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EFFECTS OF BAKING TEMPERATURE AND TIME ON OPEN BREAD PROPERTIES

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ABSTRACT

The objective of this study is to determine which thermal processing parameters i.e. baking temperature or time, has more significant impact on bread organoleptic and shelf-life properties. The bread crust colour and thickness were measured using Minolta chromater CR410 and colour separation technique while moisture content and firmness were evaluated according to standard method provided by American Association of Cereal Chemist (AACC) and American Institute of Baking (AIB), respectively. Baking temperature and time cause significant differences in crust colour ($P<0.001$), thickness ($P<0.05$), initial moisture content ($P<0.001$) and firmness ($P<0.001$). Breads baked at high temperature have higher initial moisture content and experienced the lowest moisture loss during storage. However, high retention of moisture content in bread after baking was not able to totally retard crumb staling, only capable of slowing down the process.

Key Words **:** Baking temperature, Time, Crust colour, Thickness, Moisture content, Firmness

1.0 INTRODUCTION

Baking is one of the processes in bread study that have received tremendous attention due to its contribution in transforming dough to bread through heat application. Several reactions occur during baking such as starch gelatinization, protein denaturation, moisture evaporation and changes in rheological properties.

Two important factors that determine the final quality of baking products are baking temperature and time. These factors influence the colour, thickness, volume, cell structure, moisture content and shelf-life of the products. In bakery industry, colour of products is one of the essential marketing tools that drives consumer buying tendency. According to Purlis & Salvadori [1], in Argentina, standard bread crust colour must be in yellow-gold. However, crust colour preference varies according to regions. In general, consumers perceive pale bread as uncooked bread that easily expose to microbial damage and staling while dark surface bread associated to overcooked and burnt product. The development of bread surface colours is related to two factors i.e. amount of moisture evaporated from dough and the extend of Maillard reaction during baking. Purlis & Salvadori [1] showed that colour difference (ΔE) on bread correlates to amount of water loss while Martins, Jongen & Van Boekel [2] stated that colour pigments formation depends on amount and types of ingredients used and react during baking. Colour of bread can be measured using *L a b* colour system [3-7]. The *L* , *a* and *b* values stand for lightness, redness and yellowness of colour components, respectively. Shittu, Raji &

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Sanni [7] showed that increasing baking temperature and time would reduce *L* value or in simple understanding, darkens the bread surface. However, no exact *a* and *b* values trend as affected by baking temperature and time ever reported in literature.

In addition, the aroma of bakery product, is also closely related to surface browning since it is a derivative of Maillard reaction. The increment of crust thickness is also a dependant of amount of moisture evaporated [8–10]. The formation of crust has important impact on bread properties. Lu Zhang et al. [11] showed that crust formation affects bread expansion, density and porosity. Early crust formation produces smaller bread with dense structure because of limitation for expansion. This is one of the potential factors that causes crumb firming. Besides, crust also functions as weight loss barrier during storage because it prevents moisture from evaporating from crumb. Primo-Martins et al. [12] showed that bread stored without crust experienced higher moisture loss to environment compared to bread intact with crust under storage condition of 40 % to 80 % of relative humidity. Wahlby & Skjoldebrand [13] showed that bun that was reheated with crust remained higher moisture content in crumb compared to the bun without crust thus this indicates that crust prevents moisture from evaporating to surrounding. This finding however contradicts the finding by Baik & Chinachoti [14] who showed that bread stored without crust has higher moisture content during storage compared to bread stored with crust the crust. These authors also hypothesized that crust is responsible for high moisture migration from crumb to crust which leads to crumb and crust staling.

As mentioned before, the combination of temperature and time during baking affect the moisture content in bread. Shittu, Raji & Sanni [7], Therthai , Zhou & Adamczak, [15] and Faridi & Rubenthaler [16], have identified that these two main factors control the moisture content in bread during baking. Basically, there are three stages of moisture loss that affect moisture content in bread; evaporation during baking, drying out during storage and moisture equilibration between crumb and crust [8,9,10,17]. High moisture loss in dough occurs during baking i.e.through evaporation. Moisture in bread is important because according to Cauvain & Young [17], moisture helps to moisten and lubricate the bread and potentially helps in slowing down the crumb firming process. Kulp & Ponte [18] and He & Hoseney [19] found that higher moisture content in bread reduced rate of crumb firming. On contrary, Zeleznak & Hoseney [20] found that starch retrogradation was directly proportional to moisture content. Starch retrogradation is the process that causes crumb firming and subsequently leads to crumb staling. Increasing baking temperature at constant baking time retains higher moisture in crumb where else increasing baking time reduces moisture in crumb [7,16,19]. Rogers et al. [21] stated that drier bread crumb after baking speeds up firming of the crumb during storage that leads to faster staling.

There have been extensive study on bread baking especially in the area modeling baking performance, moisture distribution during baking, crust formation mechanisms and etc., however the study focusing on the sole effects baking temperature and time on open bread crust and crumb properties is lacking in literatures.

2.0 EXPERIMENTAL

2.1 Materials

The open bread formulation is provided in Table 1.

Table 1 Bread formulation (supplied by Interflour)-based on 3000 gram flour loading

Ingredients	Percentage (Baker's Percentage)
Flour (strong)	100
Water (maximum temperature 2°C)	63
Sugar	6
Salt	1.5
Yeast	1
Shortening	5

2.2 Methods

2.2.1 Bread Preparation and Baking Test

Straight dough method was used in preparing the bread samples. All ingredients were mixed in vertical mixer (SPN25053, Lian Huat, Malaysia), for a total of 16 minutes. The whole dough was let to rest for 5 minutes after mixing. The dough were weighed and divided into 380 gram dough balls. After dividing, these dough balls were rounded and let to rest again for another 5 minutes before proceeded to the automatic moulding machine (CM750, Lian Huat, Malaysia). The moulded dough were put into stainless steel baking tins with dimension of 10 cm X 19 cm X 10.5 cm and stored in the retarded proofer (LRP36052, Lian Huat, Malaysia) for 1 hour and 30 minutes at 28°C and 85% relative humidity. After proofing completed, the dough were baked in a deck oven (EO3050C5, Lian Huat, Malaysia) at specified combination of baking temperature and time. The open loaf was baked without covering the baking tins with lids. The baked bread samples were stored unwrapped on cooling racks for 96 hours in ambient condition of 28°C and 75% relative humidity. The analysis of crust colour, thickness, moisture content and firmness were performed during this storage period.

2.2.2 Top Crust Colour Measurement

The bread crust colour was measured using Minolta Chroma Meter (CR-410, Konica Minolta, Japan). This equipment reads the surface colour of product in *L a b* values. The scanning of the bread colour was performed by placing the chromameter probe directly onto the bread surface as shown in Figure 1. This measurement was performed on non-sliced bread loaves.

Figure 1 Method of measuring crust colour

2.2.3 Crust thickness measurement

This method has been explained in Mohd. Jusoh (in review process).

2.2.4 Crumb Moisture Content Measurement

Moisture content measurement was performed according to AACC 14-5A via the one-stage procedure using only the crumb portion. The crumb sample was grind using a blender (IT013, Itronic, Malaysia). The 3 gram sample was dried in an oven (HA1350, Hanabishi, Malaysia) at 103°C for 60 minutes. After drying, the dried sample was stored in the dessicator for 60 minutes. The moisture content was calculated immediate after the dessication process completed. The moisture content percentage was calculated using the following formulation:

$$\text{Moisture Content (\%)} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Wet weight}} \text{x}100\% \qquad (1)$$

2.2.5 Crumb Firmness Measurement

Crumb firmness was measured using the texture analyzer (TA.TX2, Exponent Micro Stable Systems, USA). The determination of crumb firmness follows the standard procedure provided by the American Institute of Bakery (AIB). This method is applicable in the TA.TX2 software (version 3.0.5.0, Exponent Micro Stable Systems, USA). In this test, a 36-R cylindrical probe was used. Two slices of bread with total of 25 mm thickness were placed on the platform. The firmness value was obtained by pressing the 36-R cylindrical probe with load of 5000 g on the bread. The probe penetrates into bread until the maximum compressible point then it moves back upward. The force needed to penetrate into bread crumb was shown in the computer. For this experiment, the firmness value at 25% compression was taken following the sample test in Exponent Micro Stable System software from TA.TX2.

2.2.6 Statistical Analysis

Minitab software (Version 14, Minitab Statistical Software, USA) was used to design a complete factorial experiment for this experiment. Three levels for baking temperatures and times were 185°C, 195°C, 205°C and 25 minutes, 30 minutes and 35 minutes, respectively. Each treatment was replicated three times. Two-way ANOVA was used to analyze the simultaneous effect of baking temperature and time. The Microsoft Excel (XP Edition, Microsoft Corporation, USA) was also used for plotting graphs and correlations.

3.0 RESULTS AND DISCUSSION

3.1 Crust colour

The analysis of crust colour focused on three elements of colour that are the *L, a* and *b* values. The results of baking tests using variation of temperature and time level on crust colour are clearly displayed in Figure 2. Based on ANOVA result shows that both baking temperature and time significantly affected the crust colour ($P<0.001$). Baking baking temperature and time have negative linear relationships with the *L a b* value of the crust.

This implies that increasing the baking temperature and time darkens the crust colour and reduces the colour saturation. It was also noticed that by increasing the temperature by 10°C the *L a b* values significantly decreases. The result of *L* value obtained in this study agrees with results from previous studies performed by Shittu, Raji & Sanni [7], Therthai, Zhou & Adamczak [15] and Zanoni , Peri & Pierucci [23]. Increasing temperature and time can cause an increment or reduction for *a* and *b* values probably due to the dependency of Maillard reaction towards baking temperature and time [2].

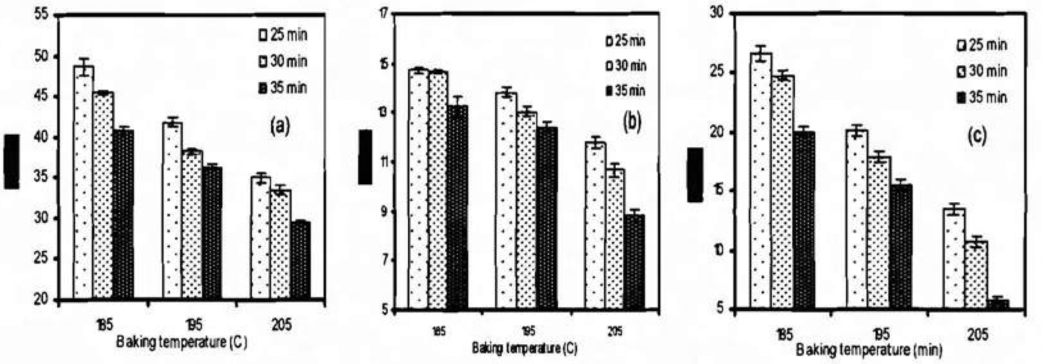

Figure 2 Effect of baking temperature and time on (a) *L*, (b) *a* and (c) *b* values of top crust

3.2 Crust thickness

Based on ANOVA, baking temperature and time also have significant impact on crust thickness ($P<0.001$) (Figure 3). The results also show that the thickness of crust increases with baking temperature and time. The thickness of crust baked at 185°C to 205°C for 25 to 35 minutes ranges from 6.08 mm to 9.00 mm. Increasing the temperature for 10°C and time for 5 minutes causes an increased in crust thickness from 10 % to 16% and 5% to 10 % . Nevertheless, the effect of baking temperature ($P<0.000003$) on crust thickness was more significant compared to baking time ($P<0.0005$).

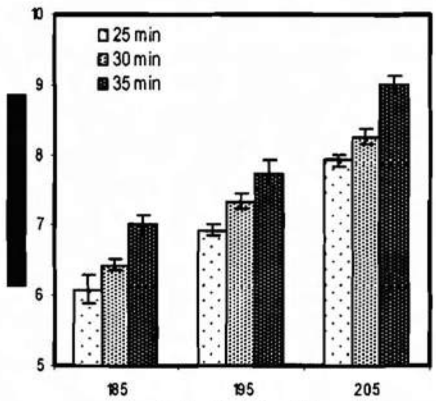

Figure 3 Effect of baking temperature and time on crust thickness

3.3 Crumb moisture content

Increasing baking temperature induces higher initial moisture content (Figure 4a) while increasing baking time reduces initial moisture content in bread (Figure 4b). Moisture content trend obtained was similar to Shittu, Raji & Sanni [7] and Wagner et al. [24]. This trend potentially caused by two factors; degree of starch gelatinization and early crust formation. Faridi & Rubenthaler [16] highlighted that baking temperature and time affects the degree of starch gelatinization. Starch gelatinization absorbs moisture therefore if higher temperature and time applies, higher degree of gelatinization occurs. Thus higher moisture retain in bread. Besides that, an early formation of crust due to high temperature and time also may prevent moisture from evaporating. The moisture retention capacity as influences by temperature and time has been mentioned in Eggleston et al. [25]. The difference in moisture content is pronounced due to baking time ($P<0.01$) but less pronounced for temperature ($P>0.05$) (Figure 4).

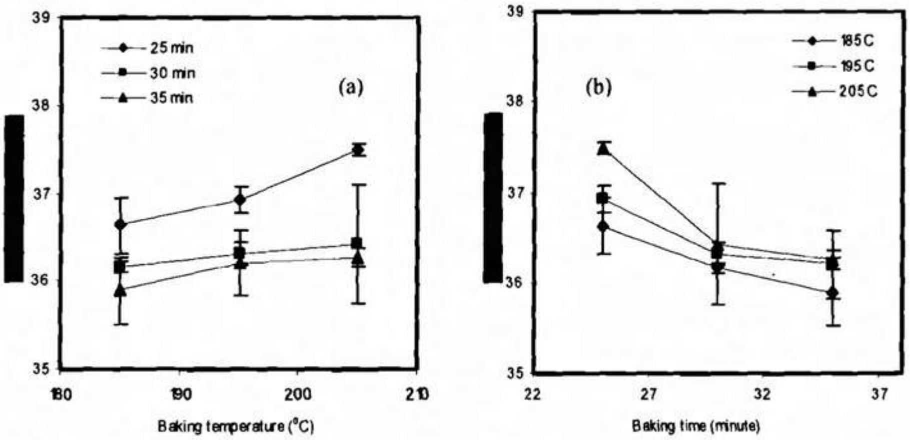

Figure 4 Effect of baking (a) temperature and (b) time on initial bread moisture content

3.4 Final Moisture Content and Moisture Retention During Storage

Figure 5 shows a decreasing moisture level in all breads in a storage period of 96 hours. This trend is expected as moisture content in bread decreases with time due to moisture migration during storage [17,26,27]. This trend is similar to results obtained by Patel, Waniska & Seetharaman [28] and Seetharaman et al. [29]. Breads baked with lowest baking time at any baking temperature have the highest final moisture content at the end of a 96 hours of storage. The result and moisture content trend obtained was similar to He and Hoseney [19]. These authors showed that bread baked at 8 minutes retained higher final moisture during storage compared to bread baked at 24 minutes. From the previous section, it was showed that breads baked at lowest baking time i.e. 25 minutes retained high moisture after baking thus it is expected that during storage moisture migration in this condition is slower than in breads baked at higher baking time. Higher baking time produces bread of low initial moisture content thus the moisture migration process during storage made the bread even dryer.

Besides a low baking time, higher baking temperatures also help in retaining final moisture after 96 hours. The moisture retention capability in bread probably links to crust thickness. Wahlby & Skjoldebrand [13] have shown that crust acted as a weight loss barrier in reheated buns. Higher baking time forms thicker crust thus there is a possibility that crust binds moisture from migrating to surrounding.

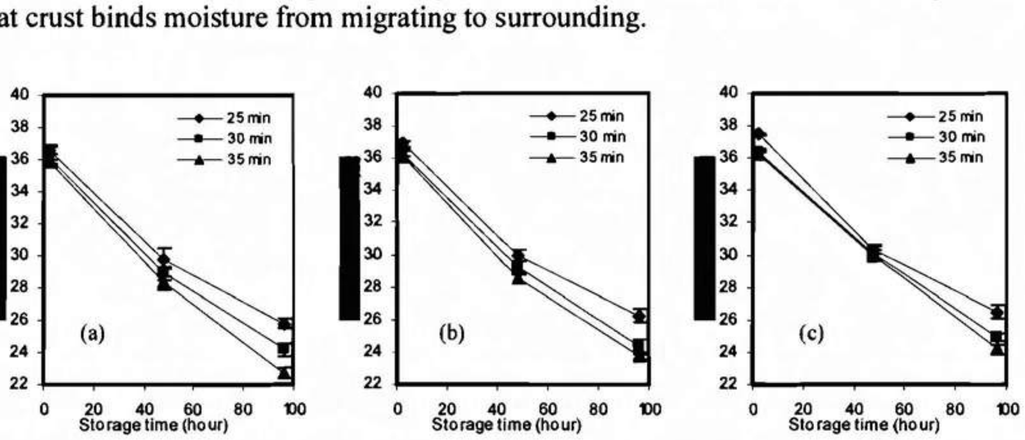

Figure 5 Effect of baking temperature and time on moisture retention in bread at (a) 185°C, (b) 195°C and (c) 205°C

3.5 Crumb firmness

Initial crumb firmness has a positive relationship with baking temperature and time (Figure 6). Increasing the baking temperature and time cause an increment in crumb firmness since crumb firming is closely related to starch properties in bread. Variation in starch properties e.g. starch gelatinization, pasting viscosities, amylose solubility and amylopectin recrystalization depends on different thermal conditions applied to it [29]. These properties influence the crumb firming values.

From ANOVA results, the variation of initial crumb firmness is significantly affected by baking temperature and time ($P<0.01$). It is also noted that the application of highest baking temperature i.e. 205°C and time i.e. 35 minutes produced breads with the firmest crumb. Temperature ($P<0.002$) has higher impact on initial crumb firming compared to time ($P<0.01$) since increasing temperature causes increment in crumb firming up to 12 % while time factor only up to 7%.

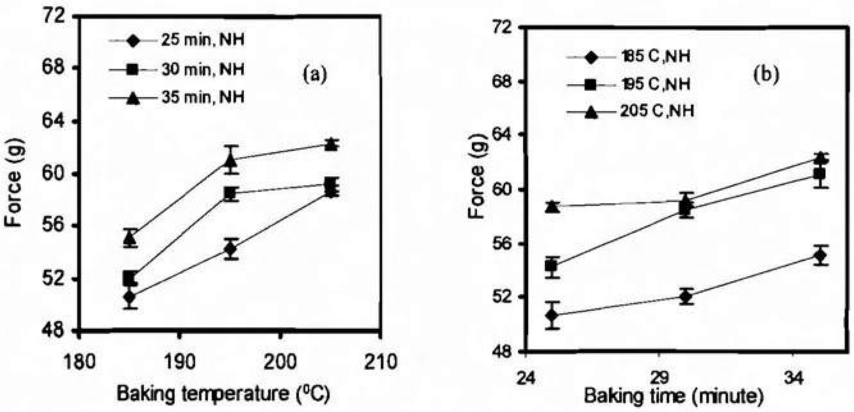

Figure 6 Effect of baking (a) temperature and (b) time on initial crumb firmness

3.6 Crumb Firming During Storage

Result also shows that crumb firming values increases as storage time increases (Figure 7). The results obtained agreeable with study conducted by Gil, Callejo & Rodriguez [30]. This is expected as bread crumb experiences aging or firming during storage. Baking temperature and time have a direct relationship with crumb firming. It was observed that bread with highest baking temperature (205°C) and time (35 minutes) experienced the highest final firmness value after 96 hour of storage. The highest firming trend is similar for baking temperature 185°C and 195°C. The change in firmness values during storage is more influenced by baking time. The impact of baking time on crumb firming during storage is similar to He & Hoseney [19].

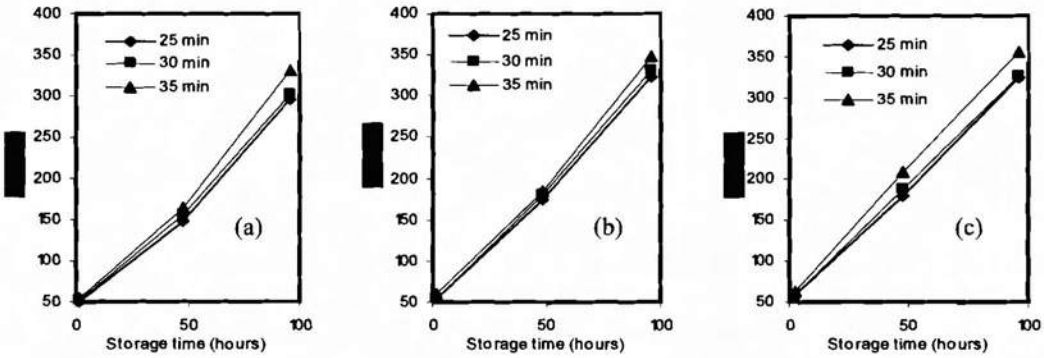

Figure 7 Crumb firmness value for baking temperature at (a) 185°C, (b) 195°C and (c) 205°C

4.0 CONCLUSION

Baking temperature and time cause significant differences in crust colour (P<0.001), thickness (P<0.05), initial moisture content (P<0.001) and firmness (P<0.001). The usage of high baking temperature causes high moisture retention in bread after baking. This is an advantage because breads with high initial moisture content experienced slower moisture loss during storage. Results from the baking tests show that baking temperature has greater influence on bread properties compared to baking time.

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