Improving the quality properties and antioxidant activities of cake using kumquat (*Fortunella margarita*) fruit powder

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ABSTRACT

The main objective of the present study was to evaluate the effect of substituting 5 and 10% of soft wheat flour with kumquat powder (KP) in cake production as a source of natural antioxidants to obtain cake with improved sensory and nutritional properties, minimize lipid oxidation and extend the shelf-life of cake. The cakes were tested for chemical composition, pasting profile, baking quality, color, sensory properties, and texture. On the other hand, the total phenols, flavonoids and antioxidant activity (DPPH%) of the kumquat cake were determined. Also, fats were extracted from cakes made from KP and antioxidant activities during storage for two weeks at room temperature (20:25˚C) were evaluated by the determination of acid value, peroxide value and thiobarbituric acid. The partial replacement of wheat flour with KP caused significant differences ($p<0.5$) in weight, volume and specific volume, whereas it caused a significant decrease in Luminosity, and a significant increase in red and yellow intensity in the crust and crump. 5% KP cake recorded the best overall acceptability scores and the highest protein content; whereas the highest moisture, ash and fiber were found in cake with 10% KP. DPPH scavenging activities, total phenolic and total flavonoids contents increased by increasing the KP percent in cake. KP had an effect on the stability of the cakes as ketonic reactions was consistently repelled due to its high amounts of phenolic compounds which enable it to play an important role in improving the antioxidant activity of the cake during storage.

Key words: Kumquat, Cake, Phenolic compound, Antioxidant activities.

INTRODUCTION

Since several of the components in citrus fruits are known to promote health and protect against chronic disease, citrus fruits have long been seen as an important component of a balanced and nutrient-rich diet. The small, oval, deep orange fruits range in acidity from sub-acid to acid, have two to five seeds, or none at all, and have a nice flavor. They are additionally slightly juicily flavored [1]. Kumquats in season taste exactly like other citrus fruits; therefore, one may eat them whole, including the skin. Despite this, kumquat research is limited compared to other popular citrus fruits like lemon and orange [2,3]. Among all fruit classes, citrus fruits typically have the highest antioxidant activity, which may help prevent cancer and heart disease [4]. *Fortunella margarita*, or kumquats, are fruits in the *Citrus* genus. Additionally, kumquats are a great source of naturally occurring antioxidants that neutralize the damaging effects of free radicals, including ascorbic acid, carotenoids, flavonoids, and essential oils [5-7].

Almost every country in the subtropical zone is home to kumquat trees. The smallest citrus fruits that may be eaten whole with the skin are kumquat fruits, which have a distinct form, size, color, and taste. These fruits are rich in minerals, vitamins, fibers, and carotenoids. The main constituents are polyphenols with antioxidant qualities, especially flavonoids, of which phloretin is the only characteristic. Their essential oils are abundant in terpenoids, which provide their scent and aroma [8].

Within the *Rutaceae* family, the kumquat is a small, productive shrub with oval or spherical fruit. Its color is golden-yellow. The fruit is frequently utilized for culinary and medicinal purposes. When compared to other citrus fruits, kumquats have distinct sensory and aromatic characteristics. The amount and components of essential oils in kumquat peel have a significant impact on the fruit's flavor, texture, and aromatic properties. In recent years, the majority of uses for kumquats are in processed foods such as cakes, preserved fruits, baked goods, vinegars, jams, jellies, juices, or fresh cuisine [9].

Fortunella margarita Swingle, known as the oval or *Nagami kumquat*, is the smallest citrus fruit and thrives as a native species in central China [10]. With a range of vitamins, amino acids, non-starch polysaccharides, essential oils, limonoids, and flavonoids, it is extremely nutrient-dense [11]. It has considerable amounts of C-glycoside flavonoids and dihydrochalcone compounds [12-16].

Total soluble solids (TSS), which are a mix of sugars and organic acids, are one of the ingredients of kumquat. Maturity Index (MI), which correlates with flavor quality, is indicated as the quotient of TSS per titratable total acidity (TTA). Approximately 80% of TSS is made up of sugars, with sucrose being the most common kind, followed by fructose and glucose [17].

The kumquat has a significant amount of ascorbic acid, a potent antioxidant that the human body cannot produce on its own and must instead be obtained from fruits and vegetables. This functions as an active antioxidant in oxidation and reduction reactions, linking the antioxidant potential of fruits and vegetables to their ascorbic acid level [18]. The entire fruit, including the peel, is used; it can be preserved in sugar syrup or candied. In addition, kumquat is utilized in traditional folk medicine to cure coughs and colds by reducing respiratory tract irritation [19-23].

F. margarita has been utilized to improve human capillaries' permeability and fragility, avoid blood vessel rupture, and slow the hardening of arteries [24]. Phloretin and acacetin, two aglycones of flavonoid C-glycosides found in kumquat, have a wide range of biological actions, including antioxidant activity [25], anti-inflammatory effect, antimicrobial effect [5], antiviral effect [26], and anticancer effect [27-31].

Cakes made using a variety of techniques are crucial to the bakery products industry since demand and production are rising quickly due to urbanization, population growth, simplicity of preparation, and the use of new technologies. Around the world, cake goods are manufactured in a wide range of compositions. The popularity of cake creation stems from the variations in formulations, which are appealing not only for their visual appeal but also for their enticing flavors. Cake goods are still popular due to their easy consumption and sweet, pleasing taste, despite their high calorie content [32,33].

Numerous studies on the phenolic content, chemical composition, and antioxidant potential of kumquat have been released [5,6,11,15,16,19,23] and study was published by Olcay and Demir [34], on the utilization of kumquat in cake. Nevertheless, there aren't enough studies on the use of kumquat in baked goods in the literature. So the current study aimed to evaluate how different substitution rates of kumquat powders (0, 5, and 10%) affected the physical, color, and sensory qualities of cake samples as well as their chemical and antioxidant activity during storage. The findings of this investigation will add to the limited number of evidence regarding the application of kumquat in baked goods.

MATERIALS AND METHODS

Materials

Fresh kumquat fruits (*Fortunella margarita*) were obtained from the Agricultural Research Institute, Giza, Egypt. Wheat flour (*Ttritucum vulgars*) (72% extraction) and other cake ingredients (sugar, margarine, fresh whole egg, skimmed milk powder, baking powder and vanilla) were purchased from a local market in Mansoura city.

Methods

Preparation of kumquat fruit powder. As represented in Figure 1, the kumquat fruits were washed, cut, seeds were separated manually, minced until they become a homogeneous paste and dried in an air oven dryer at 40-50 °C for 24 hours, milled to a fine powder to pass through a 30 mesh sieve, and then kept in glass jars at room temperature (24±1 °C) till analysis and cake preparation.

Technological treatment: preparing the cake mixes. The blends of soft wheat flour (extraction 72%) with kumquat fruit powder flour had the following ratios: 100:0, 95:5 and 90:10 w/w.

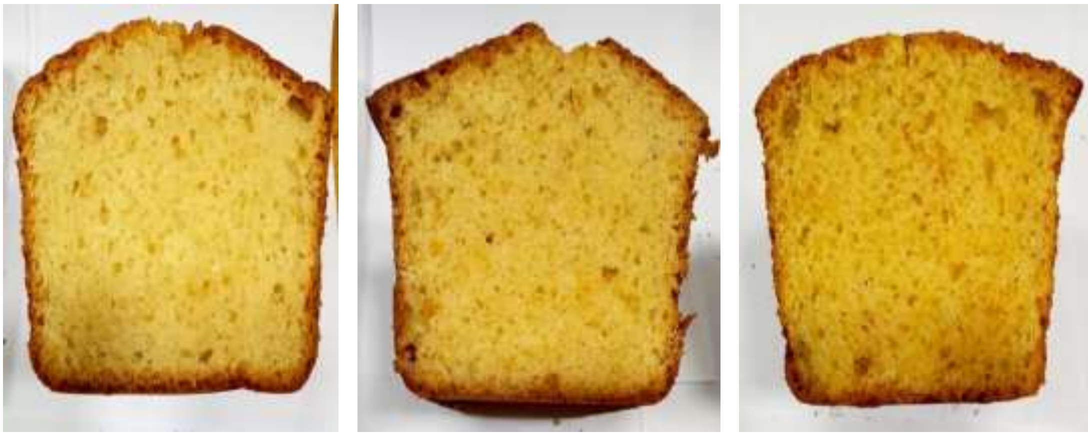
Figure 1. Preparation of kumquat fruit powder

Pasting profile. The rapid-viscoanalyzer tests followed the guidelines developed by the American Association of Cereal Chemists to determine the rheological qualities of the samples [35].

Production of cake samples. The cake samples were prepared using the modified method given by Sharoba et al. [36]. The used formula is represented in table 1. After completely beating the margarine, the sugar was added and stirred until it became smooth like cream. Next, a well-blended egg and vanilla were added and combined. The mixture was mixed with 5, 10% of kumquat powder while the control was without kumquat powder. After it was thoroughly homogenized, the cake batter was poured into a pan that had been buttered and baked at 200 °C for 25 minutes. It was baked, allowed to cool to ambient temperature, and then stored pending analysis for two weeks at room temperature (20:25˚c). Cake samples are represented in Figure 2.

Table (1) Cake formulation (g).

Ingredient	wheat Flour	Sugar	Margarine	Fresh whole egg	Skimmed Milk Powder	Baking Powder	Vanilla
Weight (g)	150	75	35	40	15	7	2



100% wheat flour **5% kumquat** **10% kumquat**

Figure 2. Photos of cake with kumquat powder

Baking quality. Triplicate measurements of the weight, volume, and specific volume were carried out.

Color attributes. A white Hunter Lab color standard tile (LXNO. 16379): X = 77.26, Y = 81.94, and Z = 88.14 was used to calibrate a CIE lab color scale (Hunter, Lab Scan XE, Reston, VA) that was used to measure the color of the cake samples as described by Sapers & Douglas [37].

Sensory evaluation. The sensory characteristics of cake samples were based on the method developed by Hoojjat and Zabik [38].

Each formulation was analyzed by twenty untrained panelists who were regular cake consumers. Based on the tasters' evaluations of appearance, color, flavor, texture, mouthfeel, and overall acceptability, the samples were graded from 0 to 10.

Texture analysis. With the use of a cylinder probe (TA. AACC36) and a texture meter (Brookfield, CT3-10 kg, USA), the texture of the cake samples was examined. A two-bit texture profile curve was produced by programming the texture profile analysis method, which was used to quantify the hardness, adhesiveness, resilience, cohesiveness, springiness, gumminess, and chewiness. The test speed was 2.5 mm/s, and the trigger load was 9.00 N g.

Analytical methods.

Chemical composition. The Association of Official Analytical Chemists [35] standards were used to determine the quantities of protein, ash, crude fiber, and fat. The following was the method used to calculate the carbohydrate content: Carbohydrates = 100 - (% fat + % ash + % crude Fiber +% protein+% moisture)

Preparing methanolic extract. The methanolic extract of the cakes was carried out according to the method of Elbadrawy and Mostafa [39].

Determination of total phenol content (TPC). The total phenolic content of the sample extracts was determined colorimetrically using the Folin-Ciocalteau reagent based on the procedure outlined by Mythili [40].

Determination of total flavonoid content (TFC). The total flavonoid content of sample extracts was determined based on the technique outlined by Ebrahimzadeh et al. [41] and Nabavi et al. [42].

Determination of DPPH radical scavenging activity. Radical scavenging activity of the tested compounds' ability was assayed using the method of Burits and Bucar [43].

Fractionation and identification of phenolic compounds. By using HPLC, phenolic compounds were identified, separated, and determined using the Goupy et al. [44] technique.

Extraction of oils: The oils of the cakes were extracted, as mentioned by Elbadrawy and Sello [45].

Chemical analysis of the extracted oils.

Each oil sample's acid and peroxide values were calculated using the procedure outlined in AOAC [35]. Thiobarbituric acid (TBA) value was carried out using the techniques previously described by Ottolenghi [46]; Kikuzaki and Nakatani [47].

Statistical analysis. The averages ± standard deviation (n = 3) and ANOVA variance analysis were used to express the results, and the average comparison Ducan Multiple Range was set to <0.05 [48]. The Statistical Package for Social Science (SPSS, V21.0) for Windows (SPSS, Inc., Chicago, IL, USA) was used for all statistical processing.

RESULTS AND DISCUSSION

Chemical composition of raw materials. The chemical composition of wheat flour and kumquat powder is given in table 2. These materials regarding chemical composition were evaluated for moisture, protein, ash, fat, crude fiber and carbohydrates. Data show that kumquat powder is higher in ash, fibers and carbohydrates, compared with WF as recorded 2.38±0.065 %, 3.60±0.085 % and 82.73±0.070%, respectively. On the other hand wheat flour was higher in moisture, protein and fat compared with kumquat powder as recorded 11.68±0.080, 11.29±0.035 and 1.63±0.035%, respectively.

As expected, wheat flour had a higher protein content than kumquat powders due to its gluten content. The whole kumquat has 9.92% moisture, 4.39% protein, 27% fats, 5.09% crude fiber, 2.08% ash, and 77.23% carbohydrates [49]. These results were closed to further analysis. In the meantime, kumquat fruits have 83.73% moisture, 1.86% protein, 0.82% ash, and 2.75% crude fiber, according to Mousa [50]. Additionally, Olcay and Demir [34] discovered that the protein content of powdered kumquat ranged from 0.98% to 1.11%.

According to the National Nutrient Database [51], a 100 g raw kumquat fruit provides 78.86 kcal of calories, 1.88 g of protein, 0.86 g of fat, 15.9 g of carbohydrates, 0.52 g of ash, 9.36 g of total sugar, 6.5 g of dietary fibre, and 43.9 mg of ascorbic acid. Comparing with orange (*Citrus sinensis*) the kumquat moisture was lower but the ash, lipids and fiber were higher than orange (*C. sinensis*) [52].

Table (2) Proximate chemical composition of raw materials, %dw

Samples	**Chemical composition of raw materials (% on dry weight basis)**					
	Moisture	**Protein**	**Ash**	**Crude fiber**	**Fat**	**Carbs.**
Wheat flour	11.68a ±0.080	11.29a ±0.035	0.82b ±0.020	0.75b ±0.040	1.63a ±0.035	73.83b ±0.090
Kumquat powder	6.62b ±0.150	3.28b ±0.030	2.38a ±0.065	3.60a ±0.085	1.39b ±0.040	82.73a ±0.070
LSD at 0.05	**0.17**	**0.16**	**0.11**	**0.31**	**0.19**	**0.40**

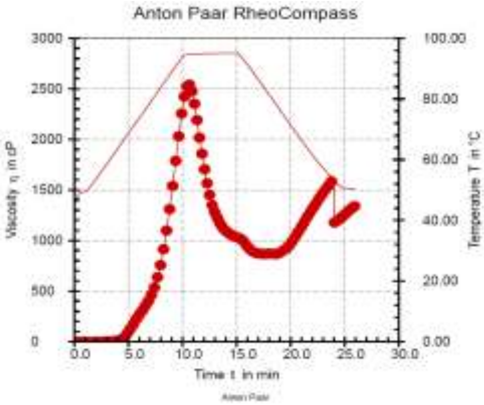
The mean value for triple analyses ± standard deviation (SD) is used to express the results. Significant differences in the same column (P<0.05) are indicated by different superscripted lowercase letters.

Pasting profile. Viscosity is seen as a component of a food's wider rheological characteristics. The fast visco-analyzer properties of dough samples containing the flour mixtures are displayed in table 3 and Fig. 3. The pasting viscosities of the soft wheat flour control sample were as follows: peak viscosity: 2542 CP, trough viscosity: 1524.3 CP, breakdown viscosity: 1678 CP, final viscosity: 1378 CP, setback viscosity: 1194 CP. The sample with 5% kumquat powder reduced the peak, trough, breakdown and setback viscosities of soft wheat flour from 1524.3 to 1163 CP, 1678 to 1546 CP and 1194 to 1148 CP, respectively, while increasing the peak viscosity and final viscosity, 2542 to 2679 CP and 1378 to 1531 CP, respectively. According to Oro et al. [53], peak viscosity is a measure of the maximal swelling of starch granules after heating and is associated with the starch's ability to absorb water. The peak viscosity significantly dropped after WBDF was added, possibly as a result of WBDF and starch granules competing with one another for water. The amount of starch, amylose, amylopectin, and the ratio of amylose to amylopectin all affect the final viscosity [54].

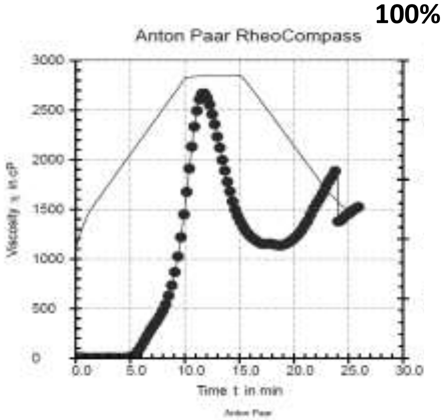
In contrast, the samples with 10% kumquat powder enhanced all the viscosity parameters: Peak viscosity - 3079 CP, trough viscosity - 1580 CP, breakdown viscosity - 1756 CP, final viscosity - 1627 CP, setback viscosity - 1452 CP. The thermal data for both 5% kumquat powder and 10% kumquat powder samples were as follows: Peak time - 11.8-11.2 min, pasting temperature - 64.8-67.2°C, peak temperature - 94.8-94.8°C. According to Hallen et al. [55], there may be less starch available for gelatinization, which could lead to the pasting profile degrading. Similar findings were reported by Symons and Brennan [56]. When 5% barley b-glucan fibre fractions were added in place of wheat starch, the peak viscosity decreased because there was less starch available for gelatinization and less water available for the initial swelling of the starch granule. Adebowale et al. [57] linked the pasting temperature with the water-binding capacity.

Table (3) Effect of kumquat powder on pasting properties (RVA)

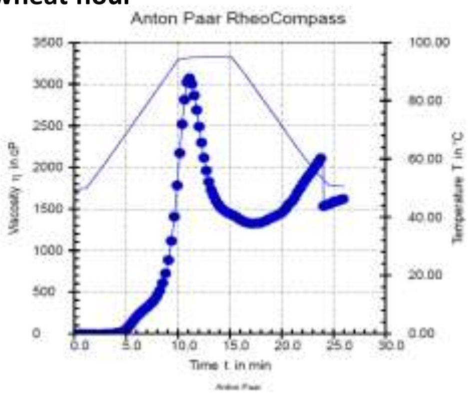
Samples	Peak Vis. (CP)	Trough1 (CP)	Break down (CP)	Final Vis. (CP)	Setback (CP)	Peak Time (Min)	Pasting Temp. (ºC)	Peak Temp. (ºC)
Control (100 % soft wheat flour)	2542	1524.3	1678	1378	1194	10.6	60.3	94.7
5% kumquat powder + 95% soft wheat flour	2679	1163	1546	1531	1148	11.8	64.8	94.8
10% kumquat powder + 90% soft wheat flour	3079	1580	1756	1627	1452	11.2	67.2	94.8



100% wheat flour



95% wheat flour + 5%



90% wheat flour +10%

Fig 3. Rapid viscoanalyzer parameters of dough samples with 5% and 10% kumquat powder

Baking quality. The baking quality values of cake samples in weight (g), volume (cm3) and specific volume (cm3/g) were represented in table 4. The partial replacement of wheat flour with 5% and 10% kumquat powder caused a significant differences ($p<0.5$) in weight, volume and specific volume compared with the control cake sample. Although cake weight increased significantly ($p<0.5$) as the percentage of kumquat powder substitution increased in the cake formulation, no significant differences were noticed between cake samples with 5% or 10% kumquat powder in cake volume at $p<0.5$. Specific volume recorded the highest value for the cake sample with 5% kumquat powder (1.91±0.035 cm3/g) followed by the control cake sample (1.74±0.025 cm3/g) then the cake sample with 10% kumquat powder (1.64±0.030 cm3/g).

Table (4) Baking quality of cakes with kumquat powder

Samples	Physical parameters		
	Weight (g)	Volume (cm^3)	Specific volume (cm^3/g)
Control (100% wheat flour)	57.13c±0.300	98.73b±1.275	1.74b±0.025
5% kumquat powder + 95% wheat flour	59.05b±0.370	112.60a±2.600	1.91a±0.035
10% kumquat powder + 90% wheat	68.13a±0.380	111.80a±1.200	1.64c±0.030
LSD at 0.05	**0.89**	**5.02**	**0.08**

The mean value for triple analyses ± standard deviation (SD) is used to express the results. Significant differences in the same column (P<0.05) are indicated by different superscripted lowercase letters.

The weight of the cake samples with kumquat powder was slightly higher than that of the control sample. It is believed that the levels of substituted fibers, which absorb more water, are the cause of this observation. Similar results on weight changes depending on substitution level were also reported for kumquat powder by Olcay and Demir [34], citrus peel powder by Shin [58] and sweet potato powder by Samiha [59]. On the other hand, because dietary fiber dilutes gluten, Welti-Chanes et al. [60] observed a low volume index when citrus fiber levels were increased during the manufacture of citrus dietary fiber-enriched biscuits.

Color characteristics. Color is a quality attribute that consumers consider important when choosing foods. Color, along with sweetness, acidity, aroma, and size, contributes to consumer acceptability [61]. For this reason, color parameters were examined to find out how different concentrations of kumquat powder affected cake samples. Color characteristics (L*, a* and b*) in the crumb and crust of cake samples are shown in table 5. The partial replacement of wheat flour with 5% and 10% kumquat powder caused a significant decrease ($p<0.5$) in luminosity, and a significant increase ($p<0.5$) in red intensity and yellow intensity in the crust and crump when compared with the control cake sample.

Because the powdered kumquat was employed as a raw material with a natural color, the L* value decreased as the substitution rate increased. In contrast to the L* value, the a* and b* values in the cake crumbs increased as the replacement rate increased. The orange color of the kumquat powders employed in the cake's manufacturing is assumed to be the cause of these findings.

Table (5) Color attributes of cakes with kumquat powder

Samples	Crumb color parameters			Crust color parameters		
	*L**	*a**	*b**	*L**	*a**	*b**
Control (100% wheat flour)	70.42a ±1.015	0.43c ±0.110	8.67c ±0.370	39.20a ±0.230	8.17c ±0.255	13.31c ±0.025
5% kumquat powder + 95% wheat flour	66.16b ±0.935	5.65b ±0.120	19.43b ±0.260	34.52c ±0.295	10.99b ±0.225	21.56b ±0.110
10% kumquat powder + 90% wheat flour	64.39c ±1.375	7.65a ±0.185	24.31a ±0.340	36.85b ±0.205	13.13a ±0.210	29.16a ±0.075
LSD at 0.05	**0.53**	**0.09**	**0.88**	**0.67**	**0.05**	**0.21**

The mean value for triple analyses ± standard deviation (SD) is used to express the results. Significant differences in the same column (P<0.05) are indicated by different superscripted lowercase letters.

The crumb of cake sample with 10% kumquat powder recorded the highest a* and b* values (7.65±0.185 and 24.31±0.340), whereas it recorded the lowest L* value (64.39±1.375). Luminosity recorded the lowest value in the crust of cake sample with 5% kumquat powder (34.52±0.295), whereas a* and b* values recorded the highest values (13.13±0.210 and 29.16±0.075) in the cake sample with 10% kumquat powder. It is noticed that when the substitution rate increased, L* value decreased probably due to browning reactions. The results were in the same trend with the results of Olcay and Demirs [34]. Also similar results regarding color variations based on substitution rate were documented in earlier studies involving cake samples enhanced with mandarin powder [62], orange pomace powder [63], citrus peel powder [58] and citrus mandarin powder [64]. On the other hand according to the results of Aamer [7], Kumquat purée had higher values of the Hunter Lab's L (lightness), a (redness), and b (yellowness) measurements than kumquat paste.

Sensory properties. The data represented in table 6 illustrates the effect of substituting 5% and 10% wheat flour by kumquat powder in cake samples compared with the100% wheat flour cake control on the mean scores of sensory characteristics. No significant differences were observed between kumquat cake samples and control in appearance and taste at p<0.5, whereas substitution of 5% and 10% wheat flour by kumquat powder in cake samples significantly affected the texture and mouth-feel scores compared with the control cake sample at p<0.5. The best color and flavor were achieved in the cake sample with 10% kumquat powder (8.90±0.48 and 9.00±0.58), meanwhile the best texture score was for the cake sample with 5% kumquat powder (8.80±0.54). According to the overall acceptability scores, 5% kumquat powder cake was recorded as the best one followed by the control sample, 10% kumquat powder cake, which recorded 9.20±0.37, 8.80±0.56 and 8.50±0.55, respectively.

Results were in line with Aamer [7] who reported that the prepared functional beverages were more widely accepted when fresh kumquat paste and purée were added to the whey and permeate. Also, similar results were reported by Olcay and Demir [34] as they found that the substitution rate of kumquat powder used affected the sensory properties of samples. As the substitution rate increased, the taste and general acceptability of cakes significantly decreased. The results of Çakmakç et al. [65] were in the same trend as they reported that the panelists found that the ice cream's slightly yellow-mottled orange-threaded color, which was achieved by adding kumquat paste, was appealing. The addition of kumquat powder significantly increased (P <0.5) the overall acceptability of ice cream compared with the control. Also the results are similar with findings of Zaker et al. [66] who reported that cakes that contained 10% powdered orange peel exhibited a greater level of acceptance compared to other samples.

Table (6) Sensory properties of cakes with kumquat powder

Samples	Appearance	Color	Taste	Flavor	Texture	Mouth Feel	Overall Acceptability
Control (100% wheat	8.60a ±0.36	7.50b ±0.24	9.10a ±0.59	8.70b ±0.48	8.40b ±0.58	9.20a ±0.43	8.80b ±0.56
5% kumquat powder	8.80a ±0.47	8.20ab ±0.41	8.50a ±0.42	8.90ab ±0.39	8.80a ±0.54	7.40b ±0.41	9.20a ±0.37
10% kumquat powder	9.00a ±0.61	8.90a ±0.48	7.80a ±0.57	9.00a ±0.58	6.90c ±0.45	6.50b ±0.58	8.50c ±0.55
LSD at 0.05	**ns**	**1.04**	**ns**	**0.22**	**0.15**	**1.31**	**0.24**

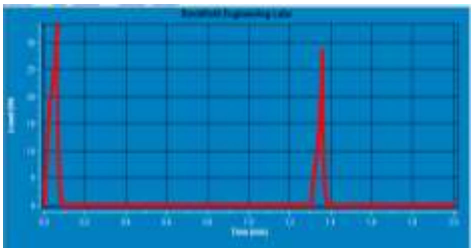
The mean value for triple analyses ± standard deviation (SD) is used to express the results. Significant differences in the same column (P<0.05) are indicated by different superscripted lowercase letters.

Texture profile analyses. The texture profile of kumquat cake samples was represented in table 7 and Fig. 4. The hardness of the cake was affected by substituting 5% and 10% wheat flour by kumquat powder compared with the 100% wheat flour cake (control). Hardness is the height of the force peak of the first compression cycle [67]. In this study, the maximum force required to compress the cake samples recorded 33.11, 24.91, 31.07 N for the control sample, 5% and 10% kumquat powder cake, respectively.

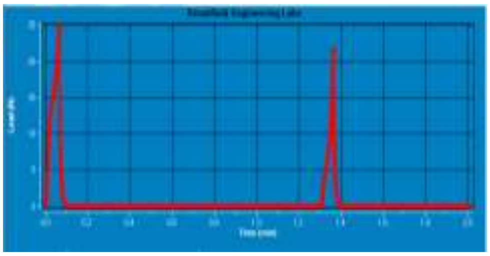
The addition of kumquat flour has a greater effect on cake adhesiveness as it decreased its score compared with the control cake sample. The kumquat cake samples with 5% and 10% were found to have less in springiness, gumminess and chewiness than the control cake sample. Olcay and Demir [34] revealed that because dietary fiber dilutes gluten, the hardness value of the cake increased as the substitution rate of kumquat powder increased as mentioned by Welti-Chanes et al. [60]. Similar results on firmness and springiness values changes depending on substitution rate were also reported for different citrus fruit substituted cakes such as mandarin [62], orange [63], citrus peel [58], citrus mandarin [64] and dangyuja [68]. Also, Walker et al. [69] noted a decrease in the springiness of muffins enriched with grape pomace powder and ascribed it to the samples' smaller volume as a result of the fiber's greater ability to absorb water.

Table (7) Texture profile analysis of cakes with kumquat powder

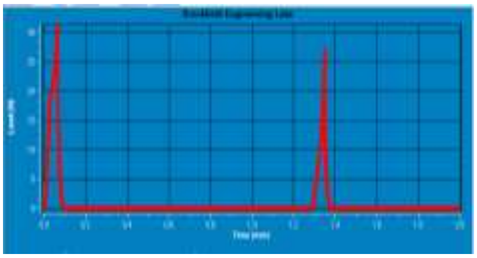
Texture profile parameters	Hardness (n)	Adhesiveness (mJ)	Resilience	Cohesiveness	Springiness (mm)	Gumminess (n)	Chewiness (mJ)
Control (100% wheat flour)	33.11	18.00	0.13	0.51	7.04	16.96	14.93
5% kumquat powder + 95% wheat flour	24.91	15.00	0.14	0.49	6.93	12.33	10.73
10% kumquat powder + 90% wheat flour	31.07	10.00	0.14	0.49	6.73	15.26	12.82



100% wheat flour



95% wheat flour +



90% wheat flour +

Fig 4. Texture profile of dough samples with 5% and 10% kumquat powder

Chemical composition of cake samples. Table 8 shows the chemical composition of cake blended with (5 and 10 %) kumquat powder in comparison with the control cake sample (100% wheat flour). Substituting 5% and 10% wheat flour by kumquat powder in cake samples significantly affected protein, ash, fiber, fat and carbohydrate contents; however, no significant differences were noticed in fat contents at p<0.5 in comparing with wheat flour cake (control). Moisture content recorded 26.14±0.185, 25.73±0.160 and 27.02±0.110% for control, 5% kumquat powder cake and 10% kumquat flour cake, respectively. Comparing with wheat flour cake (control), it could be noticed that cake with 5% kumquat powder scored the highest protein content (8.88±0.040%); whereas the highest moisture, ash and fiber found in cake with 10% kumquat flour (27.02±0.110, 1.87±0.015 and 0.99±0.030)%, respectively.

Table (8) Chemical composition of cakes with kumquat powder, %dw

Samples	**Chemical composition of raw materials (% on dry weight basis)**					
	Moisture	**Protein**	**Ash**	**Crude fiber**	**Fat**	**Carbs.**
Control (100% wheat flour)	26.14b ±0.185	7.66b ±0.045	1.34c ±0.010	0.43c ±0.020	23.16 ±0.035	41.27a ±0.100
5% kumquat powder + 95% wheat flour	25.73c ±0.160	8.88a ±0.040	1.68b ±0.015	0.71b ±0.025	23.12 ±0.030	39.88c ±0.115
10% kumquat powder + 90% wheat flour	27.02a ±0.110	7.10c ±0.030	1.87a ±0.015	0.99a ±0.030	23.08 ±0.040	39.94b ±0.135
LSD at 0.05	**0.09**	**0.02**	**0.03**	**0.01**	**ns**	**0.04**

The mean value for triple analyses ± standard deviation (SD) is used to express the results. Significant differences in the same column (P<0.05) are indicated by different superscripted lowercase letters.

The obtained results for the proximate composition and dietary fiber are comparable with findings reported by Zaker et al. [66] who reported that when orange peel powder concentration increased during cake preparation, the amount of protein and fat reduced and the amount of dietary fiber increased. The results of Nassar et al. [70] and Bandyopadhyay et al. [71] were in the same trend.

DPPH radical scavenging activity, total phenolic contents, and total flavonoid content of the cake sample. The highest absorption of DPPH, a stable free radical, in methanol occurs at 517 nm. When DPPH comes into contact with a material that donates protons, like antioxidants, the radical is scavenged and the absorbance at 517 nm decreases [72]. Phenols are crucial components of plants since their hydroxyl groups enable them to scavenge free radicals [73]. Numerous investigations have revealed a strong connection between antioxidant activity and phenols. Deeply colored fruits and vegetables are recognized to be excellent providers of carotenoids and phenolics, such as flavonoids and anthocyanins [74 -76]. Flavonoids' hydroxyl groups give them the potential to scavenge, making them crucial components of plants. The anti-oxidative activity may be directly aided by the flavonoids. It is well known that polyphenolic chemicals have inhibitory effects on human mutagenesis and carcinogenesis when ingested up to 1 g daily from a diet rich in fruits and vegetables [77].

Based on this idea polysaccharides' antioxidant activity can be defined as their capacity to scavenge DPPH free radicals. Table 9 represents the DPPH scavenging activities, total phenolic contents (TPC) and total flavonoids content (TFC) of cake extracts blended with (5 and 10 %) kumquat powder in comparison with the control cake sample (100% wheat flour). Substituting 5% and 10% wheat flour by kumquat powder in cake samples affected significantly DPPH, TPC and TFC at $p<0.5$ in comparing with wheat flour cake (control). It is obvious that DPPH, TPC and TFC increased significantly ($p<0.5$) by increasing the kumquat powder percent in cake. The extract of cake sample with 10 % kumquat powder recorded the highest values of DPPH scavenging (69.52±0.620 %), total phenols (62.20±0.800 mg GAE /g) and total flavonoids (34.83±0.890 µg QE/ g), followed by the extract of cake sample with 5 % kumquat powder which recorded 52.69±0.800, 55.15±0.940 mg GAE /g and 25.51±0.860 µg QE/ g for DPPH, TPC and TFC, respectively. These results unequivocally show that the various amounts of kumquat powder in the cakes positively correlate with one another. Consequently, the strong antioxidant activity of kumquat may be due to its high phenolic component content [78]. According to Al-Sayed [49], the whole kumquat powder's total polyphenol and flavonoid levels were determined, and they were found to be 51.85 mg/g and 0.24 mg/g, respectively. Additionally Çakmakç et al. [65] revealed that 1 mg of ice cream samples B, C, and D contained 491.85, 515.56, and 659.63 µg GAE of phenols, respectively. In terms of flavonoids, 1 mg of ice cream samples containing 5, 10, and 15% kumquat paste provided 917.27, 1059.09, and 1148.18 µg QE of flavonoids, respectively.

According to the results of Aamer [7], kumquat paste and purée had substantial phenolic contents, ranging from 309.00 mg and 393.89 mg/100g, respectively. These numbers are more than those stated by Ramful [11], who said that kumquat fruits had a total phenolic content of 169.4 mg/100g fresh weight. It was also observed that the flavonoid concentration of the kumquat paste and purée was quite high, at 14.23 and 17.58 mg/100g, respectively. Nonetheless, it has been discovered that the overall flavonoid content is more than what Wang et al. [79] stated. The findings also revealed that the antioxidant activity percentages of kumquat paste and purée were comparatively high, at 42.74% and 56.66%, respectively. These findings supported the potential use of kumquat paste and purée as a natural source of antioxidants. Jayaprakasha [24] found that *Fortunella margarita*, the fruit of the kumquat tree, has potent antioxidant properties and a high capacity to scavenge free radicals, making it a potentially health-promoting fruit.

Table (9) DPPH scavenging activities, total phenolic contents (TPC) and total flavonoids content (TFC) of cake sample extracts

Samples	Total phenolic contents (TPC) (mg GAE /g sample)	Total flavonoids content (TFC) µg QE/ g sample	DPPH radical scavenging %
Control (100% wheat flour)	50.212c ±0.948	19.92c ±0.600	21.05c ±0.490
5% kumquat powder + 95%	55.15b ±0.940	25.51b ±0.860	52.69b ±0.800
10% kumquat powder + 90%	62.20a ±0.800	34.83a ±0.890	69.52a ±0.620
LSD at 0.05	**2.38**	**1.93**	**0.35**

The mean value for triple analyses ± standard deviation (SD) is used to express the results. Significant differences in the same column (P<0.05) are indicated by different superscripted lowercase letters.

Phenolic compounds. Due to their antioxidant properties, phenolic compounds have received a lot of attention lately. High concentrations of these compounds may lower the chance of developing certain diseases [80]. Table 10 presents the primary phenolic components found in kumquat powder and cakes supplemented with 5% and 10% kumquat powder. Results show that the predominant phenolic compounds in kumquat powder were syringic, quercetin, sinapic, rosmarinic, apigenin and ferulic (171.91, 98.09, 75.81, 53.41, 24.45 and 13.32 ppm, respectively). Data in table 10 show that phenolic compounds in fortified cakes with 5 and 10% kumquat powder recorded higher content in vanillic, syringic, protocatechuic, ferulic and cateachin (66.54 vs 80.76, 36.69 vs 47.16, 15.19 vs 0.68, 3.36 vs 3.97 and 1.89 vs 3.04 ppm) whereas in the control cake their values reached 78.95, 37.18, 4.23, 3.77 and 3.63 ppm, respectively.

Results obtained by Al-Sayed et al. [49] showed that the two main flavonoid components in kumquat were rosmarinic (144.10 µg/g) and naringeen (50.36 µg/g), whereas Lou et al. [16] reported that no nobiletin and tangeretin were found in kumquat . On the other hand, kumquat flavonoid profiles differed significantly from citrus flavonoid profiles, which are dominated by polymethoxy flavones such as tangeretin and nobiletin, as well as naringin and hesperidin.

The main flavonoids that were quantified in the kumquat's edible portion were quercetin, narirutin, rhoifolin, kaempferol, luteolin, poncirin, hesperidin, neoponcirin, and eriocitrin [81]. Meanwhile Lou and Ho [82] found that Phloretin, acacetin, and apigenin are the main aglycones in kumquat, whereas dihydrochalcone, flavone, and flavanone are the major flavonoids.

Table (10) Phenolic compounds (ug/g) of kumquat powder and cakes with kumquat powder.

Compound	Kumquat powder	Control (100% wheat flour)	5% kumquat powder + 95% wheat flour	10% kumquat powder + 90% wheat flour
Gallic	ND	ND	ND	ND
Protocatechuic	8.54	4.23	15.19	0.68
p-hydroxybenzoic	ND	ND	ND	ND
Gentisic	ND	ND	ND	ND
Cateachin	ND	3.63	1.89	3.04
Chlorogenic	ND	ND	ND	ND
Caffeic	5.35	ND	0.13	0.13
Syringic	171.91	37.18	36.69	47.16
Vanillic	ND	78.95	66.54	80.76
Ferulic	13.32	3.77	3.36	3.97
Sinapic	75.81	0.27	1.00	1.44
Rutin	2.78	ND	ND	ND
p-coumaric	2.88	ND	ND	ND
Apigenin-7-glucoside	15.58	ND	ND	ND
Rosmarinic	53.41	ND	ND	ND
Cinnamic	6.01	0.38	0.14	0.17
Qurecetin	98.09	ND	0.50	1.48
Apigenin	24.45	ND	ND	0.68
Kaempferol	ND	ND	ND	ND
Chrysin	ND	ND	ND	ND

Effect of storage period on AV, PV and TBA. The development of free fatty acid content in oils is usually considered to be one of the main parameters used in evaluating the quality of the oil [83].

Table (11) Effect of kumquat powder addition on some indices extracted from fortified cakes during storage for two weeks in room temperature (20:25˚c)

Samples	Acid value (mg/g)			Peroxide value (meq/k)			TBA (abs at λ = 533 nm)		
	Zero time	One week	Two weeks	Zero time	One week	Two weeks	Zero time	One week	Two weeks
Control (100% wheat flour)	2.43a± 0.040	2.11a± 0.020	1.86a± 0.035	0.40a± 0.010	2.76a± 0.010	4.22a± 0.013	0.378a ±0.016	0.564a ±0.012	0.758a ±0.015
5% kumquat powder +	2.30b± 0.020	1.97b± 0.020	1.64b± 0.040	0.37b± 0.015	2.48b± 0.010	3.34b± 0.021	0.357a ±0.024	0.472b ±0.016	0.669b ±0.017
10% kumquat powder +	0.91c± 0.010	1.21c± 0.014	1.58c± 0.020	0.36b± 0.015	2.38c± 0.015	3.18c± 0.011	0.285b ±0.019	0.476b ±0.013	0.617c ±0.016
LSD at 0.05	**0.03**	**0.048**	**0.03**	**0.02**	**0.002**	**0.04**	**0.05**	**0.034**	**0.03**

The mean value for triple analyses ± standard deviation (SD) is used to express the results. Significant differences in the same column ($P<0.05$) are indicated by different superscripted lowercase letters.

From table 11, it is noticed that the acid value increased by increasing storage time in cake samples with 5% and 10% kumquat powder. Different results were observed in acid values between the control without kumquat powder which reached 1.86±0.035mg KOH/gm oil and those fortified with 5% and 10% kumquat powder which reached 1.64+0.040 and 1.58±0.020 mg KOH/gm oil respectively, after two weeks of storage. The effect of kumquat powder during the storage period on PV values of lipids extracted from fortified cakes samples are shown in table 11. Results show that peroxide value significantly decreased ($p <0.05$) in cakes fortified with 5% and 10% kumquat powder (3.34±0.021 and 3.18±0.011 meq/kg, respectively) than those of control which reached 4.22±0.013meq/kg after two weeks of storage. Data in table 11 show that lipids extracted from fortified cakes with 5 and 10 % kumquat powder recorded a significant decrease ($p<0.05$) in TBA values (0.669±0.017 and 0.617±0.016, respectively) than those of control without kumquat powder which reached 0.758+0.015. The results showed that kumquat powder influenced the stability of the cakes as ketonic reactions was consistently repelled due to its high amounts of phenolic compounds which enable it to play an important role in improving the antioxidant activity in cake during storage for two weeks in room temperature. Results were in the same trend of the results of Ucom et al. [84] who stated that cakes containing grapefruit peel powder had improved shelf stability, reduced FFA and PV values, and stronger antioxidant scavenging activity in comparison to the control cakes.

CONCLUSION

Kumquat fruit has a high concentration of dietary fiber, flavonoids and total phenolic compounds which enhance its potent antioxidant properties. Kumquat is a good substitute for other crops in terms of planting, marketing, and consumption since it may support food and nutritional security and sovereignty while giving agricultural households a source of income. Consequently, kumquat fruit can be used as a suitable source of natural additives in cake to enrich sensory properties and nutritional characteristics, especially for the phenolic contents and antioxidant activities during storage.

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تحسين خصائص الجودة والأنشطة المضادة للأكسدة للكيك باستخدام مسحوق فاكهة الكمكوات

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الملخص العربي

استهدفت الدراسة تقييم تأثير استبدال دقيق القمح بنسبة 5 و10% بمسحوق فاكهة الكمكوات في إنتاج الكيك كمصدر لمضادات الأكسدة الطبيعية للحصول على كيك ذات خصائص حسية وغذائية جيدة مع خفض أكسدة الدهون و إطالة العمر الافتراضي للكيكة. تم اختبار الكيك من حيث التركيب الكيميائي، وخواص العجينة، وجودة الخبز، واللون، والخصائص الحسية، والملمس. من ناحية أخرى، تم تحديد إجمالي الفينولات والفلافونويدات ونشاط مضادات الأكسدة (DPPH) في كيك الكمكوات. كما تم استخلاص الدهون من الكيك وتقييم النشاط المضاد للأكسدة أثناء التخزين لمدة أسبوعين في درجة حرارة الغرفة من خلال تحديد قيمة الحمض وقيمة البيروكسيد وحمض الثيوباربيتوريك. أدى الاستبدال الجزئي لدقيق القمح بمسحوق الكمكوات 5% و 10% إلى اختلافات معنوية في الوزن والحجم والحجم النوعي، في حين أدى إلى انخفاض معنوي ($p<0.5$) في اللمعان وزيادة معنوية في شدة اللون الأحمر وكثافة اللون الأصفر في القشرة واللب مقارنة بعينة الكيك الكنترول. وفقا لدرجات القبول العام، سجلت عينة كيك الكمكوات 5% الأفضل، تلتها عينة كنترول ثم كيك الكمكوات 10% . سجلت الكيكة التي تحتوي على 5% من مسحوق فاكهة الكمكوات أعلى محتوى من البروتين ؛ في حين أن أعلى نسبة رطوبة ورماد وألياف وجدت في كيك الكمكوات 10% ، ارتفع محتوى الفينولات والفلافونويد الكلية و أنشطة الكسح بشكل معنوي بزيادة نسبة الكمكوات في الكيكة. أدت إضافة مسحوق فاكهة الكمكوات للكيك إلى تحسين الخواص المضادة للأكسدة وثبات الكيك حيث يتم الحد من التفاعلات الكيتونية بسبب احتوائه على كميات عالية من المركبات الفينولية مما يمكنه من لعب دور مهم في تحسين نشاط مضادات الأكسدة في الكيك أثناء التخزين.

الكلمات المفتاحية: الكمكوات، الكيك، المركبات الفينولية، أنشطة مضادات الأكسدة