Electronic Letters on Science & Engineering 17(2) (2021)
Available online at dergipark.org.tr/else

The Impacts of Batter and Baking Temperatures and Baking Time on Sponge Cake Characteristics

Halef DİZLEK[1*], Ali ALTAN[2]

[1]Department of Food Engineering, Faculty of Engineering, Osmaniye Korkut Ata University, Osmaniye, Turkey
[2]Department of Food Engineering, Faculty of Agriculture, Çukurova University, Adana, Turkey
hdizlek@osmaniye.edu.tr, ORCID: 0000-0001-5873-5462

Abstract: The cake, which can be produced with several methods, has a very important place in bakery products and modern life. Sponge cake is a special type of cake used in the production of wet creamy cakes as "pastry under the cake". Cake quality depends on so many factors. Batter temperature, baking temperature and baking time are probably the most critical factor governing the quality of final product. Incorrect baking can negative effect of all other important cake making factors, such as qualified ingredients, correct formulas and processing steps/techniques. In this study; the impacts of different batter temperatures (19±1 °C, 26±1 °C, and 33±1 °C), baking temperatures (165, 180, 195, 200, 215, and 230 °C) and baking times (20, 25, 27, 30, 35, and 40 min) on the important quality characteristics of sponge cake were investigated. It was possible to obtain sponge cakes with larger volume and higher acceptability when batter temperature was at 33 °C rather than around 20-25 °C and when they were baked at 200 °C for 27 min. If lower baking temperatures (<200 °C) and/or shorter baking times (particularly 20 min) were applied during sponge cake production, cakes with small volume, close or irregular pore structures were observed. Too hot oven temperatures (>200 °C) and/or too long baking times (35 and 40 min) were caused to dark crust color, cracks on the top surface, weak crumb and insufficient volume on the sponge cake. By selecting correct batter temperature and baking norms, it could be possible to produce high quality and moist cakes with larger volume. Besides, economic losses could be prevented.

Keywords: Batter temperature, sponge cake, baking norms, cake features

Hamur ve Pişirme Sıcaklığı ile Pişirme Süresinin Pandispanya Üzerine Etkileri

Özet: Çeşitli yöntemlerle üretilebilen kek, unlu mamuller içerisinde ve modern yaşamda oldukça önemli bir yere sahiptir. Pandispanya, kremalı kek (yaş pasta) üretiminde "pasta altı kek" olarak kullanılan özel bir kek çeşididir. Kek kalitesi pek çok faktöre bağlıdır. Hamur sıcaklığı, pişirme sıcaklığı ve pişirme süresi, muhtemelen nihai ürünün kalitesini belirleyen en kritik etmenlerdir. Hatalı pişirme; kaliteli bileşenler, doğru formüller ve işleme adımları/teknikleri gibi diğer tüm önemli kek yapım faktörlerini olumsuz etkileyebilir. Bu çalışmada; farklı hamur sıcaklığının (19±1 ºC, 26±1 ºC ve 33±1 ºC), pişirme sıcaklığının (165, 180, 195, 200, 215 ve 230 ºC) ve pişirme süresinin (20, 25, 27, 30, 35 ve 40 d) pandispanyanın önemli kalite özellikleri üzerine etkileri araştırılmıştır. Hamur sıcaklığının 33 ºC olması 20-25 ºC sıcaklıklarda hazırlanan hamurlara göre ve pandispanyaların 200 ºC'de 27 d pişirilmesi daha büyük hacimli ve yüksek albenili pandispanya üretimini mümkün kılmıştır. Pandispanya üretimi sırasında daha düşük pişirme sıcaklığı (<200 ºC) ve/veya daha kısa pişirme süresi (özellikle 20 d) uygulandığında küçük hacimli, kapalı veya düzensiz gözenek yapılı kekler elde edilmiştir. Çok yüksek fırın sıcaklığı (>200 ºC) ve/veya çok uzun pişirme süresi (35 ve 40 d) pandispanyada kabuk renginin koyulaşmasına, üst yüzeyde çatlaklara, zayıf kek içi yapısına ve yetersiz hacme neden olmuştur. Doğru hamur sıcaklığı ve pişirme normları seçilerek, yüksek kaliteli ve nemli, daha büyük hacimli kekler üretilebilir. Ayrıca ekonomik kayıpların önüne geçilebilir.

Anahtar Kelimeler: Hamur sıcaklığı, pandispanya, pişirme normları, kek özellikleri

Reference to this paper should be made as follows: Dizlek, H., Altan, A., 'The Impacts of Batter and Baking Temperatures and Baking Time on Sponge Cake Characteristics', Elec Lett Sci Eng, vol. 17(2), (2021), 89-95.

1. INTRODUCTION

Cakes are very important flour products in cereal industry for many years [1]. Cake products are difficult to define precisely because of their wide variety and the broad range of their formulations. Essentially, they are products that are leavened mainly by baking powder, but occasionally also by air incorporation, as in the case of foam-type cakes. They usually contain relatively high levels of such enriching ingredients as sugar, shortening, eggs, milk and flavorings, in addition to soft wheat flour, and are consequently characterized by a sweet taste, a short and tender texture, and pleasing flavors and aromas. They may be classed into two broad categories, shortening-based cakes and foam-type cakes [2].

In foam-type cakes sponge cakes are very important. The main sponge cake ingredients are soft wheat flour, egg, sugar, water or milk, surfactants, few baking powder and flavoring [3]. To have a thin and sponge type structure are the two main properties of sponge cakes. Foaming of this kind of cakes can be provided by the aid of proteins of eggs, surfactants and incorporation of air bubbles which formed during the mixing of batter and especially during the beating of egg whites [4].

A qualified cake should show a multitude of evenly distributed minute cells without any large holes. It should have good color and sheen, should eat moist, have good flavor and the general appearance should be attractive, with a good eye appeal. The quality of cakes in all instances is governed by three major parameters, namely, the special auditability of the ingredients for the type of cake being made, an appropriate and properly balanced formula, and the adherence to optimal mixing and baking procedures. In last parameter, factors associated with quality cake making are largely determined by the batter temperature, baking temperature, and baking time. Because the temperature attained during the batter mixing operation exerts a marked influence on the final cake quality directly. This derives from the temperature's effect on the viscosity of the batter which, in turn, affects both batter aeration and batter stability. Also, incorrect baking can negative effect of all the other factors, for example high quality ingredients, correct recipes and processing techniques.

In the present study; the effects of different batter temperatures (19±1 $^{\circ}$C, 26±1 $^{\circ}$C, and 33±1 $^{\circ}$C), baking temperatures (165, 180, 195, 200, 215, and 230 $^{\circ}$C) and baking times (20, 25, 27, 30, 35, and 40 min) on the main sponge cake characteristics were investigated.

2. MATERIALS AND METHODS

2.1. Materials

Commercial soft wheat flour purchased from Ova Milling Factory (Konya, Turkey). The flour had 14% moisture, 0.59% ash content, total acidity 0.03%, pH 5.9, dry gluten amount 10.3%, gluten index 77%, sedimentation 34 mL, falling number 343 s, farinograph water absorption 62.2%, stability 6.3 min, softening degree 170 BU; extensograph maximum resistance to extension 570 BU, extensibility 105 mm, and energy 85 cm^2 [5]. Surfactant (Ovalette brand) which has gel structure containing E471 and E475 was obtained from the Katsan Food Co. (İstanbul, Turkey). Powdered sugar, fresh egg, vanilla and salt were supplied from a local market. Potable water was supplied within the campus of Çukurova University (Adana, Turkey). In the study, 3 different baking powder (BP) formulations were prepared manually by using sodium bicarbonate (Mersin Soda Industry, Mersin, Turkey), potassium bitartarate (PB) and

sodium acid pyrophosphate (SAPP, Mühlenchemie, Germany) with corn starch (Sadıkoğlu, Adana, Turkey) (Table 1).

Table 1. Ingredients and quantity (g) of baking powder formulas used in the study.

Formula code	Ingredients[(1)]			
	Sodium bicarbonate	PB	SAPP	Corn starch
Baking powder 1 (BP_1)	30.0	-	-	70.0
Baking powder 2 (BP_2)	30.0	66.7	-	3.3
Baking powder 3 (BP_3)	30.0	-	41.7	28.3

(1) PB: potassium bitartarate, SAPP: sodium acid pyrophosphate.

Sponge cake batter was prepared in Kitchen Aid KSM 45 model electric mixer (KitchenAid Inc., St. Joseph, MI, USA) by using the formulation listed in Table 2. The sponge cake batter (425 g) was placed in stainless steel baking greased pans (inside diameter 203 mm and depth 38 mm) as described American Association of Cereal Chemists International (AACCI) Approved Method 10-90.01 [5] and baked different temperatures and times which were given below. In cake baking trials, Arçelik 'MF6' model oven (Arçelik Company, İstanbul, Turkey) that is fired electrically and capable of maintaining temperature range of ±3 °C was used.

Table 2. Sponge cake batter formulation used in the study.

Ingredients	Weight (g)	Portion of composition (%)
Flour	200.0	36.3
Sugar	144.0	26.1
Egg	120.0	21.8
Water	60.0	10.9
Surfactant	19.3	3.5
Baking powder[(1)]	(4.1-6.9)	(0.75-1.25)
Vanilla	1.5	0.3
Salt	0.8	0.1
Total	549.7-552.5	99.75-100.25

(1) It used 0.75%, and 1.25% percentages based on total sponge cake batter weight.

2.2. Cake making method

Sponge cake batter was prepared according to "Creaming method" [6] with some modification. Details of sponge cake making method are given in Dizlek and Altan [1]. In the study, to determine optimal baking norms for sponge cake, firstly, batter was cooked 165, 180, 195, 200, 215, and 230 °C in the oven temperature for 20, 30, 35, and 40 min. After the data obtained from the first phase of the study, sponge cake batters were baked in oven for 25, 27, and 30 min at 200 °C. Finally, to determination of the effect of batter temperature on sponge cake volume characteristics, batters were prepared 3 different temperature, 19.0±1.0 °C, 26.0±1.0 °C, and 33.0±1.0 °C, respectively. For this purpose, BP_1 and BP_2 formulas were used at two different ratios (as 0.75% and 1.25%, based on batter weight) in cake recipe and optimal baking norms (200 °C for 27 min) also used in this experiment. The norms specified as batter temperature (19, 26 and 33 ºC) were adjusted to be the temperature of the mixed batter. The temperature of the (cold) water, flour, sugar to be used in batter making was adjusted for the temperature of mixed batter to be 19±1, 26±1 and 33±1 ºC, respectively.

2.3. Cake analyses

Cakes were weighed within 6 h after baking; volumes of cakes were measured by the method of Dizlek and Altan [1]. The specific volume of individual cakes was calculated from the ratio between volume and weight of the cake [7]. Volume, symmetry, uniformity and shrinkage indexes of cake samples were determined by using the layer cake measurement template according to AACCI Method 10-91.01 [5] procedure in terms of millimeters. Total volume index of cake samples determined according to Bath et al. [8].

2.4. Data analysis

All experiments were carried out in three replicates. Analyses of variance (ANOVA) were conducted by using the Statistical Analysis System (SAS) procedures [9]. When a significant difference was found among treatments, Duncan's multiple range tests were performed to determine the differences among the mean values.

3. RESULTS AND DISCUSSION

Sponge cakes which were baked for short time (20 min) staying battery (they are not cooked enough) and/or they had small volume. On the other hand, too long baking times (35 and 40 min) were caused to high crust color, cracks on the top surface, and insufficient volume were observed (data not shown). The results of average cake volume values baked for 30 min at different temperatures are shown in Table 3.

Table 3. The effects of different baking temperatures on sponge cake volume.

Baking temperature (°C)	165	180	195	200	215	230
Sponge cake[(1)] volume (cm^3)	$1436^{e(2)}$	1570^{d}	1675^{c}	1725^{a}	1700^{b}	1655^{c}

[(1)] Slow acting baking powder formula (BP3; Table 1) was used in this experiment as 0.75% batter weight.
[(2)] Mean values in the table followed by different superscript with lowercase are significantly different ($p<0.01$).

Table 3 reveals that, in terms of cake volume with best result (average 1725 cm^3) was obtained from 200 °C baking temperature. After, sponge cake was baked at 200 °C temperature in oven for 25, 27, and 30 min separately and cake volume was investigated as 1715, 1725, and 1725 cm^3, respectively, and there was not any significant difference ($p<0.01$) on cake volume of these different baking times. We observed that, for crust color (bright, light yellowish brown), general appearance, and a good eye appeal, cakes which were 27 min baked best, so after the part of this study we conclude that cakes were baked for 27 min at 200 °C temperature.

The results of average cake volume characteristics values baked for different batter temperatures are shown in Table 4. By examining the Table, it is seen that the cake volumes vary between 749 and 1729 cm^3, which is approximately 2.5 times the other. Although there was no significant difference between the volumes of the sponge cakes produced with the BP_1 formula, it was observed that the cake volumes increased significantly in parallel with the increasing batter temperature in the sponge cakes made with the BP_2 formula ($p<0.01$).

Specific volume values of cakes varied between 1.99 and 4.55 cm^3/g (Table 4). According to the findings, although there was no significant difference between the specific volume values of the cakes produced with the BP_1 formula, the specific volume values of the cakes increased in direct proportion with the increase in the batter temperature in the cakes made with BP_2 ($p<0.01$).

In terms of volume index values, it was determined that the cakes prepared from the batter of

both ratios of BP_2 at 33.0±1.0 °C had the best results (189 and 187 mm, respectively). On the other hand, it was observed that the volume index values of the cakes made with the BP_2 formula and batter with a temperature of 19.0±1.0 °C were lower (51 and 78 mm) than all other samples.

Table 4. The effects of different batter temperatures on sponge cake characteristics.

BP Formula Code	BP Ratio (%)	Batter Temperature (°C)	Volume (cm^3)	Specific Volume (cm^3/g)	Volume Index (mm)	Total Volume Index(mm)	Symmetry Index (mm)	Shrinkage Value (mm)	Uniformity Index (mm)
BP_1	0.75	19.0±1.0	1659^{bc} (1)	4.35^{bc}	179^{cd}	652^{bc}	24^{a}	4.2^{cdef}	2.2^{a}
		26.0±1.0	1630^{c}	4.29^{c}	169^{f}	638^{d}	27^{a}	2.2^{f}	2.0^{a}
		33.0±1.0	1680^{abc}	4.42^{abc}	176^{de}	650^{bc}	26^{a}	3.0^{cdef}	0.7^{a}
	1.25	19.0±1.0	1710^{ab}	4.48^{ab}	182^{bc}	656^{b}	25^{a}	2.8^{def}	1.8^{a}
		26.0±1.0	1676^{abc}	4.41^{abc}	173^{ef}	645^{c}	26^{a}	2.4^{ef}	2.4^{a}
		33.0±1.0	1692^{abc}	4.43^{abc}	182^{bc}	652^{bc}	25^{a}	2.7^{ef}	3.3^{a}
BP_2	0.75	19.0±1.0	773^{f}	2.03^{f}	78^{i}	531^{g}	-16^{d}	7.6^{a}	1.4^{a}
		26.0±1.0	1470^{d}	3.87^{d}	160^{g}	624^{e}	17^{b}	7.4^{ab}	1.0^{a}
		33.0±1.0	1729^{a}	4.55^{a}	189^{a}	664^{a}	25^{a}	5.4^{abc}	2.2^{a}
	1.25	19.0±1.0	749^{f}	1.99^{f}	51^{j}	515^{h}	-1^{c}	4.8^{cde}	1.2^{a}
		26.0±1.0	958^{e}	2.52^{e}	100^{h}	569^{f}	-22^{e}	5.2^{bcd}	2.8^{a}
		33.0±1.0	1710^{ab}	4.51^{ab}	187^{ab}	666^{a}	20^{b}	3.0^{cdef}	3.3^{a}

(1) Mean values in the table in the same column followed by different superscript with lowercase are significantly different ($p<0.01$).

By examining the data of the total volume index, it was seen that the cake samples, which had the highest values in volume, specific volume and volume index analysis, also got the highest values in this index analysis, and the total volume index values of the cakes increased in parallel with the increasing batter temperature, especially in cakes made with BP_2 (Table 4). In the cake experiments made with the BP_1 formula, it could not be determined a significant effect of the baking powder ratio and batter temperature on the symmetry index value. On the other hand, in the cakes made with BP_2, symmetry index values increased in parallel with the increase in batter temperature. There was a fluctuation in both baking powder ratios of cakes made with BP_2 since some cakes are fluffy, and some are collapsing.

By examining the data of the shrinkage value (Table 4), it was seen that this value varied between 2.2 and 7.6 mm. It was determined that the cakes prepared with batter at 19.0±1.0 °C and 26.0±1.0 °C temperature, which are relatively small in volume and contain BP_2 in their composition, shrink (contraction) more from the edges and therefore the shrinkage values are higher in these cakes ($p<0.01$). As expected, batter temperature had no significant effect ($p>0.01$) on the uniformity index values of sponge cakes (Table 4).

According to AACCI Method 10-90.01 and 10-91.01 [5] the volume index is a primary quality measurement between the index's values. The volume index gives an indication of the overall size of the cake. The symmetry index assesses how peaked the cake is, while the uniformity index reflects how central the cake peak is. The symmetry index describes the top surface of cakes, which may be sunken (collapsed), flat or rounded and indicated by negative, zero or positive values, respectively [7, 10, 11]. The uniformity index is used as a measure of cake symmetry. For the optimum cake, this index should be zero – which indicates a cake with equal halves – because positive or negative values occur when one side of the cake is higher than the

other [12, 13, 14]. Ideally, high quality cakes have slightly rounded symmetrical tops, a large volume, and a low degree of shrinkage. The volume is related to the amount of air bubbles incorporated into a cake [8]. The volume is one of the most important factors for most of the baking products, especially for the cakes in terms of external view. The measurement of volume is a valuable tool in the evaluation of cake quality, because of it contributes not only to visual appeal but also it serves as an indicator of the structural development of the cake [1, 12, 13]. The specific volume is the most significant physical property of cakes because of its determination on consumer preferences [15].

Cake quality is affected by many factors during production. The main factors affecting the cake quality are formula balance, functions of the ingredients in the formula, before mixing the ingredients temperature, correct application of the mixing method, aeration of cake batter, temperature, specific gravity and pH values of the batter obtained at the end of mixing, accurately weighing the batter and filling it into the pans, stability of the fluid batter in the first stage of cooking and baking norms [7, 16, 17].

By evaluating together, the findings in the Table 4, it was observed that the batter temperature had no significant effect on the cake properties in cakes made with BP_1 containing only sodium bicarbonate in its composition, whereas the batter temperature had a significant effect on the quality of the final product in cakes made with the fast-acting formula BP_2. Parallel to the increase in batter temperature, it was determined that the volume-related values of the cakes belonging to volume, specific volume, volume index, total volume index and symmetry index increased, whereas the shrinkage value decreased (It was determined that the volume of sponge cakes made with BP_2 increased in direct proportion to the increase in batter temperature). It is seen that the cakes have a large volume in the experiments made with batter at an average temperature of 33.0±1.0 °C. On the other hand, values related with the volume (volume, specific volume, volume index and total volume index) were decreased whose cakes made from the batter at an average temperature of 19.0±1.0 and 26.0±1.0 °C with the BP_2 formula in both baking powder ratios. It was also observed that the symmetry index value was either negative or positive, but lower than the other cakes when the batter temperatures are 19.0±1.0 and 26.0±1.0 °C.

The findings obtained from our study are consistent with the findings and/or statements of other researchers who reported that batter/dough temperature affects the quality of bakery products [2, 17]. Recently, Dizlek and Özer [18] showed that dough temperature has a significant effect on bread quality.

4. CONCLUSION

In this study; the effects of different batter temperatures, baking temperatures and baking times on the important quality characteristics of sponge cake were investigated. It was possible to obtain sponge cakes with larger volume and higher acceptability when batter temperature was at 33 °C rather than around 20-25 °C and when they were baked at 200 °C for 27 min. If lower baking temperatures (<200 °C) and/or shorter baking times (particularly 20 min) were applied during sponge cake production, cakes with small volume, close or irregular pore structures were observed. Too hot oven temperatures (>200 °C) and/or too long baking times (35 and 40 min) were caused to dark crust color, cracks on the top surface, weak crumb and insufficient volume. By selecting correct batter temperature and baking norms, it could be possible to produce high quality and moist cakes with larger volume. Besides (by choosing the most convenient norms), economic losses could be prevented.

Acknowledgement

This work was supported by the Scientific Research Projects Unit of Çukurova University [grant number FBE.2002.YL.147].

References

[1] Dizlek, H., Altan, A., Determination of sponge cake volume with a mathematical method, Quality Assurance and Safety of Crops and Foods, 7(4), 551-557, 2015.
[2] Pyler, E.J., Baking science and technology, Sosland Publishing Company, Merriam, KS, USA, 1345 p, 1988.
[3] Dizlek, H., Kremalı kek (yaş pasta) bileşenleri ve üretimi, Dünya Gıda Dergisi, 18(2013-06), 77-84, 2013.
[4] Dizlek, H., Altan, A., The effects of egg and baking powder on the sponge cake characteristics, 15th International Cereal and Bread Congress, April 18-21, İstanbul, 169, 2016.
[5] AACCI, International Approved Methods of the American Association of Cereal Chemists (11th Edition), Method 08-01.01, Method 10-90.01, Method 10-91.01, Method 38-12.02, Method 44-19.01, Method 54-10.01, Method 54-21.02, Method 56-60.01, Method 56-81.04, The Association: St. Paul, MN, USA, 2010.
[6] Sultan, W.J., Practical baking, The Avi Publishing Company, Inc. Westport, CT, USA, 755 p, 1976.
[7] Dizlek, H., Effects of amount of batter in baking cup on muffin quality, International Journal of Food Engineering, 11(5), 629-640, 2015.
[8] Bath, D.E., Shelke, K., Hoseney, R.C., Fat replacers in high-ratio layer cakes, Cereal Foods World, 37, 495-500, 1992.
[9] SAS Institute, SAS user's guide to statistical analyses. SAS Institute, Inc. Raleigh, NC, USA, 1982.
[10] Dizlek, H., Özer, M.S., Gül, H., Keklerin yapısal özelliklerinin belirlenmesinde kullanılan ölçütler, Türkiye 10. Gıda Kongresi, 21-23 Mayıs, Erzurum, 371-374, 2008.
[11] Chesterton, A.K.S., Wilson, D.I., Sadd, P.A., Moggridge, G.D., A novel laboratory scale method for studying heat treatment of cake flour, Journal of Food Engineering, 144, 36-44, 2015.
[12] Cloke, J.D., Davis, E.A., Gordon, J., Volume measurements calculated by several methods using cross-sectional tracings of cake, Cereal Chemistry, 61, 375-377, 1984.
[13] Şümnü, G., Use of various starches in microwave baked cakes, The Journal of Food, 26(1), 9-11, 2001.
[14] İpek, T., Dizlek, H., Farklı form ve oranlarda yerfıstığı ürünleri kullanılmasının top kek kalitesine etkisi, Gıda Dergisi, 43(4), 591-604, 2018.
[15] Jia, C., Huang, W., Ji, L., Zhang, L., Li, N., Li, Y., Improvement of hydrocolloid characteristics added to angel food cake by modifying the thermal and physical properties of frozen batter, Food Hydrocolloids, 41, 227-232, 2014.
[16] Gómez, M., Ronda, F., Caballero, P.A., Blanco, C.A., Rosell, C.M., Functionality of different hydrocolloids on the quality and shelf-life of yellow layer cakes, Food Hydrocolloids, 21, 167-173, 2007.
[17] Dizlek, H., Altan, A., Pişirme öncesinde hamurun kısa süre bekletilmesinin pandispanya nitelikleri üzerine etkisi, Gıda Dergisi, 38(1), 31-38, 2013.
[18] Dizlek, H., Özer, M.S., Improvement bread characteristics of high-level sunn pest (*Eurygaster integriceps*) damaged wheat by modification in kneading and fermentation conditions, Journal of Cereal Science, 102, 103336, 2021.