



Modelling the cooking doneness via integrating sensory evaluation and kinetics



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ABSTRACT

The aim of the current work was to develop a novel method to model and quantitatively determine cooking doneness via integrating sensory evaluation and kinetics based on the maturity value (M value) which was redefined. The well-done food was first selected from a series of samples with different M values by sensory evaluation, the average termination maturity values (AM_T values) were obtained in accordance with the weighted M values of the selected doneness samples. Among, the changes of M values were assumed to be accorded with the first-order reaction kinetic model and a specific z_M value was set as well. The z_M value was then obtained due to the rationality of the hypothesis, which was validated by rigorous data analysis. Results showed that maturity time values (M_T values) were existing and stable for specific types of materials and a specific population. Quantitative determination of the degree of doneness has profound significance in industrial production.

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1. Introduction

Doneness is defined by Merriam–Webster Unabridged Dictionary (2008) as the state of being cooked completely or sufficiently and is delimited as the condition of being cooked to the desired degree, the term is synonymous to “*huohou*” in Chinese cooking. Obviously, doneness is subjectively judged by consumers. This judgment, a comprehensive sensory stimulation of taste, smell, vision, touch, etc., can be extremely complicated (Geldenhuis, Hoffman, & Muller, 2014; Horita, Messias, Morgano, Hayakawa, & Pollonio, 2014; Trinderup & Kim, 2015); meanwhile, the human sensory evaluation of doneness is related to material types, grades, cooking methods, and personal factors, such as cultural background, preferences, gender, regional, age, and educational background (Kemp, Hollowood, & Hort, 2011; Meilgaard, Carr, & Civille, 2006; Sweeney, 2015).

However, the complicated cooking doneness plays an important role in production, processing and consumption because it is a key indicator for terminating a heating process (Bosse, Gibis, Schmidt, & Weiss, 2015; Buchanan, 1995). The best quality of cooked food cannot be obtained even if the heating process is ended a little early or a bit late. Therefore, we would like to develop a quantitative determination index for doneness, which can be used to reflect the judgment of consumers on

doneness and to indicate the quality changes during cooking process by instrumental measurement or theoretical calculation.

By judging well-done food, numerous literature showed positive results (Brunton et al., 2005; Kassier, 2016; Klassen & Gill, 2015; Oz & Yuzer, 2016). Among most of these literature, researches on meat doneness were the main objective. Although, this process is too short to be controlled well, it does have a high commercial value. Subjective methods, such as color identification, texture inspection and taste degustation, have been commonly used to judge the degree of meat doneness to date (Ellies-Oury et al., 2013; Quevedo et al., 2013; Stone, Bleibaum, & Thomas, 2012). However, these methods cannot be used to accurately determine meat doneness because they simply depend on human senses. Furthermore, these methods also have the characteristics of quite variable over time, significantly variable among themselves, extremely prone to bias, highly costs of time and money, etc. (Meilgaard et al., 2006). Objective methods, such as the thermometry method or the time-keeping method, are not supported by mathematical formulas with a rigorous theoretical foundation, such that their application value in food engineering field is still limited to date (Blake, Haidekker, Viator, Hdeib, & Lorenzen, 2008), meanwhile, these methods have nothing to do with sensory evaluation, thus they are unable to reasonably reflect consumers' judgment on doneness.

For the evaluation and optimization of sterilization process, the quality changes are usually described by parameters which are based on the first-order reaction kinetic model (Bosse et al., 2015; Ranilla, Kwon, Genovese, Lajolo, & Shetty, 2010; Turturică, Stănciuc, Bahrim, &

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Răpeanu, 2016). For example, F value which indicates to the microbial inactivation process as a constraint function (Heldman, Lund, & Sabliov, 2006); C value which represents the quality changes during thermal processing is used as an objective function (Jun & Irudayaraj, 2008). However, the objective of bulk cooking process is surely to get food doneness such that we expect is to obtain a function like F value so as to describe doneness. Due to cooking doneness is an accumulated consequence of a series of complicated reaction, which can be reflected by the results of appropriate sensory evaluation (Zhang, Lee, Tippetts, & Lillywhite, 2014), our current study has assumed that the sensory quality changes of food during cooking process might in accord with the first-order reaction kinetic model because it is the kinetic reaction which essentially leads to the sensory stimulation of food ingredients. Accordingly, this study went to track this assumption.

However, two problems should be solved before using kinetics to study the degree of doneness which is depended on sensory analysis. First, no kinetic function is available to describe the degree of cooking doneness. Although, Deng (2013b) reported that doneness is the result of an accumulation of temperature and time, thus, the function of M value was proposed based on kinetics. However, this concept is not integrated with sensory evaluation, so, it is impossible to reveal the essence of doneness. Second, the degree of doneness is a subjective parameter that relies on sensory analysis; thus, reactions order and kinetics parameters, such as k and D values, cannot be determined by performing frequently used kinetic experiments.

The objective of our study was to develop a novel method to model the cooking doneness and to obtain its kinetic parameters via integrating sensory evaluation and kinetics, and then to verify the feasibility of this method by using specific materials, such as pork loin, shoulder, top round, chuck steak, and other parts of meat.

2. Definitions and formulas related to the maturity value

2.1. Maturity value (M value)

The M value is defined as the equivalent heating time compared with a reference temperature for the maturity degree of a certain quality, which is judged by the sensory evaluation of a population. Named as M value to distinguish it from the existing D value, this term was not called the degree of doneness, which is calculated according to Eq. (1)

$$M = \int_0^t 10^{\left(\frac{T-T_{ref}}{z_M}\right)} dt \quad (1)$$

where z_M is the z value of a certain quality factor representing maturity for a population, in °C; T is the temperature (°C) located in a specific spot of food; t is the heating time (min); and T_{ref} is the reference temperature. For meat, T_{ref} should be set at 70 °C because this temperature is the health and safety temperature limit of meat. In addition to that, meat rapidly starts to approach maturity at this temperature (Deng, 2013b; Lawrie & Ledward, 2006). The M value represents the variable of sensory evaluation accumulated by time and temperature, although its function is similar to that of C value, whereas they are not same in essence because the M value and the C value are based on sensory evaluation and chemical reactions, respectively. Different T_{ref} values should not have an essential effect because the ratio of M values at different heating time will not be affected by various T_{ref} .

2.2. Termination maturity value (M_T value)

The M_T value represents M_T value at which a single quality reaches its best maturity point judged by the sensory evaluation during cooking

process, which is calculated according to Eq. (2)

$$M_T = \int_0^{t_M} 10^{\left(\frac{T-T_{ref}}{z_M}\right)} dt \quad (2)$$

where t_M is the terminal maturity time (min), which is the time when cooking is well done. We can easily get M_T values by sensory evaluation methods because a population is always sensitive to the maturity point of food, however, it is impossible to get continuous M values using those methods.

2.3. Obtain M_T value by sensory evaluation

A batch of samples with different M values should be obtained at first, among, well-done samples will be selected by many sensory evaluation assessors. The M_T value of a single quality factor can be calculated using the following formula (Yan et al., 2014):

$$M_T = \frac{\sum_{j=1}^{n_j} M_j \times K_j}{\sum_{j=1}^{n_j} K_j} \quad (3)$$

where n_j is the number of times a certain sample was selected as well-done food; j is the ordinal number of each M value for the selected sample; M_j is the M value of the selected well-done sample where ordinal number is j ; and K_j is the number of people who rated M_j as an indication of well-done sample.

The M value is determined by sensory evaluation, but its changing rule is in accordance with kinetic law showed in formula (1)–(2), due to the food components which decide the results of sensory evaluation are agreed with the first-order reaction kinetic model.

2.4. Calculation of the average termination maturity value

The average termination maturity value (AM_T value) represents the M value at which multi-qualities reach their best maturity point, which is based on the judgment of a population; in other words, the AM_T value is the average of multi- M_T values calculated by the statistical method.

The following formula was used to compute AM_T values. The mean M_T value was calculated on the basis of quality factors in each group of every experimental condition.

$$AM_T = \sum_{i=1}^{n_i} \left(\frac{\sum_{j=1}^{n_j} M_j \times K_j}{\sum_{j=1}^{n_j} K_j} \times R_i \right) / \sum_{i=1}^{n_i} R_i \quad (4)$$

where i represents the ordinal number of a certain quality factor, such that $i = 1, 2, 3$ can stand for color, odor, or taste; n_i is the number of quality factors, and R_i is the weight of the quality factor where ordinal number is i .

3. Materials and methods

3.1. Materials

In general, pork loin has uniform color and texture with moderate size, making it appropriate to track the sensory changes of meat doneness during processing (Kim, Yong, Park, Choe, & Jo, 2013; Omana et al., 2014). For these reasons, two parts of pork loin materials with obviously different colors were studied as representative. Material A (Large

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