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Bread Crust Thickness Estimation Using *L a b* Colour System

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ABSTRACT

The crust formation of bread is imperative as it contributes to aroma, flavour and texture of the product. The extent of surface browning during formation of crust is suspected to correspond to the thickness of crust and gradually affects the quality of the bread produced. A method to distinguish the crust and crumb was developed using the *L a b* colour system. Commercial breads of different categories, sandwich, open and standing breads, were used as samples to set up the colour range for crust and crumb. In general, *L* is always higher in the crumb compared to crust. However, *a* and *b* values in crust are consistently higher than crumb which indicates the browning effect. The xE between crust and crumb in sandwich, open and standing breads were 30.98, 29.86 and 25.96, respectively. Bread crust is identified as the brown region with *L* value lower than 66, *a* value higher than 2.4 and *b* value higher than 22.3. Baking temperatures in the range of 175 to 200°C and baking times from 30 to 50 minutes were used to bake open loaves with different crust colours and thickness. Higher baking temperature and time are proven to produce bread with intense surface colour and thicker crust. The correlation between crust colour and its thickness shows good linear relationships indicating the possibility of predicting crust thickness using its surface colour.

Keywords: Bread crust, surface browning, *L a b* colour system, DE

INTRODUCTION

The study on crust is a challenging new area in bread research. Previous studies on bread mainly focus on bread crumb, thus the important functions of the crust on bread have not been thoroughly investigated. Bread crust has many effects on bread properties. Lu Zhang *et al.* (2007) showed that the formation of crust affects bread volume, density and porosity. It also acts as a natural protective layer that prevents moisture evaporation as reported by Walhby and Skjoldebrand (2002).

Crust as interpreted by Jefferson *et al.* (2005) is the surface of bread which has higher density than crumb. Crust coloration and thickening occurs simultaneously during the baking process. Therthai *et al.* (2002) highlighted that crust colour and bread qualities e.g. moisture content, crumb firmness and shelf-life are affected by baking conditions. Furthermore, high baking conditions may cause excessive evaporation that leads to dryer crumb in the finished product. Patel *et al.* (2005) reported that higher heating rate

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application also causes higher degree of firmness in crumb since heat affects the starch properties and subsequently influences the storage quality of bread. Gil *et al.* (1997) shows that higher moisture in bread can retard staling process since it helps to reduce crumb firmness. The relationship between colour and moisture content in bread during baking was reported by Purlis and Salvadori (2007). The findings justify the importance of investigating crust colour since it can be associated with ingredients, processing factors, quality and shelf-life of produced breads.

The first objectives of this study were to develop a method to distinguish the crust from its crumb through the application of *L a b* colour system and to find the correlation between crust thickness and its colour for estimation of crust thickness.

MATERIALS AND METHODS

Crust and Crumb Measurement

Three categories of breads, sandwich (SW), open (OP) and standing (ST) breads were chosen for this study. Each category was represented by three different loaves. The Colour Reader (CR-10, Konica Minolta, Japan) (*Fig. 1*) was used to measure the level of lightness of material, (*L*), redness, (*a*), and yellowness, (*b*), of the samples. The total colour variation or difference, (ΔE), was calculated using Equation [1].

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \qquad [1]$$

Fig. 1: Colour reader (CR-10, Konica Minolta, Japan)

The locations for crust and crumb colour measurements are shown in *Fig. 2*. The colour of the crust was measured by pointing the colour reader directly to the top surface of the crust. The *L, a,* and *b* values were indicated after the scanning process. The colours of crumb were measured and recorded at five locations, from 1 to 5 cm from the crust. The crumb of the bread was divided into five layers where the first layer was 1 cm from the crust surface while the second layer was 1 cm from the first layer and so on.

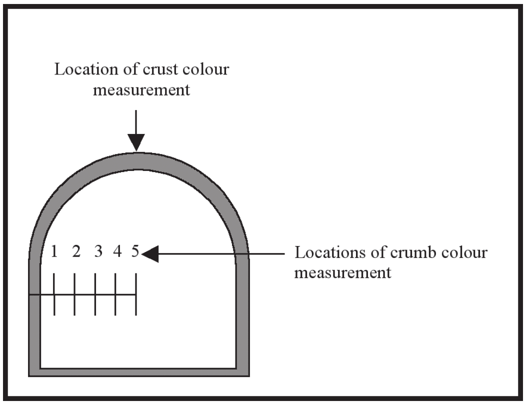

Fig. 2: Locations for measuring crust and crumb

Crust Thickness Determination

The thickness of crust was measured using a digital vernier caliper (500-196-20, Mitutoyo, Japan) (*Fig. 3*). In measuring the thickness, a simple colour guide drawn from the results obtained from Section 2.1 was used. The crust is defined as the brown region with $L < 66$, $a > 2.4$, $b > 22.3$ while the crumb is the white region with values below or above the *L a b* ranges that have been set for the crust.

Crust Colour and Thickness Investigation

The relationship between the crust colour and its thickness was investigated by conducting a factorial design experiment for standard baking tests in AACC 10-10 (1976). Three levels of baking temperatures (175, 185 and 200°C) and three levels of baking time (30, 40 and 50 minutes) were varied in triplicate. Table 1 shows the formulation used in the baking test. The colour and thickness of the bread crust were measured after resting for two hours using the crust colour and thickness methods mentioned earlier.

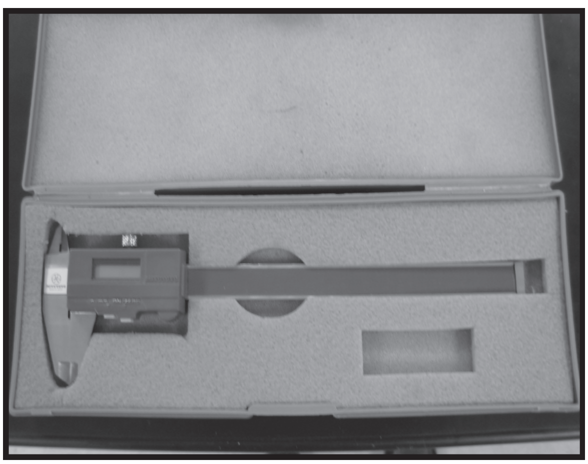

Fig. 3: Digital vernier caliper (500-196-20, Mitutoyo, Japan)

TABLE 1
Formulation of bread for baking tests

Ingredients	% (based on 500 g flour loading)
Flour	100
Water	63
Sugar	5
Yeast	3
Salt	1

RESULTS AND DISCUSSION

Crust and Crumb Colour Range

Figs. 4 to *6* show the average *L a* b values of crust and crumb for all three commercial bread samples. The *L* values of crumb for all samples were always higher than that for the crust showing that the crumb is always lighter than the crust. This is true for baked goods as the crust becomes darker due to direct heat penetration during the baking process. The bread crumb maintains a lighter colour because it is protected from direct heating. The major difference in *L* values between the crust and crumb was found in the sandwich and open bread samples. The difference in *L* values between the crust and crumb for standing breads were less significant. This may be due to the less dense crumb structure of the standing bread compared to the sandwich and open breads. The high porosity crumb surface may be the cause of insufficient reflection of brightness, thus resulting in lower *L* crumb values.

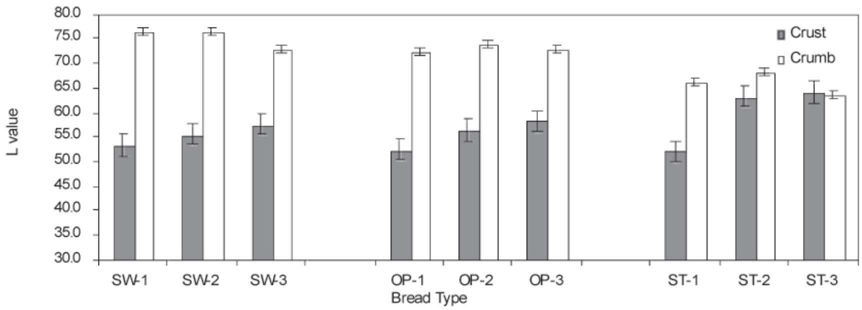

Fig. 4: L value for crust and crumb of commercial SW, OP and ST breads

The values of *a* and *b* are always higher in the crust compared to the crumb. This condition may be related to caramelization and Maillard reaction during crust formation. These two prominent processes during baking are responsible for transforming reducing sugars to other components and changing the colours of material with the existence of heat. The difference of *a* values between crust and crumb is more vivid than *b* values. The open bread in general has higher *a* and *b* values in the crust region compared to

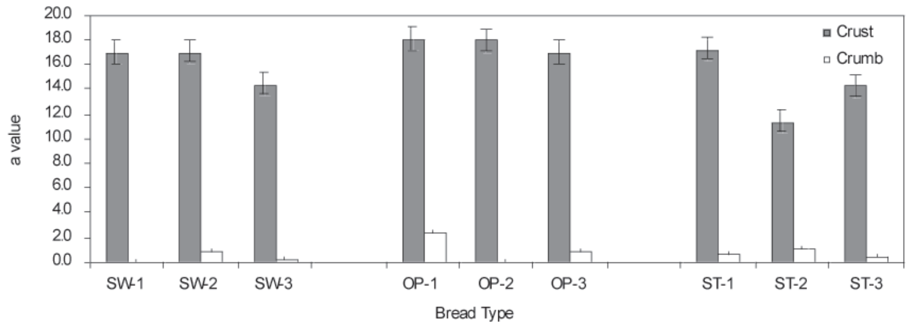

Fig. 5: a value for crust and crumb of commercial SW, OP and ST breads

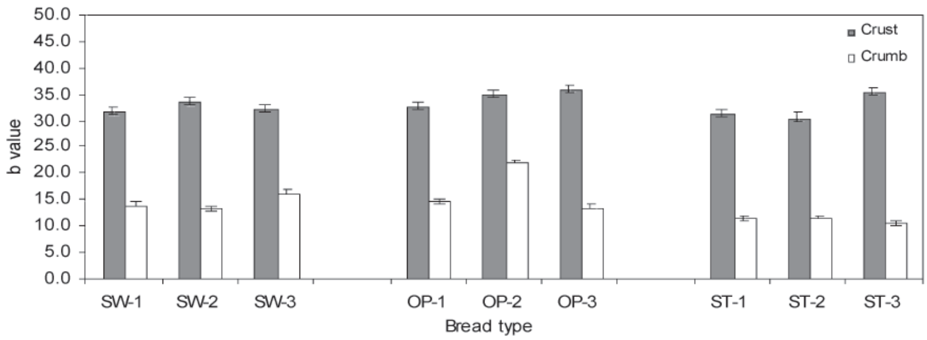

Fig. 6: b value for crust and crumb of commercial SW, OP and ST breads

the sandwich and standing breads. This is highly associated with its baking operations as the open bread is exposed to higher heat surface areas and thus possesses a significant browning effect. Baking temperature is one of the main factors that cause browning effect. Martin *et al.* (2001) emphasized that caramelization and Maillard browning were governed by baking temperature and time. Extensive modeling for bread baking and browning kinetics of bread surface have been conducted by Zanoni *et al.* (1993, 1994, 1995) and Purlis and Salvadori (2007).

Effect of Baking Conditions on Crust Colour

The baking tests conducted by varying the baking temperatures and times show that these conditions have a significant impact on the surface colour and thickness of the top crust. *Fig. 7* illustrates the effect of temperature and time on *L* value of crust. Both factors were inversely proportional with the *L* value. Bread baked at lower temperature and time has higher *L* value. The other colour components, *a* and *b,* however, reacted differently from *L*. *Fig. 8* and *9* show that the *a* and *b* values are directly proportional to baking temperature and time. Lower baking temperature and time produced breads of lower *a* and *b* values indicating lower redness and yellowness intensity. Variation in baking conditions has significant impact on crust colour ($p<0.05$).

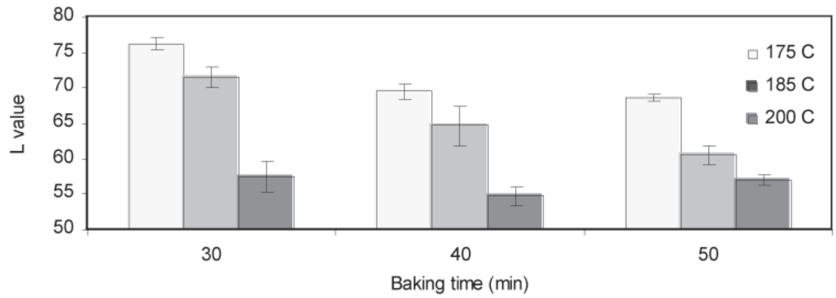

Fig. 7: Effect of baking temperature and time on L value of open bread top crust

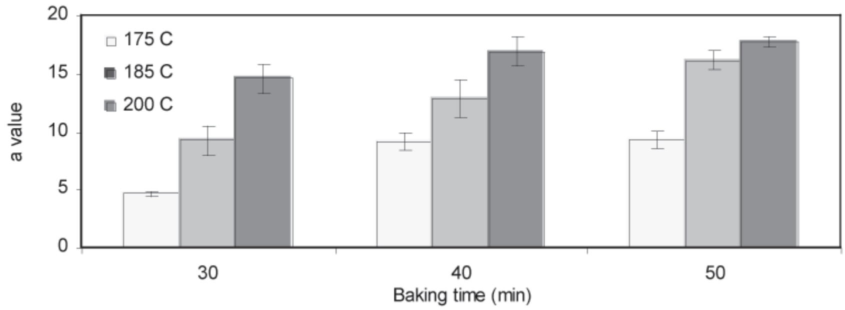

Fig. 8: Effect of baking temperature and time on a value of open bread top crust

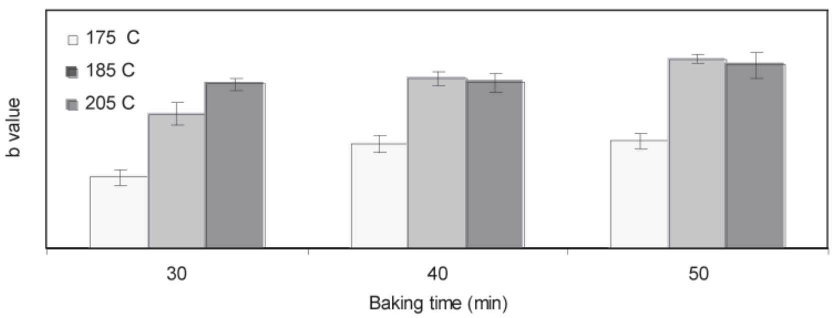

Fig. 9: Effect of baking temperature and time on b value of open bread top crust

Correlations between Baking Conditions and Crust Thickness

Besides bread crust colour, the baking conditions also affected the formation of crust. Zanoni *et al.* (1993) suggested that the formation of the two separate regions, crust and crumb, is due to the progressive advance of heat into inner bread as a result of the evaporation front phenomena. *Fig. 10* shows the correlation between baking conditions and crust thickness. Crust thickness increases as baking temperature and time increase. The increment in crust thickness was more pronounced for bread baked at 200°C compared to bread baked at lower temperatures as indicated by the steep slope value of

0.0465. The reason for this condition is probably due to the high temperature gradient between the surface of the crust and the inner bread. Excessive heat made the crust dry and forced inner moisture to evaporate from crumb. This excessive evaporation caused the bread structure at the surface to collapse and become dense. As a result, thicker and darker crust was formed. On the other hand, only slight increment in thickness was observed in bread baked at 175°C suggesting that increasing baking time at this temperature does not significantly affect crust thickness.

Correlations between Crust Colour and Thickness

As baking conditions directly affected the colour and thickness of the crust, thus the correlations between the colour and crust thickness of bread were also investigated. These correlations are important as they allow prediction of crust colour when thickness is known or vice versa. These correlations are presented in *Figs. 11(a)-(c)*. *Fig. 11(a)* shows a negative relationship between the *L* value and the crust thickness. As the crust thickness

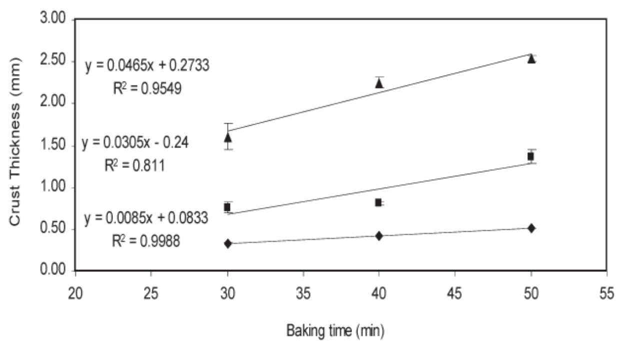

Fig. 10: Correlation between baking time and top crust thickness for baking temperatures at 175°C (◆), 185°C (■) and 200°C (▲)

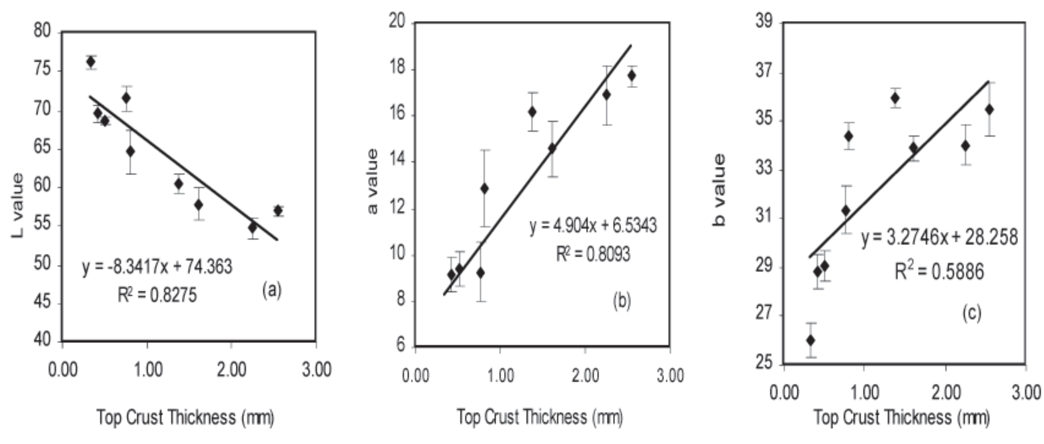

Fig. 11: Correlations between colour components of L (a), a (b) and b (c) with thickness of top crust

increases, the lightness of the crust surface decreases. In order to make the crust thicker, the bread surface must be exposed to higher baking temperature and time which in the end results in darker bread surface (*Fig. 10*). The values of *a* and *b* behave otherwise. The correlations between crust thickness with *a* and *b* values result in positive straight lines as shown in *Fig. 11(b)* and *(c)*. These relationships indicate that the thicker the crust, the higher the *a* and *b* values or in other words the redness and yellowness of the crust increases as the crust becomes thicker. Heat supplied causes intense browning effect on the bread surface resulting from the caramelization and Maillard process.

CONCLUSIONS

A method to distinguish bread crust and crumb using *L a b* colour system was successfully developed. The bread crust is identified as the brown region with *L* value lower than 66, *a* value higher than 2.4 and *b* value higher than 22.3. Different types of breads give different values of *L a b*. These differences occur due to the processing factors, *e.g.* method of heat exposure to bread during baking (whether direct or indirect) and/or baking times. The correlation study between crust colour and its thickness shows good linear relationships indicating the possibility of predicting crust thickness via its surface colour.

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