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Application of fuzzy linear regression method for sensory evaluation of fried donut

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ABSTRACT

Sensory evaluation is a scientific discipline that is widely used to determine the quality of food products. But sensory characteristics cannot be quantified exactly; hence, the relationships among variables are not clear. In this paper, a Fuzzy linear regression was proposed to model the relationship between overall acceptance and sensory characteristics (aroma, surface color, porosity, hardness, oiliness, and flavor) of 36 different types of fried donuts. Modeling was done assuming that independent variables are crisp and coefficients are triangular fuzzy numbers. Coefficients were estimated considering 864 limits due to 36 samples, 12 evaluators (432 instance) and 2 limits for each sample. Between different states of fuzzy numbers (symmetrical, constant asymmetrical, increasing asymmetrical and decreasing asymmetrical) symmetrical fuzzy coefficient provided the best fitting of sensory data. This function showed aroma did not have any effect on overall acceptance, on the contrary, flavor exerted the strongest effect on desirability of donuts, increasing brownness of crust color yet decreasing oiliness reduced desirability of donuts. More porous and softer texture led to more acceptable products.

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1. Introduction

Sensory evaluation is a scientific method to gather information about the evaluated product [1]. The principal uses sensory evaluation techniques are used in quality control, product development and research in food science [2]. Making decisions is based on sensory testing to gather valid and reliable data about the evaluated product. Sensory evaluation data are characterized by imprecision, inaccuracy and uncertainty [3]. A typical problem about analysis of vague data is that of assigning numbers to subjective perceptions or to linguistic variables. In fact, there are many cases where observations cannot be verified or quantified exactly and relationships among variables are not clear. Thus, one can only provide their approximate description, or intervals to enclose them [4]. Fuzzy approaches have been successfully applied in many experiments that involved fuzzy data. Zhou and Zeng [2] explained a fuzzy logic based method for analyzing sensory evaluation data of industrial products. Evaluation of sensory scores of green tea samples was conducted using fuzzy logic [3]. Alternatively, one of the recommended methods for analysis of linguistic data is fuzzy linear regression. Fuzzy linear regression was first introduced by Tanaka et al. [5–7], which is based on possibility theory and fuzzy set theory [8,9]. Uncertainty in this type of regression model becomes fuzziness, not randomness [10], while classic regression is based on probability theory and both the independent and dependent variables are real numbers. Statistical regressions have some disadvantages in the certain situations: if the number of observations is inadequate, if there is difficulty verifying that whether the error is normally distributed, and if there is vague relationship between the independent and dependent variables, if there is ambiguity associated with the event or if the linearity assumption is inappropriate. These are the very situations fuzzy regression was meant to address [11]. Parameter estimation of fuzzy linear regression (FLR) is commonly done under two factors: the degree of the fitting and the vagueness of the model which can be transferred into two approaches viz. (i) Linear programming and (ii) fuzzy least squares methods. FLR models for crisp input-fuzzy output data can be represented as follows:

$$\tilde{Y}_i = f(x, A) = \tilde{A}_0 + \tilde{A}_1 x_{i1} + \cdots + \tilde{A}_j x_{ij} + \cdots + \tilde{A}_m x_{im} \quad (1\text{-}1)$$

where $\tilde{Y}$ is the fuzzy output, $\tilde{A}_i$ for $i = 1, \ldots, n$ are fuzzy coefficients, $x = (x_1, x_2, \ldots, x_n)$ is an n-dimensional crisp input vector and x_{ij} is the jth observed value of the ith input variable. A tilde character ($\sim$)

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is placed above the name of a fuzzy variable to distinguish a fuzzy variable from a crisp variable [12].

In this study sensory characteristics of fried donut including aroma, surface color, porosity hardness, oiliness and flavor were evaluated. Donut is a proper case study and it has distinctive sensory parameters. It is a sweet fried golden-brown snack with high energy value that is served as a convenient food. It represents one of the largest breakfast categories in the bakery products because it is portable and easy-to-eat. The donut market alone is a $3–4 billion business in the U.S. [13]. Therefore the study of sensory characteristics of donut plays an important role in the production of donut with higher quality in this market. Donuts are divided into two general classes: cake donuts (chemically leavened) and yeast-raised donuts (requires fermentation and proofing time). The fat content of fried donut may reach up to 50% of the total weight [14,15]. Nowadays, what is abundantly observable is problem associated to lipid consumption and relevant diet problems like excess weight and coronary heart disease. This, in turn, leads to an increase in research corresponding to production of fried foods with lower oil content and the same quality. In this study, pre-baking process, hydrocolloid coating and partial substituting wheat flour with soy flour, were applied and sensorial characteristic of different formulations of donut were evaluated. Then, analysis of sensory data with new method according to fuzzy linear regression was carried out. To our knowledge there is no published data on application of fuzzy linear regression in sensory evaluation of foods.

2. Materials and methods

2.1. Donut preparation

Donut ingredients including wheat flour, soy flour, sugar, yeast, butter, egg, milk powder, vanilla, lemon juice and salt were purchased from local market in Mashhad. Powder additives including flour, milk powder, vanilla and salt were sifted twice then mixing additives by an Electric Standard Mixer (Hugel, No. HG550TMEM) for 15 min. Dough was rested at 35 °C for 45 min in a proofer (Irankhodsaz, Iran), rolled out to 1 cm thickness and cut with a manually donut cutter (inner diameter: 2.95 cm; outer diameter: 7.60 cm), then proofed at 35 °C for 15 min after second proofing. Prebaking was done at 100 °C for 20 min (SINMAG, 705E). Prebaked samples were then cooled at room temperature for 20 min. Coating the donuts with methyl cellulose solution (1%) and Gum tragacanth (1%) solution was accomplished. Finally, frying was carried out in a domestic thermostatically temperature-controlled fryer (Black & Decker, Type 01) at 150 ± 3 °C for 6 min. Fried donuts were cooled and their surface oil was removed by paper towel for 30 min. Schematic of dough preparation is depicted in Fig. 1. Fig. 2 shows different formulations of prepared donut.

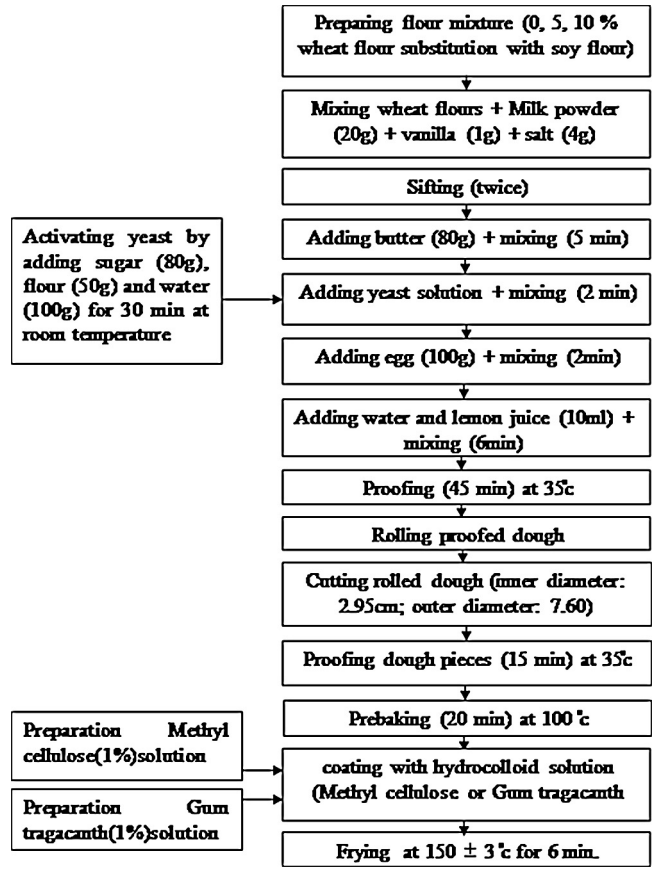

Fig. 1. Donut preparation procedure.

2.2. Sensory evaluations

Sensory evaluation of fried donuts was carried out in 6 days. Judges were selected from students of Ferdowsi university of Mashhad, aged between 22 and 30 (6 male and 6 female). Evaluators were interested in sensory evaluation of donut. Scoring was carried out in a 5 point hedonic scale according to Table 1. Quality attributes including aroma, surface color, porosity, hardness, oiliness, and flavor of samples and overall acceptance. Each sample was randomly numbered and presented to panel members.

3. Theory

3.1. Fuzzy linear regression

Assuming unclear relationship among sensory characteristics and overall acceptance, sensory evaluation data were modeled

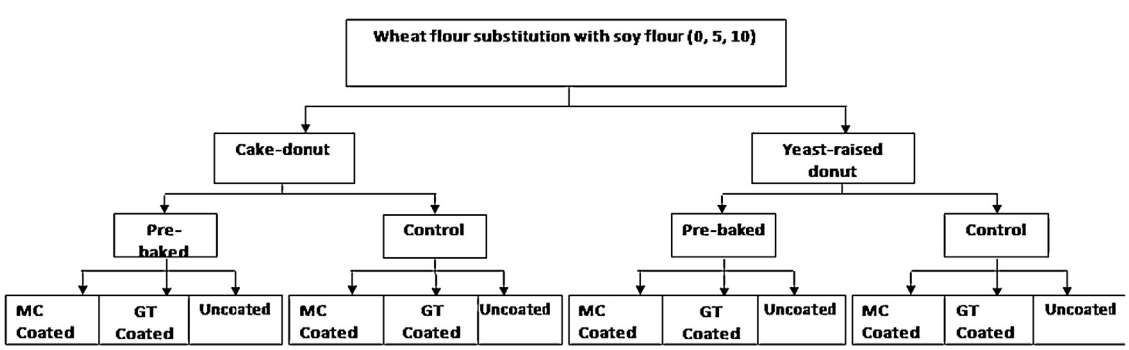

Fig. 2. Different formulations of donuts.

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