Electronic Letters on Science & Engineering 16(2) (2020)
Available online at dergipark.org.tr/else

The Usage Possibilities of Kumquat Fruit Dried by Different Techniques in The Production of Biscuits

Nezahat OLCAY[1*], Mustafa Kürşat DEMİR[1]

[1]Department of Food Engineering, Faculty of Engineering and Architecture, University of Necmettin Erbakan, Demeç Street, 42090, Konya, Turkey
olcaynezahat@gmail.com, mkdemir@konya.edu.tr
ORCID: 0000-0003-3302-8969, 0000-0002-4706-4170

Abstract: Kumquat (*Fortunella margarita*) is a highly nutritious citrus fruit and used in traditional Chinese medicine due to its therapeutic effect against diseases. Due to its phenolic compounds, kumquat demonstrates high antioxidant activity and may, therefore, be evaluated as an ingredient to obtain functional foods. In this study, kumquat fruit which was dried by different techniques (convection, microwave and vacuum) was partially (10%, 20% and 30%) replaced with wheat flour in the formulation of biscuits. In this context, drying characteristics of kumquat powders dried by different techniques as well as some physical (color, texture, diameter, thickness, spreading ratio), chemical (moisture, ash, crude fat, crude protein, carbohydrate, energy, total phenolic and phytic acid content) and sensory properties of the biscuits were investigated. The L* values decreased, and a* and b* values increased with the usage of kumquat powder in the biscuit formulation. When the kumquat fruit powder substitution rate increased from 0% to 30%; the total phenolic content of biscuit samples increased from 746.18 µg GAE/mg to 2080.10 µg GAE/mg, while the content of phytic acid decreased from 116.86 mg/100 g to 53.60 mg/100 g. 10% kumquat powder substitution provided the most suitable rate for sensory acceptability of biscuits. The usage of kumquat powders in the production of biscuits may improve both sensory properties and functionality of end products. Also, microwave and vacuum drying may be used as suitable techniques to obtain kumquat powder.

Keywords: Kumquat, *Fortunella margarita*, microwave drying, vacuum drying, biscuit

Farklı Tekniklerle Kurutulan Kamkat Meyvesinin Bisküvi Üretiminde Kullanım Olanakları

Nezahat OLCAY[1*], Mustafa Kürşat DEMİR[1]

[1]Department of Food Engineering, Faculty of Engineering and Architecture, University of Necmettin Erbakan, Demeç Street, 42090, Konya, Turkey

Özet: Kamkat (*Fortunella margarita*) yüksek besin değerine sahip bir narenciye meyvesi olup, hastalıklara karşı terapötik etkisi nedeniyle geleneksel Çin halk tıbbında kullanılmaktadır. Fenolik bileşik içeriğiyle kamkat, yüksek antioksidan aktivite göstermekte ve bu özelliği ile fonksiyonel gıda üretiminde potansiyel bir bileşen olarak değerlendirilebilmektedir. Bu çalışmada, farklı tekniklerle (konveksiyon, mikrodalga ve vakum) kurutulan kamkat meyvesi, bisküvi formülasyonunda buğday ununa (%10,%20 ve %30) ikame edilmiştir. Bu bağlamda, farklı tekniklerle kurutulan kamkat tozlarının kurutma özellikleri ile üretilen bisküvilerin bazı fiziksel (renk, tekstür, çap, kalınlık, yayılma oranı), kimyasal (nem, kül, ham yağ, ham protein, karbonhidrat, enerji, toplam fenolik madde ve fitik asit içeriği) ve duyusal özellikleri araştırılmıştır. Bisküvi formülasyonunda kamkat tozu kullanımı ile örneklerin L* değerleri azalmış, a* ve b* değerleri artmıştır. Kamkat meyve tozu ikame oranı %0'dan %30'a çıktığında; bisküvi örneklerinin toplam fenolik içeriği 746.18 µg GAE/mg'dan 2080.10 µg GAE/mg'a yükselmiş, fitik asit içeriği ise 116.86 mg/100 g'dan 53.60 mg/100 g'a düşmüştür. Bisküvilerin duyusal olarak kabul edilebilirliği için en uygun oranı %10 kamkat tozu ikamesi sağlamıştır. Bisküvi üretiminde kamkat tozlarının kullanımı, son ürünlerin hem duyusal özelliklerini hem de fonksiyonelliğini artırmıştır. Ayrıca, kamkat tozu elde edilmesinde mikrodalga ve vakumlu kurutma uygun alternatif teknikler olarak kullanılabilir.

Anahtar Kelimeler: Kamkat, *Fortunella margarita*, mikrodalga kurutma, vakum kurutma, bisküvi

Reference to this paper should be made as follows:
Olcay, N. , Demir, M.K., 'The Usage Possibilities of Kumquat Fruit Dried by Different Techniques in The Production of Biscuits', Elec Lett Sci Eng , vol. 16(2) , (2020), 108-120

1. INTRODUCTION

Kumquat (*Fortunella margarita Swingle*) which is a citrus fruit, is a member of the *Fortunella* genus in the Rutaceae family [1,2]. Edible peel and small fruits of kumquat are its characteristics when compared to other citruses [2]. Most common species of kumquat can be listed as nagami (*Fortunella margarita*), marumi (*Fortunella japonica*), meiwa (*Fortunella crassifolia*), Hong Kong (*Fortunella hindsii*), *Fortunella obovata* and *Fortunella polyandra* [2,3]. Usually, kumquats are consumed as fresh fruit or added to fruit salads as well as beverages. Also, it can be used on the production of candy, sugar syrup, marmalade, wine, liqueur and sauce [1-3]. Not only is kumquat rich in pectin, calcium, phosphorus, iron, vitamins, dietary fiber, carotenoids, flavonoids and essential oils but also its antioxidant capacity and phytochemical contents are high [3-5]. The composition of kumquat essential oil which consists of mostly terpenes, have effects on aroma in addition to human health with its phytochemical content [3,6]. It was determined that among the terpenes, the major compound is limonene followed by myrcene and germacrene-D [2,7]. A number of studies reported that essential oil content of kumquat has therapeutic effects on allergies, inflammatory diseases, cancer, capillary fragility and arteriosclerosis [6,8]. The antioxidant activity of kumquat consists of the synergistic effect of phenolic compounds and other phytochemicals. The phenolic content of kumquat has a significant effect on also the radical scavenging activity [8,9]. It was reported that 3',5'-Di-C-β-glucopyranosylphloretin (DGPP) is the major and characteristic compound among kumquat phenolics which mostly consist of conjugated flavonoids [1,10,11]. It was detected that DGPP and margaritene are the most effective compounds on the antioxidant activity of kumquat [1,8].

Drying can be defined as removing the moisture content of the product with mass and heat transfer [12]. The main purpose of the drying process is to protect the product from microbial, enzymatic and chemical degradation by decreasing the moisture content [13]. It was researched the new drying techniques including microwave and vacuum drying, because of the long drying times and relatively high temperatures which often leads to thermal degradation of the final products, in the convection drying process. In the literature, the microwave drying had been recommended to protect product quality, to have a quick and easy process with low energy, and to evaporate more moisture than convection [14-16]. In the vacuum drying technique, oxidation reactions in the product can be reduced based on removed oxygen with vacuum application, thus color, texture, aroma, taste, and quality properties can be preserved [15]. Dried foods can be used as an additive in some products like instant soups, baby foods and convenience foods with their condensed nutritional values [12,15].

To the best of our knowledge, there is no available literature regarding dried kumquat powder utilization in bakery products. Therefore, this study was designed to investigate the usage of kumquat powder in biscuit production. The aim of this study was to 1) determine the effects of different drying techniques (convection drying, microwave drying and vacuum drying) on kumquat powders and biscuits, 2) determine the effects of different substitution rates (10%, 20% and 30%, w/w, based on the wheat flour used) of kumquat powders on some chemical, physical and sensory properties of biscuits, and 3) develop a novel formulation of biscuits with kumquat powders to obtain functional bakery products.

2. MATERIALS AND METHODS

2.1. Materials

Nagami kumquat fruits (*Fortunella margarita*) were obtained from Batı Akdeniz Agricultural Research Institute (BATEM) in Antalya, Turkey. Wheat flour, powdered sugar, shortening, fructose syrup, milk powder, salt, sodium bicarbonate and water were purchased from local market in Konya, Turkey.

2.2. Production of Kumquat Powders

Kumquat fruits which were stored at 4°C until use, were washed and manually sliced as 2 mm thick cylindrical shape, before the drying process. According to the results obtained from the preliminary experiments, sliced fruits were dried by three different techniques (convection, microwave and vacuum drying) with different norms.

To obtain kumquat powder with convection drying (CD), kumquat slices were lined up to trays and dried in tray dryer (Eksis Lab., Isparta, Turkey) at 70°C for 2 hours 40 minutes. To obtain kumquat powder with microwave (MD) and vacuum drying (VD), kumquat slices were dried respectively in the microwave oven (LG SolarDOM, MP-9485, Seul, South Korea) at 360 W of microwave power for 50 minutes (MD), and in the vacuum oven (JSR, JSVO-60T, Gongju, South Korea) at 70°C and 100 mmHg absolute pressure for 2 hours (VC).

To obtain the kumquat powders, all dried samples were milled with a laboratory-type grinder (Alveo, Konya, Turkey), and sieved with 500 µm sieve. The kumquat powders were stored until analysis in the glass jars at room temperature (24 ± 1°C).

2.3. Preparation of Biscuits

Control biscuits without additives were prepared according to modified AACC Method No: 10-54 with 100 g wheat flour, 42 g powdered sugar, 40 g shortening, 1.5 g fructose syrup, 1.25 g salt, 1 gr milk powder, 1.5 gr sodium bicarbonate and 21 ml water. According to 100 g flour basis, 10, 20, and 30 gr kumquat powders obtained by 3 different drying techniques (convection, microwave, vacuum drying) were replaced with wheat flour in the biscuit formulation. Utilization ratios of kumquat powder replacements were determined with preliminary experiments. The mixture including all ingredients was kneaded using a laboratory type mixer (Kenwood KMX, Havant, UK) for 8 minutes, and the dough was manually shaped into 55 mm diameter, 5 mm thickness circles. The biscuits were baked in an oven (Vestel SF8401, Manisa, Turkey) at 160 ± 2°C for 15 min.

2.4. Physical Analysis

Colour parameters (L*, a* and b*) of the kumquat powders and biscuits were measured with Minolta CR 400 (Konica Minolta Inc., Tokyo, Japan). After calibration of the instrument was made with a white reference tile, the colour measurements were replicated six times from different points for each sample.

Hardness and fracturability of biscuits were measured with texture analyzer (Stable Micro Systems TA-XT Plus, Surrey, UK) after 24 hours. A three point bend rig probe was used for

Texture Profile Analysis. The method used by Adeola and Ohizua [17] was modified and used with a measurement speed of 3 mm/sec and a distance of 5 mm.

The diameter and thickness of the biscuit samples were determined with a calliper (Mitutoyo, Kanagawa, Japan). Spread ratio was estimated by calculating diameter/thickness values.

2.5. Chemical Analysis

Moisture (AACC Method 44-19), ash (AACC Method 08-01), crude protein (AACC Method 46-12) and crude fat (AACC Method 30-25) contents of kumquat powders (dried by convection, microwave, vacuum drying) and biscuit samples were determined using standard methods [18]. The total carbohydrates contents of biscuit samples were calculated by difference (100 – (protein + fat + ash + moisture)) according to Karaağaoğlu et al. [19]. Energy values of biscuit samples were calculated according to Karaağaoğlu et al. [19] by the following formula: (4 *(carbohydrate% + protein%) + 9*(fat%)).

Total phenolic content (TPC) was determined spectrophotometrically by Folin-Ciocalteu method. Initially, 4 gram powdered samples were extracted with 4 ml acidified methanol solvent (HCl/methanol/water, 1:80:10, v/v/v) by shaking in water bath (24 ± 1°C) for 2 hours. After the extraction, the samples were centrifuged at 3000 rpm for 10 minutes and the supernatant was obtained [20,21]. 0.1 ml of supernatant, 0.5 ml of Folin-Ciocaltaeu reagent (10%, v/v, in water) and 1.5 ml of sodium carbonate solution (20%, m/v, in water) were mixed in the test tube, then the mixture was incubated for 2 hours at room temperature (24 ± 1°C) in the darkness. At the end of this period, the absorbance of the final solutions was recorded with a spectrophotometer (Biochrom, Libra S60, Cambridge, UK) at 760 nm wavelength. Total phenolic contents were expressed as gallic acid equivalent (micrograms of gallic acid per gram of dry weight, GAE) [22,23].

The phytic acid content of samples was determined by a colorimetric method according to Haug and Lantzsch [24]. For this purpose, phytic acid was extracted with 0.2 N hydrochloric acid solution from the samples, then was precipitated with Fe III (ammonium iron (III) sulfate) solution. After 2′,2-bipyridine solution was added, the absorbance was measured in a spectrophotometer (Biochrom Libra S60, Cambridge, UK) at 519 nm wavelength and phytic acid content was calculated [24].

2.6. Sensory Evaluation of Biscuit Samples

Sensory evaluation of biscuits was subjected by 12 untrained panelists healthy and nonsmoker. Sensory evaluation criteria were determined as color, taste, odor, friability and overall acceptability. Samples were coded with letters, and served to the panelists at random evaluated using a five-point hedonic scale (1: dislike extremely, 2: dislike, 3: acceptable 4: like and 5: like extremely). At last, all data were subjected to joint evaluation.

2.7. Statistical Analysis

The data obtained from the duplicate samples were evaluated with JMP (SAS Institute Inc., Cary, NC, USA) software. The averages of the obtained data were compared using the Tukey HSD comparison test [25].

3. RESULTS AND DISCUSSION

3.1. Some Properties of Kumquat Powders

The effects of drying techniques on the color values and chemical properties of kumquat powders and the comparison of kumquat powders with wheat flour are demonstrated in Table 1. As expected, the highest L*, and lowest a* and b* values were determined in the wheat flour. Among the kumquat powders, the highest brightness and lowest redness were determined in samples dried by microwave technique. Also, the minimum yellowness was found in samples dried by vacuum technique. Similarly, Michalska et al. [26] investigated the effect of drying technique on color parameters of plum powders and reported that samples used microwave and vacuum drying had higher brightness than convective drying. Probably, the lower process time and temperature applied during microwave and vacuum drying resulted in changes in color parameters. Also, it was probably due to the inhibition of color pigments oxidation in the vacuum drying technique.

Ash contents of kumquat powders varied between 2.15 and 2.18%. All kumquat powders presented greater ash content compared to wheat flour. These high values are quite reasonable owing to the fact that kumquat fruits have high mineral content. Protein contents of kumquat powders changed between 0.98% (for CD) and 1.11% (for VD). As expected, wheat flour had higher protein content than kumquat powders. The maximum total phenolic contents (TPC) were found for MD and VD followed by CD, whereas the lowest TPC was obtained in wheat flour. The reasons for the higher phenolic contents in both MD and VD are probably the high temperature and vapor pressure inside the kumquat fruit cells during the drying process [26,27]. Similar results were obtained by Michalska et al. [26] who reported the disruption of cell wall might release the bounded phenolics. As mentioned in the literature, lower phenolic content of CD suggesting the influence of the oxidation reactions of phenolics owing to the fact that CD has high heat treatment at the long process time [27-29]. Wheat flour sample had the highest phytic acid content, while the MD sample had the lowest ($p < 0.05$). Cereals and legumes have higher phytic acid content than other plants [30]. In the studies of Alonso et al. [31] and Mohamed et al. [32], it was reported that some processes such as autoclaving, microwave, extrusion, and heat treatment reduced the phytic acid content in foods. These reports could be correlated to our phytic acid results.

3.2. Physical Properties of Biscuit Samples

Table 2 presents the physical properties of kumquat powder substituted biscuit samples produced by different drying techniques and substitution rates. The L* values of biscuits significantly decreased with VD substitution. Also, higher rates of kumquat powders caused a greater decrease in L* values. Lower brightness with higher substitution rates may be due to the own color of kumquat powders. Significant variation in the brightness of biscuits was also demonstrated by Can [33] and Demirel [34] who produced orange peel powder and citrus albedo powder substituted biscuits respectively. In these studies, it was reported that carotenoid and phenolic compounds of citruses caused enzymatic browning on biscuits and resulted in the loss of brightness. The highest a* value (2.62) was shown by biscuits produced with VD and the lowest (2.12) by biscuits produced with CD. It was determined that biscuits produced with CD had the lowest yellowness. As expected, both a* and b* values of biscuits increased with the increasing level of kumquat powder substitution due to the orange color of the fruit. Similar color results for substituted biscuits with pumpkin powder [35], orange peel powder [33] and some citrus albedo powders [34] were reported in the literature.

Among biscuits produced with kumquat powders dried by different techniques, the most positive effect on the hardness values of biscuits was observed when biscuits supplemented with MD. It was observed that the substitution of VD to the biscuit resulted in increased hardness values. It was determined that the increase in kumquat powder substitution rate in the formulation led to a significant ($p < 0.05$) decrease in the both hardness and fracturability of the biscuits. The reason for the decrease is probably the increase in hydrophilic compounds like dietary fiber and pectin. Similarly, Aydın [35] reported that cookies with pumpkin powder substitution had a decrease in hardness and fracturability values owing to the fact that the gluten content of biscuit formulation decreased with pumpkin powder substitution. In another study, it was reported that the hardness of the cookies increased with citrus powder substitution [36]. The differences between studies could be related to the structural differences of citrus fruit powders.

The most positive effects on the diameter, thickness and spread ratio were observed when biscuits substituted with MD. The increase of kumquat powder substitution rate caused decreased diameter and thickness, and increased spread ratio compared with the control biscuit. It can be concluded that kumquat powder had positive effects on the physical properties of biscuits owing to the fact that high spread ratio values are desirable for better biscuit quality. Opposite to the current finding, the spread ratios of citrus powder supplemented biscuits were found to decrease with the increased substitution rates in many studies [36-39]. The differences between studies could be related to the dietary fiber content differences of citrus fruit powders.

3.3. Chemical Properties of Biscuit Samples

Chemical composition of biscuits are presented in Table 3. There were no significant differences ($p > 0.05$) in the contents of moisture, ash, crude fat, crude protein, carbohydrate and energy in the dry matter among the biscuits produced with kumquat powders dried by different techniques. Among substitution rates, the moisture content of biscuits changed between 4.69% and 5.44%. The increase in the moisture content of biscuits may be due to increased dietary fiber content and water holding capacity of samples, as mentioned by Aydın [35]. Similar results were also reported by Demirel [34] who replaced citrus albedo powders with wheat flour in biscuit formulation and by Tripathi et al. [40] who replaced orange bagasse powder with wheat flour in biscuit formulation. Compared to the control biscuit, the substitution rates had no significant effect on the ash content of all types of biscuits containing kumquat powder. It was observed that the increase in kumquat powder substitution rate led to a significant ($p < 0.05$) decrease in the protein content of the biscuits. The low protein content of kumquat powders may reflect the protein content of the end products (Table 1). Significant variation in the protein content of biscuits was also demonstrated by Demirel [34]. Also, Can [33] determined a decrease in the protein content of biscuit samples with orange peel powder substitution but reported that had no significant change in protein content by substitution of orange peel powder. Compared to the control sample, kumquat powder substitution caused a substantial ($p < 0.05$) decrease in the crude fat content and energy values on the biscuits. When the substitution rates are compared among themselves, it was observed that the increase of substitution rates increased the crude fat contents and energy values of biscuits. A similar change of crude fat content for orange peel powder substitution [33] was reported in the literature. Also, many studies concluded that supplementation of citrus powders led to a decrease on crude protein and crude fat contents of biscuit samples [37-41]. Generally, the carbohydrate values of kumquat powder supplemented biscuits found higher than the control biscuit. Similar findings were reported for citron powder [37], orange pulp and peel powder [38] and orange peel powder [39].

Among applied drying techniques, total phenolic contents of biscuit samples changed between 1352 μg GAE/g (for CD) and 1451 μg GAE/g (for VD). When CD was used in biscuits, lower total phenolic content was observed suggesting the influence of the drying temperature and time on the total phenolic content. As expected, higher levels of kumquat powders caused a greater increase in the total phenolic content of samples. The rich total phenolic content of kumquat powders may reflect the total phenolic content of end products. Many studies concluded that the addition of citrus fraction powders was one of the most effective methods of improving total phenolic content [33,34].

Phytic acid contents of biscuits have varied in the range of 82.26 mg/100 g (for VD) to 86.10 mg/100 g (for CD), and drying techniques had no significant effect on phytic acid content. However, increased substitution rates of kumquat powders caused a great decrease in the phytic acid content of samples. Probably, the lower phytic acid content of kumquat powders resulted in the lower phytic acid content of end products.

3.4. Sensory Scores of Biscuits

Figure 1 presents the sensory properties of kumquat powder supplemented biscuits. According to the crude scores, kumquat powder supplementation in all drying techniques and substitution rates resulted in an increase in color scores of biscuits. All of the drying techniques and substitution rates provided similar results in terms of odor in biscuits. Increased kumquat powder substitution rate had a negative influence on the taste, friability, and overall acceptability of biscuits compared to the control sample. However, the highest taste, friability and overall acceptability scores were obtained with biscuits containing 10% of kumquat powder in all drying techniques among all samples. Biscuits produced with VD and containing 10% kumquat powder were determined as superior in terms of individual sensory properties.

4. CONCLUSION

The usage of kumquat powder in the formulation improved the color properties of biscuits. Usage of MD improved the physical properties such as diameter, thickness and spread ratio in biscuit samples followed by CD and VD. On the other hand, kumquat powder substitution in particular MD had a negative effect on textural properties such as hardness and fractuability. Increased kumquat powder substitution resulted in a higher total phenolic content in biscuits. MD and VD significantly increased the total phenolic content compared to CD. Compared to the control biscuit sample, the increasing level of kumquat powder provided a significant decrease in phytic acid content. Biscuits with 10% kumquat powder substitution had higher preference levels for sensorial attributes.

It could be concluded that kumquat has significant potential as a natural additive to enhance nutritional characteristics and sensory properties of foods. It is possible to make the consumption of foods more beneficial and improve the functionality of end products by kumquat powder. Microwave and vacuum drying techniques may be good alternatives in the production of kumquat powder to enhance functionality.

Acknowledgements
This research was summarized from Master Thesis (University of Necmettin Erbakan the Graduate School of Natural and Applied Science Department in Food Engineering) by Nezahat OLCAY.

References

[1] Barreca, D., Bellocco, E., Caristi, C., Leuzzi, U., Gattuso, G., Kumquat (*Fortunella japonica Swingle*) juice: flavonoid distribution and antioxidant properties, Food Research International, 44(7), 2190-2197, 2011.
[2] Peng, L.W., Sheu, M.J., Lin, L.Y., Wu, C.T., Chiang, H.M., Lin, W.H., Lee, M.C., Chen, H.C., Effect of heat treatments on the essential oils of kumquat (*Fortunella margarita Swingle*), Food Chemistry, 136(2), 532-537, 2013.
[3] Wang, Y.W., Zeng, W.C., Xu, P.Y., Lan, Y.J., Zhu, R.X., Zhong, K., Huang, Y.N., Gao, H., Chemical composition and antimicrobial activity of the essential oil of kumquat (*Fortunella crassifolia Swingle*) peel, International Journal of Molecular Sciences, 13(3), 3382-3393, 2012.
[4] Chang, S.C., Lee, M.S., Lin, C.J., Chen, M.L., Dietary fiber content and composition of fruits in Taiwan, Asia Pacific Journal of Clinical Nutrition, 7(3/4), 206-10, 1998.
[5] Liu, Y., Liu, Y., Liu, Y., Liu, H., Shang, Y., Evaluating effects of ellagic acid on the quality of kumquat fruits during storage, Scientia Horticulturae, 227, 244-254, 2018.
[6] Güney, M., Öz, A.T., Kafkas, E., Comparison of lipids, fatty acids and volatile compounds of various kumquat species using HS/GC/MS/FID techniques, Journal of the Science of Food and Agriculture, 95(6), 1268-1273, 2015.
[7] Quijano, C.E., Pino, J.A., Volatile compounds of round kumquat (*Fortunella japonica Swingle*) peel oil from Colombia, Journal of Essential Oil Research, 21(6), 483-485, 2006.
[8] Lou, S.N., Lai, Y.C., Hsu, Y.S., Ho, C.T., Phenolic content, antioxidant activity and effective compounds of kumquat extracted by different solvents, Food Chemistry, 197, 1-6, 2016.
[9] Ramful, D., Tarnus, E., Aruoma, O.I., Bourdon, E., Bahorun, T., Polyphenol composition, vitamin C content and antioxidant capacity of Mauritian citrus fruit pulps, Food Research International, 44(7), 2088-2099, 2011.
[10] Ogawa, K., Kawasaki, A., Omura, M., Yoshida, T., Ikoma, Y., Yano, M., 3’,5’-Di-C-β-glucopyranosylphloretin, a flavonoid characteristic of the genus *Fortunella*, Phytochemistry, 57(5), 737-742, 2001.
[11] Lou, S.N., Lai, Y.C., Huang, J.D., Ho, C.T., Ferng, L.H.A., Chang, Y.C., Drying effect on flavonoid composition and antioxidant activity of immature kumquat, Food Chemistry, 171, 356-363, 2015.
[12] Tokdemir, M., Boran, K., Aktaş, M., Alkaç, S.P., Production of powder apple and apple chips with heat pump drying technique: performance analysis, Journal of Polytechnic, 21(4), 887-894, 2018.
[13] Alwazeer, D., Reducing atmosphere drying as a new technique for the preservation of the color of dried foods, Journal of the Institute of Science and Technology, 8(4), 125-131, 2018.
[14] Dadalı, G., The investigation and modelling of drying kinetic, colour change kinetic and porosity analysis of okra and spinach undergoing microwave, MSc. dissertation, University of Yıldız Teknik, İstanbul, 2007.
[15] Erbay, B., Küçüköner, E., Different drying systems using in the food industry, Turkey

10th Food Congress, 21-23 May, Erzurum, 1045-1048, 2008.
[16] Lüle, F., Comparison of different drying methods on the collected çaşır mushrooms (*Pleurotus Eryngii*) in Malatya-Arguvan region, Ph.D. dissertation, University of Namık Kemal, Tekirdağ, 2014.
[17] Adeola, A.A., Ohizua, E.R., Physical, chemical, and sensory properties of biscuits prepared from flour blends of unripe cooking banana, pigeon pea, and sweet potato, Food Science & Nutrition, 6(3), 532-540, 2018.
[18] AACC Methods, 11th Ed., American Association of Cereal Chemists (AACC) International, St. Paul, MN, USA, 1990.
[19] Karaağaoğlu, N., Karabudak, E., Yavuz, S., Yüksek, O., Dinçer, D., Tosunbayraktar, G., Eren, F.H., Protein, fat, moisture, carbohydrate and energy values of different types of bread, The Journal of Food, 33(1), 19-25, 2008.
[20] Gao, L., Wang, S., Oomah, B.D., Mazza, G., Wheat quality: antioxidant activity of wheat millstreams, In: Ng, P., Wrigley, C.W., (ed.), Wheat Quality Elucidation, AACC International, St. Paul, MN, USA, 219-233, 2002.
[21] Beta, T., Nam, S., Dexter, J.E., Sapirstein, H.D., Phenolic content and antioxidant activitiy of pearled wheat and roller-milled fractions, Cereal Chemistry, 82(4), 390-393, 2005.
[22] Slinkard, K., Singelton, V.L., Total phenolic analysis, automation and comparison with manual methods, AJEV, 28(1), 49-55, 1977.
[23] Gamez-Meza, N., Noriega-Rodriguez, J.A., Medina-Juarez, L.A., Ortega Garcia, J., Cazarez-Casanova, R., Angulo-Guerrero, O., Antioxidant activity in soybean oil of extracts from thompson grape bagasse, JAOCS, 76(12), 1445-1447, 1999.
[24] Haug, W., Lantzsch, H.J., Sensitive method for the rapid determination of phytate in cereals and cereal product, Journal of the Science of Food and Agriculture, 34(12), 1423-1426, 1983.
[25] Düzgüneş, O., Kesici, T., Kavuncu, O., Gürbüz, F., Research and trial methods, Publications of Ankara University Faculty of Agriculture, Ankara, 1987.
[26] Michalska, A., Wojdyło, A., Lech, K., Łysiak, G.P., Figiel, A., Physicochemical properties of whole fruit plum powders obtained using different drying technologies, Food Chemistry, 207, 223-232, 2016.
[27] Inanoğlu, S., Effect of microwave-vacuum drying on quality parameters of sage leaves, MSc. dissertation, University of Mersin, Mersin, 2017.
[28] Karaman, S., Toker, Ö.S., Çam, M., Hayta, M., Doğan, M., Kayacier, A., Bioactive and physicochemical properties of persimmon as affected by drying methods, Drying Technology, 32(3), 258-267, 2014.
[29] Tontul, I., Topuz, A., Effects of different drying methods on the physicochemical properties of pomegranate leather (pestil), LWT, 80, 294-303, 2017.
[30] Şat, İ.G., Keleş, F., Phytic acid and effects on nutrition, Journal of Food Science, 29(6), 405-409, 2004.
[31] Alonso, R., Orue, E., Marzo, F., Effects of extrusion and conventional processing methods on protein and antinutritional factor contents in pea seeds, Food Chemistry, 63(4), 505-512, 1998.
[32] Mohamed, K.R., Abou-Arab, E.A., Gibriel, A.Y., Rasmy, N.M.H., Abu-Salem, F.M., Effect of legume processing treatments individually or in combination on their phytic acid content, African Journal of Food Science and Technology, 2, 036-046, 2011.
[33] Can, F., Investigation of the effect of orange peel powder on biscuit dough and biscuit quality, MSc. dissertation, University of İnönü, Malatya, 2015.
[34] Demirel, H., The albedos utilization possibility to biscuit production which obtain from different citrus, MSc. dissertation, University of Necmettin Erbakan, Konya, 2017.

[35] Aydın, E., Effects of pumpkin (*Cucurbita moschata*) flour addition on the antioxidant activity and nutritional quality of cookie, Ph.D. dissertation, University of Uludağ, Bursa, 2014.
[36] Younis, K., Islam, R., Jahan, K., Kundu, M., Ray, A., Investigating the effect of mosambi (*Citrus limetta*) peel powder on physicochemical and sensory properties of cookies, QASCF, 8(3), 393-398, 2016.
[37] Kong, H.J., Kim, H.Y., Preparation and quality characteristics of sugar cookies using citron powder, Korean Journal of Food and Cookery Science, 22(5), 712-719, 2006.
[38] Nassar, A.G., AbdEl-Hamied, A.A., El-Naggar, E.A., Effect of citrus by-products flour incorporation on chemical, rheological and organolepic characteristics of biscuits, World Journal of Agricultural Sciences, 4(5), 612-616, 2008.
[39] Zaker, A., Sawate, A.R., Pati, B.M., Sadawarte, S.K., Studies on effect of orange peel powder incorporation on physical, nutritional and sensorial quality of cookies, IJESRT, 7(05), 2278-0181, 2016.
[40] Tripathi, B., Tripathi, R., Vaidya, M., Influence of orange bagasse addition on chemical composition of biscuits, Pharma Innovation, 7(11), 338-341, 2018.
[41] ul Haquea, E., Hanifa, M.S., Nadeem, M., Mehmood, A., Ibrar, M., Physicochemical and rheological study of orange pulp fortified cookies, Science Letters, 3(2), 64-67, 2015.

Table 1. Color values and chemical properties of kumquat powders dried by different techniques

	Wheat Flour	CD	MD	VD
Color values				
*L**	92.48 ± 0.01^{a}	70.29 ± 0.02^{d}	71.94 ± 0.01^{b}	71.20 ± 0.02^{c}
*a**	-0.62 ± 0.01^{d}	5.02 ± 0.01^{b}	4.68 ± 0.02^{c}	7.76 ± 0.04^{a}
*b**	11.12 ± 0.02^{d}	62.00 ± 0.01^{a}	55.96 ± 0.01^{b}	55.28 ± 0.10^{c}
Chemical properties				
Moisture (%)	11.18 ± 0.06^{b}	16.05 ± 0.67^{a}	14.32 ± 0.34^{ab}	15.62 ± 0.93^{ab}
Ash (%)	0.62 ± 0.02^{b}	2.18 ± 0.01^{a}	2.18 ± 0.01^{a}	2.15 ± 0.01^{a}
Crude Fat (%)	0.92 ± 0.06^{a}	0.77 ± 0.04^{a}	0.81 ± 0.01^{a}	0.77 ± 0.02^{a}
Crude Protein (%)	11.44 ± 0.22^{a}	0.98 ± 0.02^{b}	1.04 ± 0.03^{b}	1.11 ± 0.04^{b}
TPC (µg GAE/g)	819.53 ± 7.16^{c}	6172.80 ± 52.65^{b}	6568.74 ± 45.55^{a}	6598.94 ± 14.54^{a}
Phytic Acid (mg/100 g)	245.53 ± 8.59^{a}	25.74 ± 0.38^{b}	18.96 ± 0.52^{b}	19.68 ± 0.47^{b}

Figures in the same column sharing a common letter in parenthesis are not significantly different ($p < 0.05$).

Table 2. Physical properties of kumquat powder substituted biscuit samples produced by different drying techniques and substitution rates

	*L**	*a**	*b**	Hardness (g)	Fracturability (mm)	Diameter (mm)	Thickness (mm)	Spread Ratio
Drying Technique								
with CD	70.10 ± 0.02^{a}	2.12 ± 0.04^{c}	39.41 ± 0.05^{b}	2337.76 ± 30.19^{b}	36.72 ± 0.02^{a}	58.60 ± 0.05^{a}	6.20 ± 0.05^{a}	9.50 ± 0.08^{b}
with MD	70.20 ± 0.05^{a}	2.50 ± 0.01^{b}	40.00 ± 0.03^{a}	1886.83 ± 14.97^{c}	36.49 ± 0.03^{c}	58.79 ± 0.06^{a}	6.08 ± 0.07^{b}	9.70 ± 0.12^{a}
with VD	69.64 ± 0.13^{b}	2.62 ± 0.04^{a}	40.04 ± 0.09^{a}	2420.66 ± 15.93^{a}	36.66 ± 0.01^{b}	57.94 ± 0.14^{b}	6.18 ± 0.05^{ab}	9.39 ± 0.09^{b}
Substitution Rate								
0	72.26 ± 0.01^{a}	1.04 ± 0.01^{d}	29.18 ± 0.06^{d}	3243.32 ± 5.83^{a}	37.58 ± 0.01^{a}	58.45 ± 0.05^{b}	6.55 ± 0.05^{a}	8.92 ± 0.08^{c}
10	70.42 ± 0.02^{b}	1.92 ± 0.03^{c}	38.26 ± 0.04^{c}	1863.67 ± 20.06^{c}	36.43 ± 0.02^{b}	58.77 ± 0.17^{a}	6.25 ± 0.08^{b}	9.42 ± 0.16^{b}
20	69.50 ± 0.18^{c}	2.69 ± 0.01^{b}	44.56 ± 0.05^{b}	1750.02 ± 32.75^{d}	36.28 ± 0.01^{c}	58.57 ± 0.07^{ab}	5.95 ± 0.05^{c}	9.85 ± 0.08^{a}
30	67.74 ± 0.06^{d}	4.00 ± 0.06^{a}	47.26 ± 0.07^{a}	2003.33 ± 22.82^{b}	36.19 ± 0.04^{d}	57.98 ± 0.05^{c}	5.85 ± 0.05^{c}	9.93 ± 0.08^{a}

Kumquat powder with different drying technique was added based on the wheat flour used (mean ± SD, %, w/w, dry basis). Figures in the same column sharing a common letter in parenthesis are not significantly different ($p < 0.05$).

Table 3. Chemical composition of kumquat powder substituted biscuit samples produced by different drying techniques and substitution rates

	Moisture (%)	Ash (%)	Crude Fat (%)	Crude Protein (%)	Carbohydrate (%)	Energy (kcal/100 g)	TPC (µg GAE/g)	Phytic Acid (mg/100 g)
Drying Technique								
with CD	4.82 ± 0.13[a]	1.43 ± 0.07[a]	17.08 ± 0.28[a]	3.71 ± 0.03[a]	72.98 ± 0.43[a]	460.41 ± 1.33[a]	1352.26 ± 6.09[b]	86.10 ± 1.44[a]
with MD	5.09 ± 0.22[a]	1.38 ± 0.08[a]	16.79 ± 0.33[a]	3.76 ± 0.03[a]	72.97 ± 0.51[a]	458.09 ± 1.12[a]	1447.78 ± 8.20[a]	82.82 ± 1.47[a]
with VD	4.98 ± 0.24[a]	1.28 ± 0.11[a]	17.18 ± 0.22[a]	3.78 ± 0.02[a]	72.77 ± 0.25[a]	460.86 ± 1.96[a]	1451.58 ± 12.13[a]	82.26 ± 1.42[a]
Substitution Rate								
0	4.69 ± 0.12[b]	1.43 ± 0.07[a]	17.14 ± 0.02[ab]	4.18 ± 0.03[a]	72.56 ± 0.10[bc]	461.22 ± 0.07[ab]	746.18 ± 9.82[d]	116.86 ± 4.50[a]
10	4.77 ± 0.17[b]	1.29 ± 0.02[a]	16.17 ± 0.14[c]	3.86 ± 0.02[b]	73.91 ± 0.28[a]	456.63 ± 0.78[b]	1223.93 ± 6.26[c]	93.26 ± 0.37[b]
20	4.95 ± 0.21[ab]	1.34 ± 0.11[a]	16.83 ± 0.50[bc]	3.65 ± 0.03[c]	73.22 ± 0.35[ab]	458.97 ± 3.19[ab]	1618.63 ± 7.82[b]	71.20 ± 0.34[c]
30	5.44 ± 0.29[a]	1.39 ± 0.14[a]	17.92 ± 0.44[a]	3.31 ± 0.02[d]	71.94 ± 0.85[c]	462.33 ± 1.83[a]	2080.10 ± 11.31[a]	53.60 ± 0.56[d]

Kumquat powder with different drying technique was added based on the wheat flour used (mean ± SD, %, w/w, dry basis). Figures in the same column sharing a common letter in parenthesis are not significantly different ($p < 0.05$).

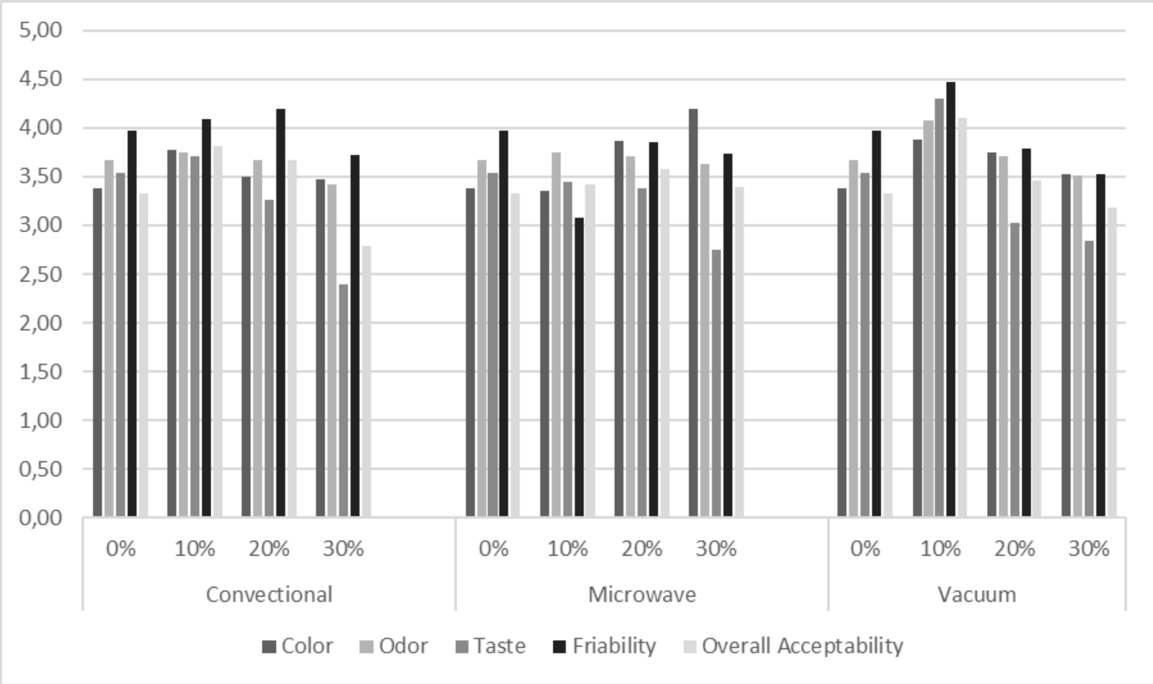

Figure 1. Sensory evaluation of biscuit samples substituted with kumquat powder

* Nezahat Olcay; Tel.: +905316287709 olcaynezahat@gmail.com

ISSN 1305-8614