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Investigating Textural and Physical Properties of Microwave-Baked Cupcake

S. Soleimanifard[1], M. Shahedi[1]*, Z. Emam-Djomeh[2], and G. R. Askari[2]

ABSTRACT

Since the microwave technology is well considered in food processing due to the speed and mechanism, in this study, cupcake was baked at different levels of MicroWave (MW) power (150, 300, 450 and 600W) and the effects of different kinds of operational time (3.5, 5, 8, 16 minutes) and power on physical properties (density, porosity, colour and height) and textural properties (crispness, hardness, cohesiveness, springiness, resilience, gumminess and chewiness) of cupcake were investigated. Results showed that the MW baking time to obtain desirable baking properties was affected by MW power. The obtained results showed that the total differences in colour from the reference batter (ΔE) and colour intensity increased with increasing of MW power. Moreover, the MW cupcake baked at a power of 600W had the least hardness, density, chewiness, gumminess values, the shortest baking time, and the highest values of cohesiveness, resilience, porosity, height, and browning index. Also, it had the highest cohesiveness, resilience, porosity, height and browning index, compared to the other powers. Therefore, the best operational power for desirable quality obtained during baking was 600W.

Keywords: Colour, Cupcake texture, Hardness, Operational power, Porosity.

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INTRODUCTION

Cake is a sweet baked food made from a thick batter, usually containing flour and sugar, and often shortening, eggs, and a rising agent (as baking powder). It is usually baked in a conventional oven (Stevenson, 2003) Conventional baking is the slow transfer of heat from the surface to the interior of products. The speed of baking is controlled by the differential in temperature from a hot surface to a cool interior (Schiffmann, 1993). Thus, a long time and high temperature is required leading to possible damages to the quality and nutritional attributes of the final product. A reduction in bulk density and vaporization of volatile compounds and, consequently, loss of flavour components will be the outcome of such improper baking (Vadivambal and Jayas, 2007). Moreover, energy efficiency is low in conventional baking. The use of microwave as alternative method to improve the quality of the baked product attributes is suggested (Drouzas and Schubert, 1996).

Microwaves themselves do not directly take part in heating, rather, electromagnetic energy is converted into heat via frictional energy of bipolar molecules and ions such as water and salts inside the product. There are many factors that affect how food is heated in a microwave field, such as dielectric properties, heat loss mechanisms, power generated in the material, microwave output, frequency of the microwave system, and so on (Schiffmann, 1993).

[1] Department of Food Science and Technology, College of Agriculture, Isfahan University of Technology, Isfahan, Islamic Republic of Iran.
[2] Transfer Phenomena Laboratory, Department of Food Science and Technology, Faculty of Agricultural Engineering and Technology, University of Tehran, Karaj, Islamic Republic of Iran.
* Corresponding author, email: shahedim@cc.iut.ac.ir

The use of microwave can significantly increase the speed of baking, due to the fact that the direct absorption of microwave energy by polar molecules and ions leads to fractional heat load and thereby a volumetric heating from inside to outside of the product being baked. Also, the efficiency of energy conversion is high as there is no need to heat another source like air or water for heating of foods (Gowen *et al*., 2006; Vadivambal and Jayas, 2007)

The lack of direct contact between the food and source of energy and instant heat generation with the variation of power results in a rapid process control. Another advantage is the improvement of product quality through avoidance of overheating problems which cause crumb and crust hardening. Moreover, desirable chemical and physical effects (expansion, protein denaturation, starch gelatinization) are promoted by heat generation during microwave baking (Schiffmann, 1993) but, non-uniform heating, no rise in temperature from boiling point, center dryness, surface wetness, and lack of desirable colour and flavour are its disadvantages (Yolacaner *et al*., 2017; Zuckerman and Miltz, 1997). An absorbance modifier was suggested that leads to the formation of a brown colour, crispiness, and causes uniform heating of food (Albert *et al*., 2009; Zuckerman and Miltz, 1997)

More researches into microwave cake baking were carried out to change ingredients and equipment that lead to increase in the shelf life and functional properties of cake MW cake baked (Al-Muhtaseb *et al*., 2010; Beikzadeh *et al*., 2017; Christaki *et al*., 2017; Majzoobi *et al*., 2015; Majzoobi *et al*., 2014; Petisca *et al*., 2013; Saatchi *et al*., 2014; Seyhun *et al*., 2003; Seyhun *et al*., 2005). Furthermore, investigating the temperature and weight loss profiles (Sumnu *et al*., 1999) and volume changes and firmness of the cake (Bilgen *et al*., 2004; Martin and Tsen, 1981; Megahey *et al*., 2005) during microwave baking.

There has been no comprehensive study on textural and physical parameters as a function of power, time, temperature and moisture content during MW baking of cake. Therefore, the main objective of this study was to investigate the effect of power and time on baking rate and textural (crispness, hardness, springiness, chewiness, gumminess, cohesiveness and resilience) and physical (volume, density, porosity and colour) properties during microwave baking of cupcake.

MATERIALS AND METHODS

Preparation of Cupcake Batter and Baking Procedure

Vanilla batter contained 100 g cupcake powder (containing wheat flour, sugar, milk powder, emulsifier- E475, salt, baking powder), 52 g liquid egg, 32 g vegetable oil and 32 g water. Liquid whole egg was mixed with a mixer (Bosch-CNCM57, 1100W, Slovenia) at high speed for 10 min. Then, water and vegetable oil were added and mixed. Cake powder was simultaneously added and mixed till uniformity in cupcake batter was obtained. Hundred g of the prepared batter was placed in a glass pan (Radius: 3.25 cm; Height: 2.5 cm). Samples were baked at a microwave oven (Butane MR-1, Iran, with a maximum output of 900W at 2,450 MHz). Operational MW powers were 150, 300, 450 and 600W. Sampling was carried out from batter at six specified time intervals during the baking period. Quality parameters were measured 1 h after baking to allow samples to cool to room temperature.

Weight Loss and Moisture Profile Measurement

Moisture loss measurements were also conducted. The cupcake was weighed by an electronic balance (AND, Japan) at specified time intervals during baking, and the

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moisture content of the samples was then calculated and plotted.

Physical Properties

Colour Measurement: An average of three replications of the top, and bottom surface, and centre colour parameters of the sample was reported. The parameters were directly read with a spectrophotocolorimeter Mini Scan XE (Germany) with a lamp (D 65) as *L** (Lightness), *a** (greenness to redness), *b** (Blueness to yellowness). Total differences in colour from the reference batter (ΔE), and Browning Index (BI) were calculated using the following equations. Fresh batter was used as the reference (subscript ‘0’) (Askari *et al*., 2008; Ozkahraman *et al*., 2016; Romano *et al*., 2008):

$$\Delta E = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b - b_0^*)^2} \qquad (1)$$

$$BI = \frac{\left[100\left(\frac{a^* + 1.75L^*}{5.645L^* + a^* - 3.012b^*} - 0.31\right)\right]}{0.17} \qquad (2)$$

Height, Density, and Porosity Measurement: The average height of cupcake samples were measured at five points (centre, c, and four other symmetric points, *a*, a_0, *b*, and b_0 on the cross-section surface) along the centre-line, using the standard. Then, the height of cupcake was represented (Zareifard *et al*., 2009).

The bulk volume of each cupcake was determined by the rapeseed displacement method and bulk density (ρ_b) determined by the mass of the sample (weighted using an analytical balance) and its bulk volume (Majzoobi *et al*., 2012; Ozkahraman *et al*., 2016), True density (ρ_t) was determined by the mass of sample and its true volume without any pore. Porosity (ε) was estimated from the bulk density and the true density in accordance with following equation. (Krokida and Maroulis, 2000):

$$\varepsilon = 1 - \frac{\rho_b}{\rho_t} \qquad (3)$$

Textural Properties

TPA Test*:* Texture Analyzer (TA Plus, Lloyd Instruments, UK), equipped with a 50 N load cell and cylindrical probe (40 mm diameter) at a speed of 60 mm, was used for the double compression Texture Profile Analysis (TPA) tests. Cylindrical crumbs of cupcake with 24.5 mm diameter and 20 mm height were compressed to 50%. A number of textural parameters were extracted from the resultant force-time curve.

The height of the force peak on the first compression cycle was defined as hardness. The ratio of the positive force areas under the first and second compressions was defined as cohesiveness (the extent to which a sample can be deformed before it ruptures). Springiness was considered as the rate at which the sample returns to its original shape after compression and resilience as the degree to which the sample returns to the original shape. Two other parameters were derived by calculation from the measured parameters: Gumminess was defined as the multiple of hardness and cohesiveness; chewiness was defined as multiple of gumminess and springiness (which is hardness× cohesiveness× springiness) (Guadarrama-Lezama *et al*., 2016; Zareifard, Boissonneault *et al*., 2009).

Puncture test*:* Texture analyzer (TA Plus, Lloyd Instruments, UK) was used to carry out a puncture test with 2 mm diameter probe. Crispness of samples having a thickness of 2.5 cm was the measured force required to push a probe into the bottom surface of cupcake and expressed in ‘N’(Kang and Chen, 2015).

Statistical Analysis

The experimental design was a split plot arranged in a completely randomized block design with three replications. Data were subjected to Analysis Of Variance (ANOVA) using SAS 5.1. Treatment means were separated using the Least Significant Difference (LSD) test (P≤ 0.05).

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RESULTS AND DISCUSSION

Temperature and Moisture Content Profiles

Figure 1-A illustrates the moisture content of samples during microwave cupcake baking under different kinds of operational MW power. These results show that moisture content was decreased by increasing the MW power at a constant time of process. Moreover, the operational time can be reduced, depending on the MW power. On the other hand, the final required time for cupcake baking decreased (from 16 to 3.5 minutes) with increase in MW power. As a result, the shortest time (3.5 minutes) for microwave cupcake baking was obtained at the largest power (600W).

As shown in Figure 1-B, the temperature at the centre of the cupcake increased with MW power and time during baking. Similar process time observations at 650W were reported by Houšová *et al.* (2002). As a result, the final temperature of the cupcake increased with increase in MW power.

As shown in Figure 1-C, the baking had three periods. First period included an increase in temperature slowly, which led to a slow increase in the moisture loss. Next period included a rapid rising temperature and moisture vaporization and then temperature remained constant. This period included most of the processing time. Final period started when the moisture content dropped, the speed of moisture loss declined, and the slope of the curve was reduced compared to the previous period. As a result, temperature increased till the end of the baking process.

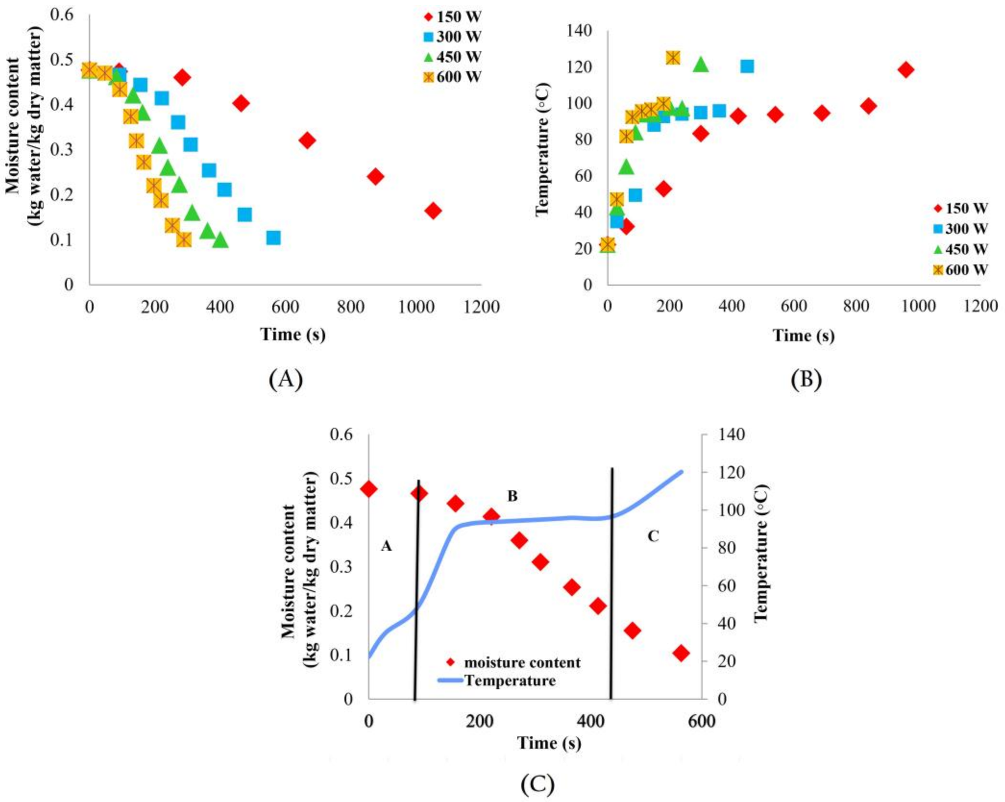

Figure 1. The moisture loss of samples during microwave baking (A), temperature profiles of cupcake microwave-baked at different time and MW power (B), and moisture and temperature profile simultaneously (C).

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Physical Properties

Colour: Cupcakes showed a decrease in the L^* value and an increase in a^* and b^* with an increase in MW power (for example, at 3 minutes, L*: From 84 to 78, a*: From 8.6 to 17.3, and b*: From 74 to 80) and time during MW baking. According to Mandala *et al*. (2005), the decrease in 'L^*' values and the increase in 'a^*' values correspond to the increase in sample browning and colour changing, as shown in Figure 2 (Mandala *et al*., 2005).

As shown in Figure 2, the colour changes (ΔE), and Browning Index (BI) of cupcake increased with time and MW power during the baking, because the baking process alters the surface properties of the food and subsequently changes light reflection and product colour (Figure 2-A). Moreover, heat and oxidation that occur during the baking procedure cause chemical changes. It means the changes in colour parameters from lighter yellow to darker yellow (Croguennec, 2016; Horuz *et al*., 2017).

As Figure 2-B shows, small increases in the *BI* were observed at the beginning of the process. With the passage of time and reduction in the moisture content, the *BI* increased rapidly and reached its final value. This indicates that a brown colour creation enhanced at lower moisture content and higher powers (Bchir *et al*., 2012).

Height, Density, and Porosity: At first, cupcake expanded with temperature due to internal vaporization of water (Manley, 2000; Mizukoshi *et al*., 1980), and air expansion that is incorporated during mixing of batter and CO_2 generation (Baik and Marcotte, 2003). When the cupcake temperature exceeded 85°C, expansion stopped, while the evaporation continued. That was proof of the end of cupcake expansion, such as opening structure, because of the formation of bubbles and massive emission of gas to the outside as soon as the temperature exceeded coagulation temperature of protein (Mizukoshi *et al*., 1980) and then structure stiffness and stopping of expansion when the cupcake temperature reached starch gelatinization temperature i.e. 90°C (Figure 3-A). Finally, the end of expansion and water evaporation lead to a shrinkage in the cupcake (Lostie *et al*., 2002). The results showed significant difference in cupcake height with increasing of MW power. Similar results were reported by Megahey *et al*. (2005). On the other hand, height of

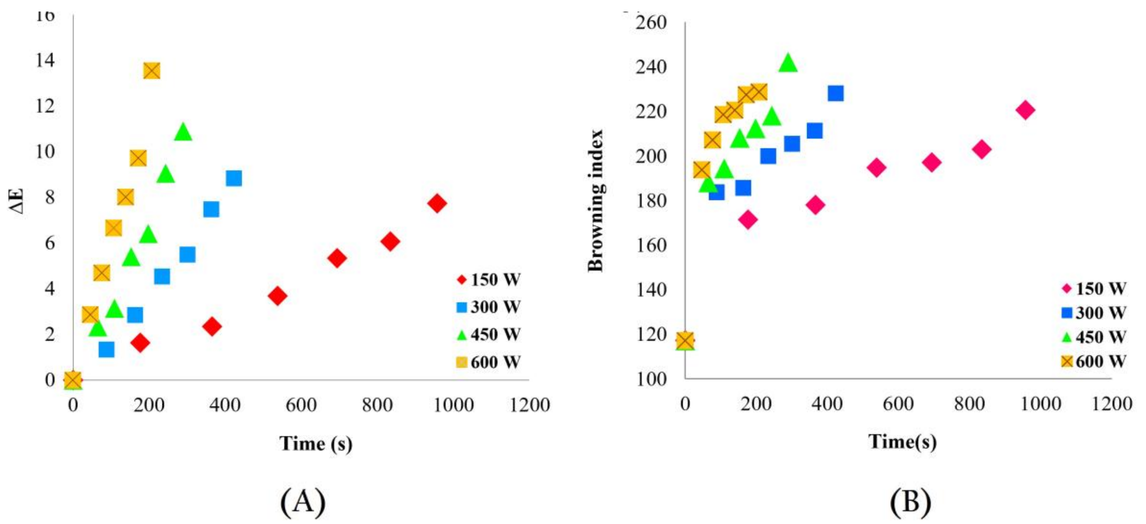

Figure 2. Effect of time and MW power on color changes (A), and browning index (B) during microwave baking.

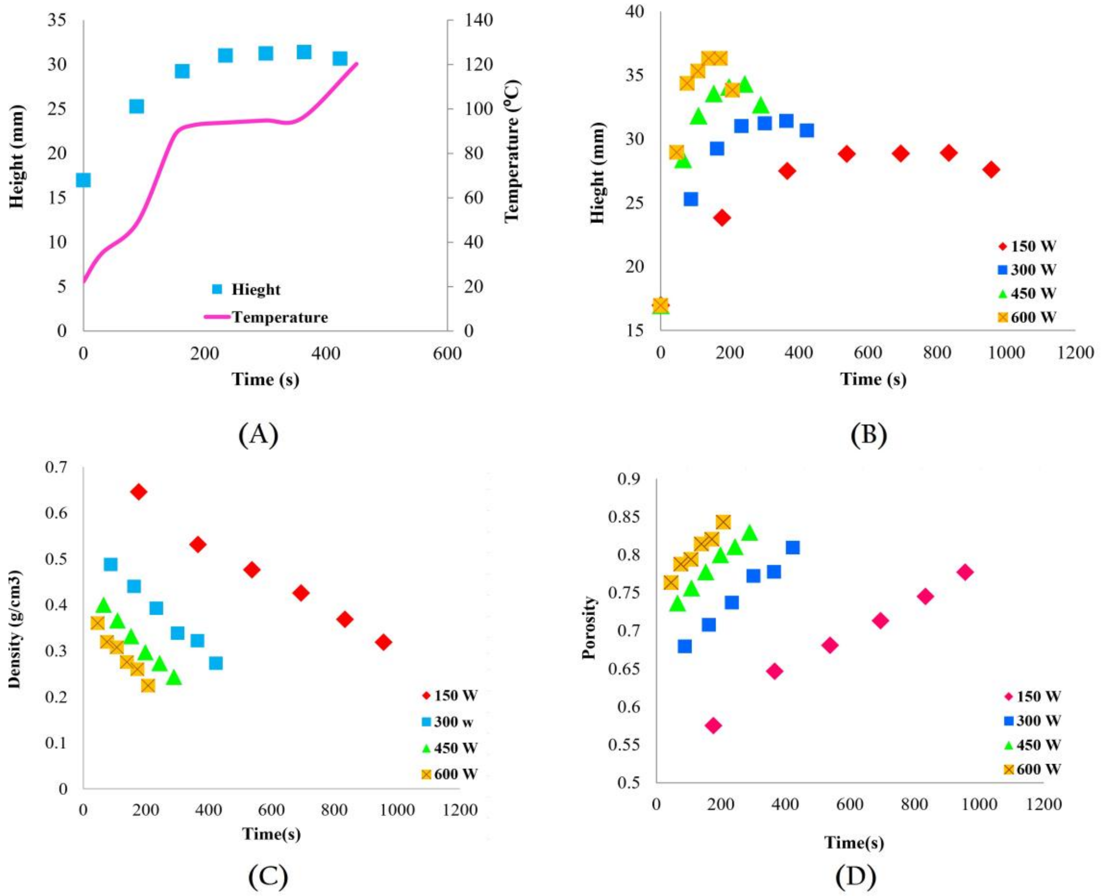

Figure 3. Effect of process time on height and temperature simultaneously (A) and MW power and time on height (B), density (C), and porosity (D) during microwave cupcake baking.

cupcake increased with MW power (Figure 3-B), such that cupcake baked with higher power had higher porosity and lower density and subsequent better quality (Figures 3-C, and -D) (Megahey *et al*., 2005; Yong *et al*., 2002).

Texture Properties

Hardness*:* Figure 4-A illustrates increase in the cupcake's hardness at constant MW power during baking that related to decrease in the moisture content (Ozkoc *et al*., 2009) and increase in the speed of the starch-protein and starch-starch interactions. Therefore, hardness increased during microwave baking (Gray and Bemiller, 2003; Ozkoc *et al*., 2009).

Also, Figure 4-A shows that hardness was increased with increase in MW power at a constant time. Similar results for bread are reported in the literature (Keskin *et al*., 2004). Hardness values of the final cupcake are 50.87, 17.14, 15.05 and 13.46 for 150, 300, 450 and 600W, respectively (Figure 4-A). As can be seen from these results, the hardness of final cupcake decreased with MW power increasing. Similar results for Madeira cupcake were found by Al-Muhtaseb *et al*. (2013). Cupcake baked at higher MW power required smaller time exposed to microwave and, so, hardness was reduced.

Springiness: This is the speed at which the cupcake returns to its original shape after it has been compressed (Clarke and Farrell, 2000). Springiness significantly increased

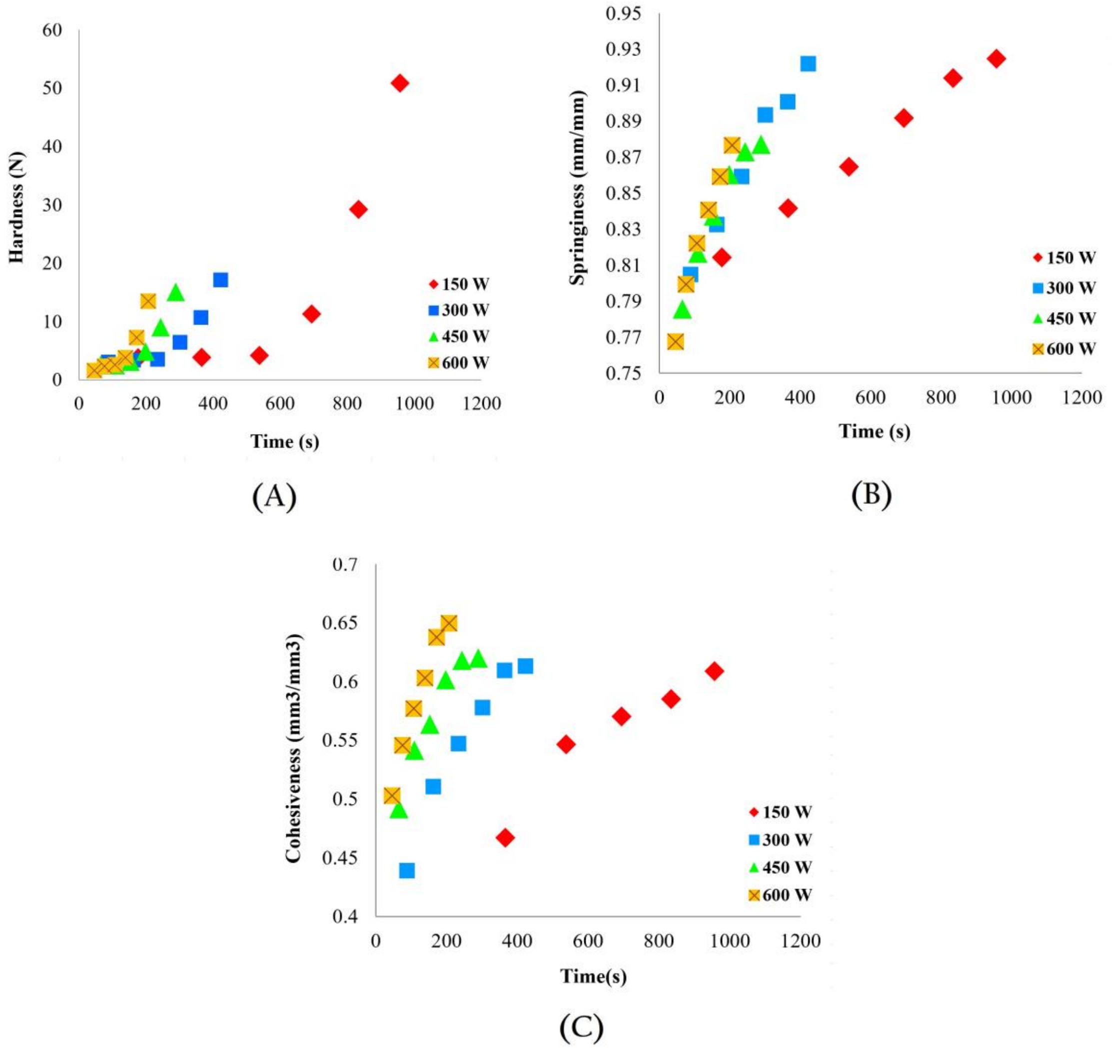

Figure 4. Hardness (A), springiness (B), and cohesiveness (C) changes of cupcake microwave-baked with time and MW power.

with time and MW power during microwave baking (Figure 4-B), which was related to increase in hardness during the process and more elapsed time for returning to the original state of the sample. Similar results were reported for pizza by Clarke *et al*. (2000). Also, elapsed time for return of cupcake to initial shape and springiness of the final cupcake decreased with increasing MW power, which was related to decrease in the final cupcake's hardness with increasing MW power. Similar observations were reported by Al-Muhtaseb *et al.* (2013)

Cohesiveness: Figure 4-C shows the changes in the cohesiveness of cupcake during microwave baking. The cohesiveness of the cupcake increased with time at constant MW power.

As shown in Figure 1-A, the moisture content was reduced when power was increased at a constant time. Therefore, the structure was stronger, and cohesiveness increased. Furthermore, with increased MW power, the sample received more energy over time and, so, the process time was reduced for obtaining final strong structure. As shown in Figure 4-C, the values of cohesiveness of final cupcakes were 0.609, 0.613, 0.620 and 0.650 at 150, 300, 450 and

600W, respectively, showing an increase in this parameter with increasing power.

Resilience*:* Figure 5-A shows the effects of time and MW power on resilience. At first, resilience increased, and after a time, decreased. Resilience and height (Figure 5-B), and also relationship between height and center temperature (Figure 3-A) of cupcake during baking showed that structure was formed at first and then its strength increased with rising time and temperature. Therefore, the resilience—that is, the degree to which the cupcake returns to its original shape/size—increased till 90˚C (gelatinization temperature of starch) so that increase in height and volume were stopped (Mizukoshi *et al*., 1980). Finally, the halt to the expansion and water evaporation led to a reduced height of the cupcake and increase in temperature (Lostie *et al*., 2002), and the crumbs of the cupcake were so hard that the return to the original state after removal of compression was decreased. Resilience was also reduced.

Chewiness and Gumminess*:* As shown in Figures

Figure 6-A and -B, gumminess and chewiness increased at the constant MW power during microwave baking. Similar results were obtained by Al-Muhtaseb *et al*. (2013). On the other hand, increase in the cupcake's hardness during baking—and then increase in the elapsed energy for chopping of samples—resulted in enhanced gumminess and chewiness.

The final value of the recent two parameters, however, decreased with increasing MW power. As the final hardness was reduced, this, in turn, was due to the reduced process time with increasing MW power (Megahey *et al*., 2005; Yong *et al*., 2002).

Crispness: Crispness decreased with an increase in MW power (Figure 6-C). Crispness was rapidly reduced from 150 to 450W and then the slope decreased at the highest operational MW power (600W). Therefore, the cupcake was baked at a higher MW power, and required smaller time when exposed to microwave. Hence, crispness was reduced, since the exposed time to microwave was reduced with increase in MW power (Hadiyanto, 2013).

CONCLUSIONS

The effects of microwave on the baking rate and the optical, physical, and textural properties of cupcakes were investigated. Results showed that the elapsed time to obtain a desirable baking was affected by different MW power (150, 300, 450, and 600W). The shortest time was obtained at

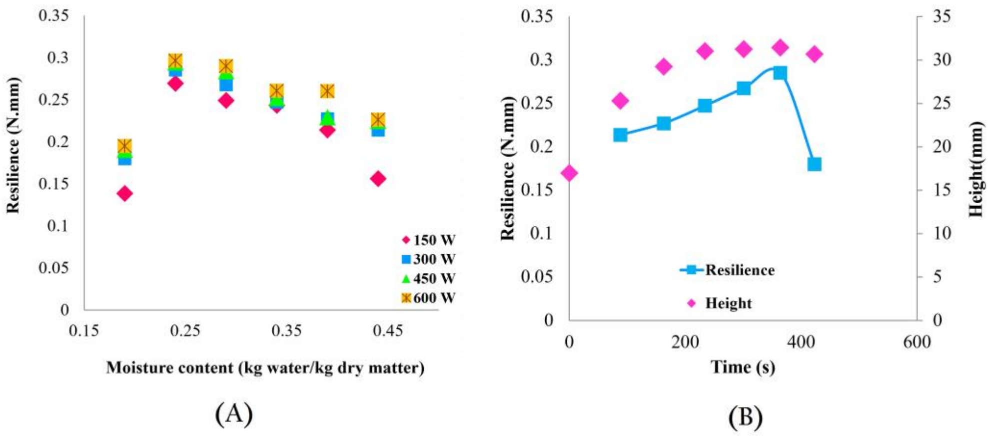

Figure 5. Effect of microwave power and baking time on resilience (A) and relationship between height and resilience (B) during microwave baking.

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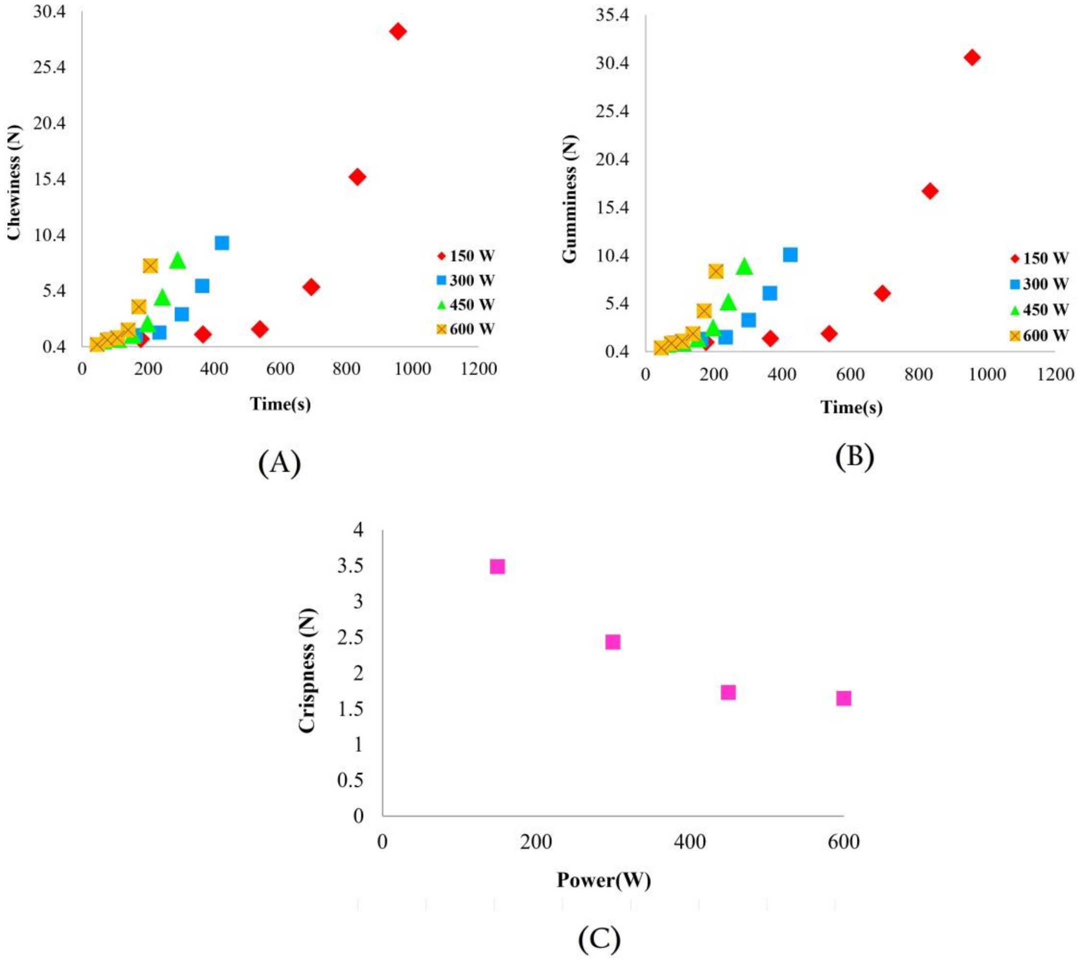

Figure 6. Effect of baking time and microwave power on chewiness (A) and gumminess (B), and relationship between MW power and crispiness of cupcake (C).

the highest applied MW power (600W). The results obtained showed that the ΔE and colour intensity increased with increase in the operational power. Microwave baking with the highest power provided the better physical and textural properties in terms of the final highest browning index, volume, height, porosity, cohesiveness, resilience and the least final values of hardness, springiness, gumminess, chewiness, and density.

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بررسی خصوصیات فیزیکی و بافتی کیک فنجانی طی پخت با استفاده از مایکروویو

ص. سلیمانی فرد، م. شاهدی، ز. امام جمعه، و غ. ر. عسکری

چکیده

امروزه تکنولوژی مایکروویو به دلیل سرعت و مکانیسم آن بسیار مورد توجه صنعت غذاست، بنابراین در این مطالعه، کیک فنجانی در سطوح مختلف توان (۶۰۰، ۴۵۰، ۳۰۰ و ۱۵۰ وات) و در زمان های مختلف (min ۱۶، ۸، ۵ و ۳/۵) پخته شد و اثر زمان و توان مایکروویو بر ویژگی‌های فیزیکی (چگالی، تخلخل، رنگ و ارتفاع) و ویژگی های بافتی (سفتی، سرعت و میزان برگشت کیک به حالت اولیه، تردی، قابلیت جویدن و استحکام ساختار) کیک فنجانی بررسی شد. نتایج نشان داد که زمان مورد نیاز برای فرایند مطلوب تحت تأثیر توان اعمالی مایکروویو است. همچنین نتایج بدست آمده نشان داد که تغییرات رنگ نسبت به رنگ اولیه و شدت رنگ با افزایش توان، افزایش می‌یابد. علاوه براین، کیک فنجانی پخته شده در توان ۶۰۰W دارای کمترین زمان پخت، سفتی بافت، دانسیته و همچنین کمترین انرژی لازم جهت جویدن و بیشترین میزان استحکام، سرعت و میزان برگشت نمونه به حالت اولیه، تخلخل و اندیس قهوه‌ای شدن را در مقایسه با دیگر توان‌های اعمالی است. بنابراین بهترین توان اعمالی مایکروویو جهت رسیدن به کیفیت مطلوب طی پخت، توان ۶۰۰ W است.

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