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Color and Volume Development of Cake Baking and Its Influence on Cake Qualities

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ABSTRACT

Baking is the last but most important step in cake making procedure because it involves moisture content, texture, browning and volume changes that are strongly coupled. The final bakery product properties are not only affected by the ingredients but also by processing conditions. Volume and browning changes were observed at three different temperatures, namely 160°C, 170°C, and 180°C, for different baking times namely 35, 40, 45, and 55 minutes, by using convection oven and its relationship with texture and water evaporation during baking process. The objective of this research is to investigate the effect and the relationship of different baking parameters to the cake qualities during baking process. The results show that the total colour difference, ΔE, and volume expansion rapidly changed due to the rise in temperature of cake and has a positive relationship with cakes' firmness and the moisture loss. The data also demonstrated that the browning and volume expansion were more significant to the baking temperature ($P < 0.001$) than baking times.

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INTRODUCTION

Although people have practiced baking for a long time, understanding of the whole process is not clear. One of the possible reasons for this is that several fundamental complex physical and biochemical processes are coupled during baking like evaporation of water, volume expansion, crust color formation, gelatinization of starch and denaturation of proteins (Mondal and Datta, 2003). The essential influence on final product quality includes the rate and the amount of heat application, the humidity level in the baking chamber and baking time. Volume and color are important characteristics in the evaluation of cakes and cake quality. A good quality cake should have a high volume and a good surface color with a fine uniform moist crumb. Too high temperature will cause high crust color, lack of volume with peaked tops and irregular crumbs. However, too low baking temperature will cause pale crust color, large volume and poor crumb structure (Wählby *et al*., 2000). Hadi Nezhad and Butler (2008) stated that a cake needs to have appreciable volume and less shrinkage during baking and a final dome shaped contour at the end of baking, whereas the crust should be thin with golden brown color.

Texture also is one major quality attributes of foods and determined from the response of tactile senses to the food product. Baik *et al*. (2000) suggested that an approximate estimation of cake texture could be achieved based on the type and quantity of the ingredients used. However, the final bakery product properties are not only affected by the ingredients but also by processing conditions. The final moisture content of cake is also important in determining the quality of cake. Measuring the water distribution and water loss during baking is fundamental to better control of the final cake quality.

Many researchers have conducted studies on the effect of process conditions or using different product formulation towards the final product qualities such as volume expansion, surface browning, texture and moisture content in bakery product. Hadi Nezhad and Butler (2008) investigated the effect of baking temperature and flour type on volume of cake during baking, while Mohd Jusoh. *et al*. (2009) performed a study on surface browning of crust and the bread thickness development at

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different baking parameters. Sanz *et al*. (2009) evaluated the different types resistant starch in muffin towards its texture, color and customer respond. However, only few studies focused on the correlation between volume and color development to the quality of cake. In the cake baking processing, there are many unique appearances, and their qualities are linked to each other and not easy to evaluate due to the different baking parameters. Therefore, this study is intended to investigate the effect and the relationship of different baking parameters to the cake qualities during baking process.

Methodology:

1.1 Cake sample preparation:

Standard ingredients for the butter cake recipe are cake flour (25%), butter (36%), sugar (39%), fresh eggs and other minor ingredients. A convection oven (model EO-4286, Elba, Japan) was used. The cakes were baked at three different temperatures which were 160°C, 170°C and 180°C and at different baking times; 0 to 55 minutes where the cakes were allowed to cool for 24 hours before being analyzed.

1.2 Cake Surface Color Evaluation:

The cake surface color was measured in Lightness (L), redness (a) and yellowness (b) values by using a digital image processing in Matlab 7.7. The image acquisition of the cake's surface was captured by using a high-resolution camera. The total color difference, ΔE* for the cake can be calculated by using a formula as follows:

$$\Delta E = \sqrt{\left[(L_o - L)^2 + (a_o - a)^2 + (b_o - b)^2\right]} \quad (1)$$

Where L_o, a_o and b_o are the values for the batter.

1.3 Dynamic Height Monitoring:

Height changes during baking are measured using the dynamic height profile method. Five stainless steel pins on the frame were clipped on the middle of the pan. A digital camera was used to take photos of the cake for five minute intervals during the baking process.

1.4 Cake Texture Measurement:

The texture characteristics of the cake in terms of springiness and firmness were measured according to AACC Approved Method (74-09) using Texture Exponent software version 2.0.7.0., (Stable Microsystems, Godalming, UK) fitted with 32 mm diameter round plunger (P/32). Four square blocks with the dimensions 2.5 x 2.5 x 2.5 cm3 crustless cake were cut from the cake 24h after baking and compressed vertically and individually to 50% compression.

1.5 Moisture Content Measurement:

By using the same sample of texture analysis, each sample were cut into three sections: top, middle and bottom. The final moisture contents of the cake were analyzed using a moisture contents under a standard drying programmer (accuracy: 0.05% min-1).

RESULTS AND DISCUSSION

2.1. Effect of baking parameters on the volume development:

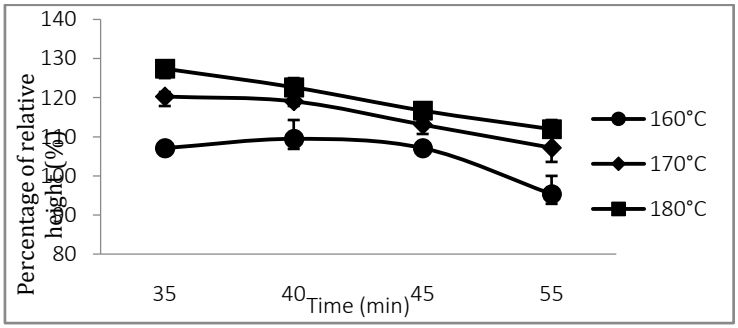

Fig. 1: Values of relative height (%) of cake

Figure 1 shows the values of relative height (%) of cake at different baking parameters. The maximum value of percentage relative height of cake reached when it was already cooked which are 109.15% for 45 minutes, 119.05% for 40 minutes and the highest percentage of relative height of about 127.35% for 35 minutes baking time at oven temperatures 160°C, 170°C and 180°C respectively. At the lowest temperature, expansion peaked at a later time thus resulted in a lower expansion rates and lower volume, whereas at high temperature, high expansion rate resulted in a larger volume (Whitaker and Barringer, 2004). According to Zanoni *et al*. (1993), there were changes in temperature, water content, and volume during bread baking. He stated that the volume decreased linearly after reached a maximum volume expansion until completion of the experiment. Further heating up to the end of baking is causes strengthening of cake structure and increase the pressure in the cake, which causes slight cake contraction. Mohd Jusoh *et al*. (2009) stated that higher heat and mass transfer, as well as evaporation process, occur at higher temperature which cause a thicker crust formation and restricts the expansion of

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the batter. In observation, Al-Dmoor (2013) mention that the degree of expansion is dependent on the viscosity of the batter. If the batter is thick, it would be difficult for the air bubbles to escape, which would result in high volume cake. However, in the most baking process, baking conditions such as time of baking and oven temperature are also predominant that affect the quality of cake (Baik *et al*., 2000). The expansion rate of cake increased rapidly at the highest temperature (180 °C) about 0.089 mm/min, until 35 minutes of baking, and the cake was about 0.018 mm/min to the end of baking. However, the volume increase in low expansion rate at the lowest temperature (160 °C) about 0.078 mm/min until 45 minutes and gave more shrinkage during baking about 0.027 mm/min. High temperature will speed up the enzymatic activities and yeast growth cause increase gas carbon dioxide gas production rapidly and keep expanding the cake volume resulted high expansion rate (Thorvaldsson & Skjoldebrand, 1998). Results have shown that a higher temperature gives appreciable volume with less shrinkage during baking and with thin crust.

2.2. Effect of baking parameters on the browning development:

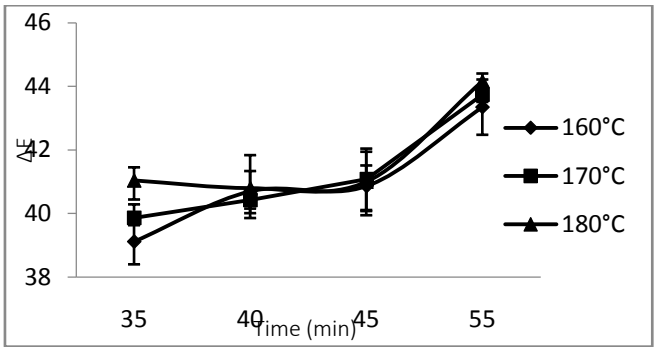
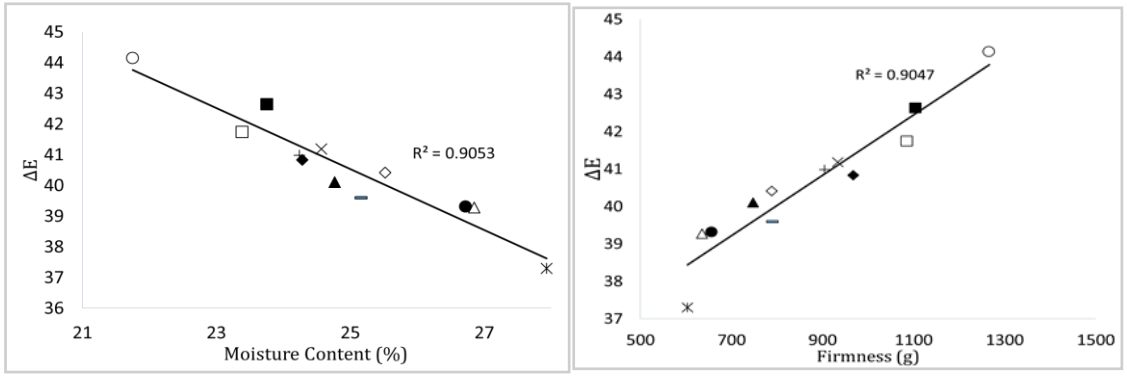


Fig. 2: Values of total color difference (ΔE)

Figure 2 shows the total color difference (ΔE) at different temperatures and baking times. In bakery product, the surface color as a quality indicator associated with aroma, taste and appearance characteristic that costumer perceived. For oven temperatures 160°C, 170°C and 180°C, cakes were completely cooked at 45 min, 40 min, and 35 min, respectively with the value for ΔE within the range of 40 – 42. Crust browning occurs when the temperature in the cake is greater than 110°C (Mondal and Datta, 2008). From the experiment, cakes at temperature 160°C and 170°C, brown color start to appear on the surface at 35 minutes of baking and increase rapidly until the cakes were cooked. The highest temperature, 180°C shows the brown color appear earlier than other temperature and gave the highest ΔE at 35 minutes. Higher temperature resulted in rapid decrease in the thermal conductivity within the product which consequently enhanced the Maillard reactions and caused the browning to appear earlier. After 45 minutes, the total change in colour increased sharply, indicating overly cooked cake. . At that point, the cakes at all the temperatures were too dark and the other sensory attributes of the cake were unacceptable.

2.3. The relationship between browning and volume development to the other qualities of cake:



(a) (b)

Fig. 3: Correlation between the total color difference (ΔE) between moisture content (%) of cake (a) and firmness (g) of cake (b). (o = 180°C, 55 min, □= 180°C, 45 min, ♦ = 180°C, 40 min, ─ = 180°C, 35 min, ■ = 170°C, 55 min, ▲ = 170°C, 45 min, ◊ =170°C, 40 min, = 170°C, 35 min, x = 160°C, 55 min, Δ = 160°C, 45 min • = 160°C, 40 min, * = 160°C, 35 min)

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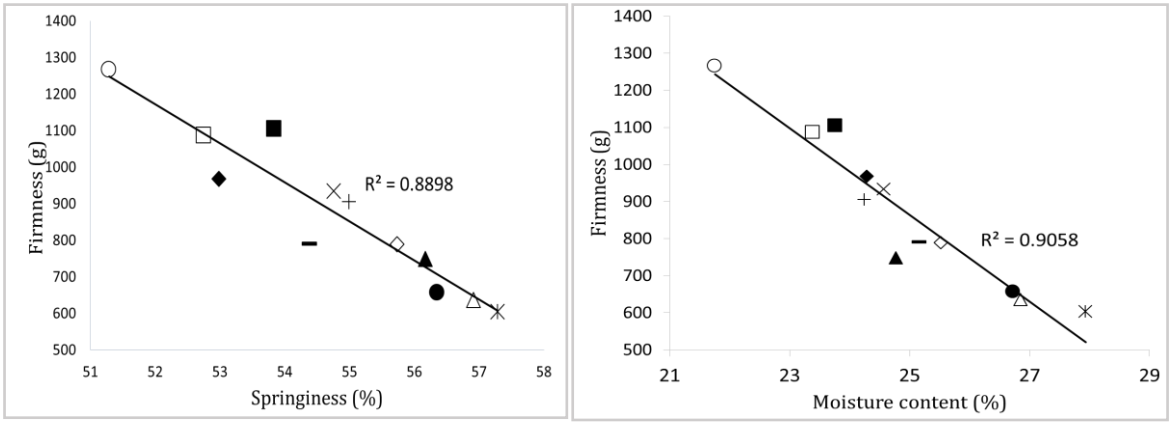
Figure 3 show the total colour different, ΔE, calculated using Equation 1, give a negative correlation with moisture content (%) of cake (a) and a positive correlation with the firmness (g) of cake (b), with high R^2 0.9053 and 0.9047 respectively. This relationship could be used to predict the surface color of cake. Increased temperature at the outer crumbs enhanced increasing moisture evaporation at the cake surface and chemical reaction rate. The colour started to change in the second stage of baking process after 35 minutes when the heat cannot be dissipated fast and is used for Maillard reaction at the surface. Therefore, the Maillard reaction occured more rapidly as the temperatures and times were increased. As the high lost moisture of cake enhance the high color changing and resulted increased hardness of the cake. When temperature and baking time increases, the water activity decrease at the product surface; therefore, enhanced the formation of colour compound (Purlis, 2010).

A good quality cake should have high volume with a fine uniform moist crumb. Starch gelatinization and protein denaturation, together with carbon dioxide formation, gives cake its porous and soft structure. The rise in temperature of the product will initiate the chemical reactions and thus rapidly increase the carbon dioxide (CO_2) gas production (Chang, 2006. Crust formation is one of the limiting factor, which restricts the expansion of the batter (Zhang *et al*., 2007). Higher water percentage resulted in more CO_2 bubbles, and a rougher crumb (Mondal and Datta, 2008). As water vapour and CO_2 expand due to high temperature, they act as an insulating agent preventing high rate of temperature rise of crumb and the possibility of excessive moisture evaporation. Therefore, larger volume expansion could cause higher water lost and higher firmness of cake.



(a) (b)

Fig. 4: Correlation between the firmness (g) and springiness (%) of the cake (a) and correlation between firmness (g) moisture content (%) (b). (o = 180°C, 55 min, □ = 180°C, 45 min, ♦ = 180°C, 40 min, ─ = 180°C, 35 min, ■ = 170°C, 55 min, + = 170°C, 45 min, ◊ =170°C, 40 min, = 170°C, 35 min, x = 160°C, 55 min, Δ = 160°C, 45 min • = 160°C, 40 min, * = 160°C, 35 min)

Figure 4 (a) shows the relationship of the cake textural, firmness (g) and springiness (%) of cake and Figure 4 (b) shows the relationship between the firmness (g) of cake with moisture content (%) that were analyze at different times and different oven temperatures. The average values were analyzed at different parts of cake. During baking, heat is transferred mainly by convection from the heating media, and by radiation from oven walls to the products surface followed by conduction to the centre. The texture and density of baked products such as bread and cakes are controlled by the way their rheology and vapour content change during the baking process, Dobraszczyk and Morgenstren (2003). Figure 4 (a) shows a strength of the relationship are strong with high coefficient of correlation, R^2 is 0.8898. Figure shows clear negative correlation between firmness and springiness of the cake. However, firmness and springiness of cake have the same value when the cakes were already cooked, which were in the range of 700-800 (g) and 54-56 (%) regardless of the time respectively. Further heating of cake resulted large pressures exerted by leavening vapor and gases due to the rise in temperature of cake caused the less homogeneous, and more distorted bubbles present within the structure of cake. Therefore the cake become hardened and less springy (Al-Muhtaseb *et al*., 2013). This was also reported by Cauvain *et al*. (2005), in that increasing the temperature and time of baking resulted in an increase of the firmness of cake and decreased of the springiness of the cake. Sumnu *et al*. (2005) also found a positive correlation between moisture loss of cakes during baking and firmness.

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Figure 4 (b) also shows negative correlation between firmness and moisture content of the cake. Water plays important role in the physical changes (e.g. expansion bubbles, hardness of cake) and chemical changes (e.g. starch gelatinization). The final moisture content of cake is also important in determining the quality of cake. A typical cake has moisture content between 25-30%, compared to bread 35-45% and biscuits 1-5% (Lostie *et al*., 2002). This shows the strength of the relationship are strong with high coefficient of correlation, R^2 is 0.9058. In increase degree on internal heating, results in the formation of significant pressure and concentration gradient, thereby causing rapid moisture loss resulted increased hardness of the cake. As the cake lost moisture, it became less springy.

According to the statistical analysis, baking time and temperature give significant effect (p <0.05) to the texture of the cake. There were significant differences (p < 0.05) in interaction between baking time and temperature of oven, resulting in different texture and moisture content of cake baked under different conditions.

Conclusions:

Monitoring the kinetics of chemical reactions during baking is necessary to obtain simultaneous access to both physical (temperature, heat flux, humidity, and so on) and chemical variables (reactants and products concentrations) throughout thermal treatment, as these physical and chemical changes are linked. A strong interaction was found between baking time and temperature of oven; as for their effect not only on volume expansion and browning color surface but also cake qualities (firmness, springiness and moisture content) during baking. However, browning and volume expansion were more significant to the baking temperature (p < 0.001) than baking times (p < 0.01). A slight increase of baking temperature had a positive effect on the volume expansion and color surface (ΔE) resulted high of cake firmness. Moisture content and springiness of cake showed a negative effect in terms of increasing the temperature and baking time. From the experiment, the higher temperature (180°C) at 35 minutes of baking gave the appreciable volume with less shrinkage during baking and thin crust golden brown color with fine uniform moist crumb.

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