 > GT10 > control. The results showed that adding green tea greatly enhanced antioxidant properties of the cakes. The improved antioxidant properties of green tea sponge cake might be due to the incorporation of phenolic compounds, mainly various catechins, which had been shown to possess antioxidant activity (Higdon & Frei, 2003; Lin et al., 2008). Although BHA and α-tocopherol had good antioxidant activity, reducing power and scavenging ability on DPPH radicals, they are additives and used or present in milligram levels in foods. However, green tea could be consumed in gram levels as food. Therefore, green tea sponge cake could be developed as a functional food with more effective antioxidant properties.

3.5. Sensory evaluation

For measuring product liking and preference, the hedonic scale is a unique scale, providing both reliable and valid results (Stone & Sidel, 1993). No statistically significant differences evaluated by the untrained consumers were found in the crust and crumb colours, sweetness, flavour, texture and overall liking scores among the control, GT10, and GT20 (Table 6). However, the sensory characteristics liking scores of GT30 were lower than those of the other cakes and the GT30 was slightly bitter. The bitterness in GT30 should be attributed to the caffeine of green tea powder. On a se-

Table 4
Content of various catechins of sponge cakes prepared with green tea powder replacement for cake flour.

	Control[a]	GT10	GT20	GT30
GC (mg/100 g)[b]	–[d]	29.00 ± 0.40C[c]	56.92 ± 1.88B	90.73 ± 0.45A
EGC (mg/100 g)	–	81.39 ± 0.66C	158.04 ± 2.08B	238.80 ± 1.75A
Catechin (mg/100 g)	–	6.86 ± 0.11C	13.12 ± 0.15B	20.38 ± 0.30A
EC (mg/100 g)	–	14.19 ± 0.15C	19.15 ± 0.25B	43.69 ± 0.96A
EGCG (mg/100 g)	–	161.29 ± 2.78C	318.58 ± 1.39B	469.98 ± 8.43A
GCG (mg/100 g)	–	5.02 ± 0.04C	9.76 ± 0.50B	14.97 ± 0.09A
ECG (mg/100 g)	–	26.16 ± 0.20C	52.69 ± 1.09B	76.89 ± 1.12A

[a] Control, GT10, GT20, and GT30: prepared with 0%, 10%, 20%, and 30% replacement of cake flour with green tea powder, respectively.
[b] GC, gallocatechin; EGC, epigallocatechin; EC, epicatechin; EGCG, epigallocatechin gallate; GCG, gallocatechin gallate; ECG, epicatechin gallate.
[c] Each value is expressed mean ± SD (n = 4). Means with different capital letter within a row are significantly different ($P < 0.05$).
[d] –, not detected.

Table 5
EC_{50} values of ethanolic extracts from sponge cakes in antioxidant properties.

	EC_{50} value[a] (mg extract/ml)			
	Control[b]	GT10	GT20	GT30
Antioxidant activity	14.83 ± 0.79A[c]	13.45 ± 0.47B	11.12 ± 0.51C	8.89 ± 0.69D
Reducing power	53.59 ± 2.19A[d]	1.84 ± 0.08B	0.78 ± < 0.01B	0.22 ± 0.04B
Scavenging ability on DPPH radicals	31.81 ± 4.26A[d]	12.86 ± 0.59B	0.11 ± < 0.01C	<0.01C
Chelating ability on ferrous ions	47.34 ± 2.65A[d]	37.23 ± 2.54B[d]	24.15 ± 1.11C[d]	9.79 ± 1.51D

[a] EC_{50} value: the effective concentration at which the antioxidant activity was 50%; the absorbance was 0.5 for reducing power; 1,1-diphenyl-2-picrylhydrazyl (DPPH) radicals were scavenged by 50%; and ferrous ions were chelated by 50%, respectively. The EC_{50} value was obtained by interpolation from linear regression analysis.
[b] Control, GT10, GT20, and GT30: prepared with 0%, 10%, 20%, and 30% replacement of cake flour with green tea powder, respectively.
[c] Each value is expressed as mean ± SD ($n = 4$). Means with different capital letter within a row are significantly different ($P < 0.05$).
[d] Obtained by extrapolation from linear regression analysis.

Table 6
Sensory evaluation of sponge cakes.

	Control[a]	GT10	GT20	GT30
Crust colour	5.9 ± 0.7A[b]	5.7 ± 0.7A	5.6 ± 1.0A	4.4 ± 0.7B
Crumb colour	5.9 ± 0.6A	5.6 ± 0.7A	5.6 ± 0.5A	4.4 ± 1.0B
Sweetness	5.8 ± 0.6A	5.9 ± 0.6A	5.7 ± 0.5A	4.7 ± 0.8B
Flavour	5.8 ± 0.6A	5.9 ± 0.6A	5.9 ± 0.7A	4.8 ± 0.9B
Texture	6.0 ± 0.5A	5.7 ± 0.5A	5.6 ± 0.7A	3.9 ± 0.8B
Overall	5.6 ± 0.5A	5.9 ± 0.6A	5.6 ± 0.7A	4.2 ± 0.6B

[a] Control, GT10, GT20, and GT30: prepared with 0%, 10%, 20%, and 30% replacement of cake flour with green tea powder, respectively.
[b] Seven-point hedonic scale with 1, 4, and 7 representing extremely dislike, neither like nor dislike, and extremely like, respectively. Each value is expressed as mean ± SD ($n = 86$). Means with different capital letter within a row are significantly different ($P < 0.05$).

ven-point hedonic scale, the sensory results of the control, GT10, and GT20 were in the range of 5.6–6.0, indicating that these three cakes were moderately acceptable. However, sensory characteristics liking scores of GT30 were the worst. The sensory characteristics liking results pointed out that a partial replacement of cake flour with up to 20% green tea powder in sponge cakes is satisfactory.

4. Conclusion

A successful and novel formulation of sponge cake production with green tea was developed. Green tea is a good source of catechins and dietary fibre. Sponge cake formulated with partial replacement of cake flour with up to 20% green tea had bioactive components and pleasant tea flavour as compared to cake prepared with 100% cake flour. Green tea sponge cake was good in antioxidant properties. Overall, green tea could be incorporated into cake and provide green tea sponge cake with more functional components and more effective antioxidant properties.

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