CHARACTERIZATION OF BAKED COLOR OF COOKIE, TOAST AND CHICKEN: A MODEL OF LIGHT-COLORED FOOD

Shuhei Nomura[1], Hiroyuki Iyota[1]* and Hideki Sakai[2]

[1]*Faculty of School of Engineering, Osaka City University, Japan*
[2]*Faculty of Human Life Science, Osaka City University, Japan*

*Corresponding author: H. Iyota, E-mail: iyota@mech.eng.osaka-cu.ac.jp

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ABSTRACT

Producing delicious-looking food is one of the features required of cooking equipment. For optimizing the technical advantages of oven cooking, color changes of light-colored food during oven cooking were characterized based on time-series colorimetric data. Three types of food materials were used as samples: toast (sliced white bread), plain cookie, and raw chicken meat pate. The colorimetric data were measured in situ using an optical fiber and a spectrometer under various conditions, with two types of steam ovens. Prediction expressions for the chroma and lightness (quantitative attributes) history of the food surface during oven baking were developed. The profiles of changes in the chroma and lightness for each material and under each set of heating conditions were investigated using the measured data and calculated values. The profiles, prediction method, and "browning index" defined in this study can be applied for optimizing automatic oven operation using the preferences index.

INTRODUCTION

In recent years, steam ovens and superheated steam ovens, in which steam is supplied to the oven chamber, are being increasingly used in the industry as well as domestic households. Heating in such an oven sometimes causes changes in the surface color of foods that is drastically different from that of foods processed in a traditional oven without supplying steam. Therefore, steam ovens must be typically operated by a human based on experience and visual confirmation of the texture of the food, while one would expect to obtain delicious-looking food using cooking equipment with automatic control.

As the first step toward the development of an automatic regulation system, an in situ (real-time) method for color measurement during high-temperature baking has been developed [1][2]. We have developed a browning scale for baked foods (plain cookies and sliced bread) based on color measurement data [3] and investigated the preference of baked food color by a method based on sensory evaluation [4]. In this research, we define a new expression for predicting the histories of the chroma and lightness of the food surface during oven baking. Three light-colored foods, plain cookies, sliced white bread, and raw chicken, are used as the model materials. The characteristic values in the expressions for each material and each set of heating conditions have been estimated from the measured colorimetric data. In addition, the optimal color of the baked food and a method to judge the optimal conditions for automatic oven operation are discussed.

METHODS

Two types of ovens are used in this research: Oven 1, a steam oven designed for domestic use (Panasonic Corporation, Model NE-V300, 1.43 kW electricity, 30 L); Oven 2, a steam convection oven designed for commercial use (Tanico Corporation, Model TSCO-4GBN2, 12.2 kW city gas, 78 L). Sliced white bread and raw chicken meat pate are used as food materials. The color changes on the food surface during oven heating were measured in situ by an optical fiber and a spectrometer coupled to the oven. Tristimulus values X, Y, and Z were calculated from the measured spectral data every 10 s and then converted to CIE 1976 L*a*b* and Chroma C_{ab}*, respectively. C_{ab}* was calculated using Eq. (1), as follows:

$$C_{ab}* = \sqrt{a*^2 + b*^2} \quad (1)$$

In this study, we mainly discussed the *L** and C_{ab}* values because they are quantitative attributes of the food color and are expected to show strong dependence on the color of baked food.

The baking time was around 1800 s for Oven 1 and 1000 s for Oven 2. The experiments were performed under conditions with and without the supply of steam (HA and SHS, respectively) at around 200°C.

RESULTS AND DISCUSSION

Color change of sliced bread and raw chicken upon oven heating

Figure 1(a) shows the changes in the *L** and C_{ab}* values for sliced white bread during baking. The *L** value decreased continually during heating, while the C_{ab}* value decreased/maintained initially and then started to increase with decreasing *L**. After reaching the peak value, C_{ab}* started to decrease again. Such a change profile was observed under all the heating conditions adopted.

Figure 1(b) shows the changes in the *L** and C_{ab}* values for the raw chicken meat pate. Under the SHS heating conditions, *L** rapidly increased within a few seconds of heating, because protein denaturation by heating with steam condensation caused the surface temperature of the meat to increase to the dew point temperature. Then, *L** started to decrease with increasing C_{ab}*. The raw chicken surface showed only a slight color change in 1800 s under the experimental conditions considered.

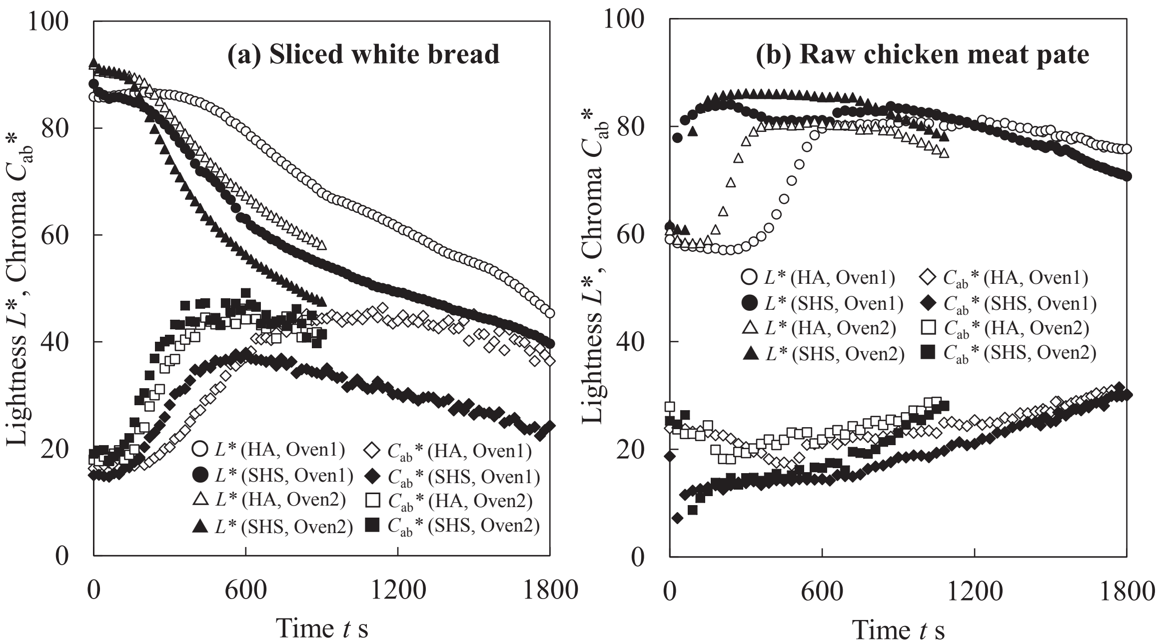

Figure 1. Measured changes in *L and C_{ab}* during oven heating**

Relationship between C_{ab}*, L*, and formulation

Figures 2(a) and (b) show the relationship between the C_{ab}* and L* with the values calculated by the approximate expression in equation (2). We proposed this equation for estimating the baking (browning) procedure. L_{max}* is the maximum value observed after 60 s elapsed; $C_{ab,0}$* is the value corresponding to the instant when L* reached the maximum and then began to decrease upon baking. A, B, and P are the fitting parameters defined by the histories of L* and C_{ab}* under each set of heating conditions.

$$C_{ab}{*} = A(L_{max}{*} - L{*})^{P} + B(L_{max}{*} - L{*}) + C_{ab,0}{*} \quad (2)$$

The profiles defined by the approximate expression in Eq. (2) are in good agreement with that based on the measured values. Figure 2(a) shows the profiles of sliced bread: L* decreased with an increase in C_{ab}*, reached the peak value, and then decreased. The acceptable range (food color considered suitable for consumption) of L* for bread defined by the European Standard [5] are shown in Fig. 2(a). The acceptable ranges for sliced white bread and plain cookies have been reported also by Sakai [4]. The ranges defined as the food color considered acceptable for consumption by most (75%) of the respondents in a survey and the values of the browning scale based on sensory evaluation are shown in Figure 3. These ranges can be defined by the profile of L* and/or C_{ab}* changes. Automatic regulation of the oven for baking can be realized using by the approximate expression and acceptable range.

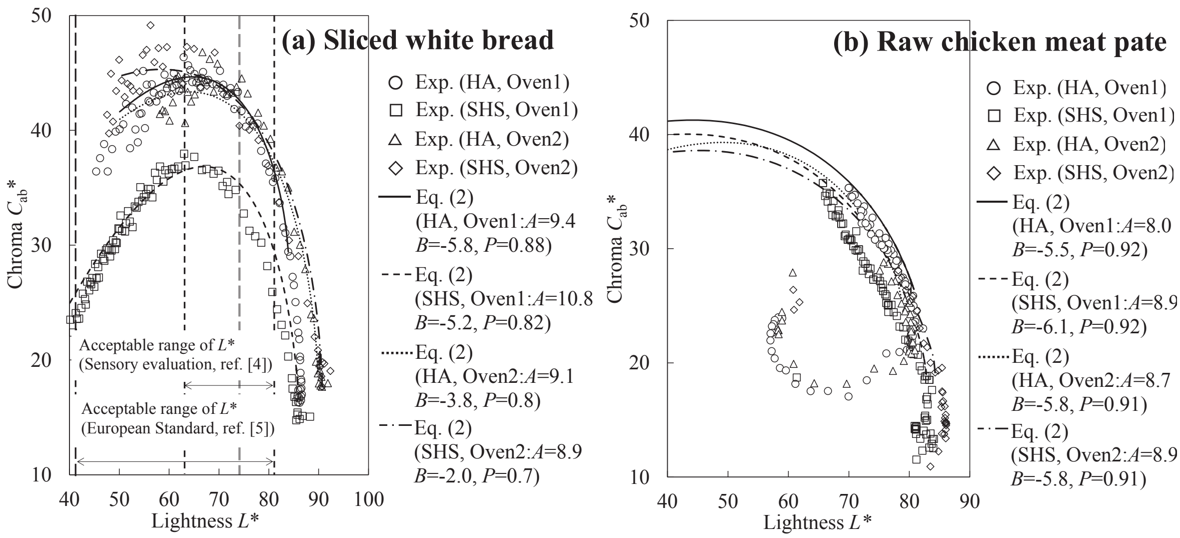

Figure 2. Profiles of C_{ab}*and L* changes by in situ measurement data and by the approximate expression in Eq. (2) with characteristic values of A, B, and P

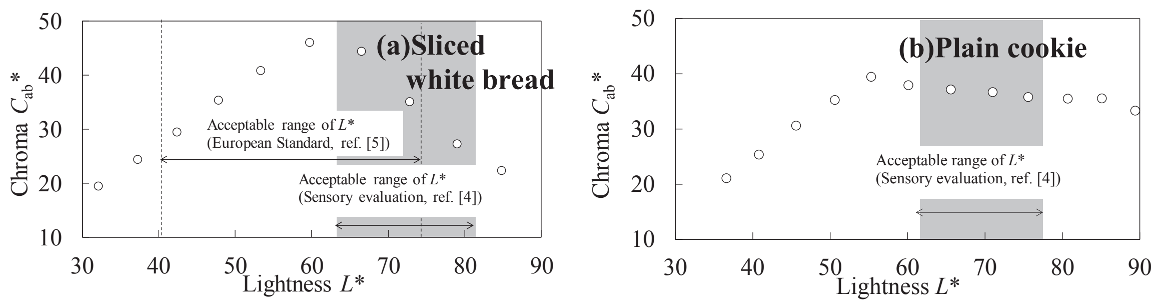

Figure 3. C_{ab}*and L* values of the browning scale using previous sensory evaluation study based on experimental data, and acceptable range of L* for consumption

Browning index for evaluating the baking procedure and future works

Two types of indexes for evaluating the baking procedure in an automatic oven for light-colored food are proposed. The values of x_L and $x_{L,C}$ are tentatively denoted as "browning Index by L^*" and "browning Index by L^* and C^*" for evaluating the color of baked food in this research. The definition of index x and the acceptable range of food color considered suitable for consumption are as follows:

$$x_L = \frac{L^*}{L_{max}^*} \quad (0.70 < x_L < 0.90 \text{ for toast, } 0.70 < x_L < 0.87 \text{ for plain cookie}) \tag{3}$$

$$x_{L,C} = \frac{L^*}{L_{max}^*} \times \frac{C_{ab}^*}{C_{ab,0}^*} \quad (x_{L,C} \text{ around the peak value for toast and plain cookie}) \tag{4}$$

For automatic oven operation, in situ color measurement is required; further, the measurement method should be simple, inexpensive, and as accurate as possible for the intended purpose. Meanwhile, there exists a strong relationship between the color of food considered acceptable for consumption and the viewer's emotion [6]. Properly browned foods are known to stimulate the appetite. The preferred color of food strongly depends on one's ethnic or cultural background. The temperature and moisture content profiles for the cooked food and their histories should be considered by the automatic operation algorithm in order to improve the quality, taste, and safety of food products.

CONCLUSION

Prediction expressions for the chroma and lightness history profiles of the surface of light-colored foods during oven baking have been developed based on in situ measurement data. The characteristic values used in the expressions for each material and under each set of heating conditions were calculated from the measured colorimetric data. Indexes for evaluating the baking color and methods for automatic oven operation were also proposed.

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