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Fuzzy logic (similarity analysis) approach for sensory evaluation of *chhana podo*

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ABSTRACT

Chhana podo is a baked traditional dairy product of India. The present study was undertaken with the following objectives: (1) to find acceptable levels of ingredients on a dry mass basis to constitute the *chhana podo* feed-mix and (2) to conduct a sensory evaluation study of *chhana podo* samples. In addition to chhana and sugar, different additional ingredients were tried in various proportions, namely, cornflour, refined wheat flour, raw semolina and roasted semolina. Acceptable levels of roasted semolina and sugar in the feed-mix was found to be 0.1 kg (db) and 0.5 kg (db) respectively per kg of chhana (db). Five samples (two market samples, two samples produced at other conditions and one produced at optimum conditions, wherein constrained optimization was done using genetic algorithm) were evaluated and results were analyzed using fuzzy logic (similarity analysis). Analysis of samples using fuzzy logic showed that product produced at optimum conditions as obtained from constrained optimization using genetic algorithm was indeed better than other samples. Importance of quality attributes for *chhana podo* in general was (in decreasing order): taste, color, aroma and mouthfeel. For the optimized product, the most important quality attribute was taste, followed by mouthfeel, color and aroma.

1. Introduction

1.1. Chhana podo – a traditional baked dairy product

Chhana podo is the only traditional baked dairy product in India and comprises *chhana (Indian cottage cheese)* and sugar as essential ingredients. It originated in Odisha and closely resembles the north Indian traditional dairy product "milk-cake" in appearance, which is prepared from whole milk by heat desiccation in contrast with heat/acid coagulation employed for *chhana podo* (Karwasra, Srivastava, & Hooda, 2001). "*Podo*" in Oriya means burning; this substantiates the term used to define the product, since *chhana podo* is a baked product. Ghosh, Rao, and Kulkarni (2002) reported that traditionally, *chhana podo* is made by smoldering *chhana*-sugar mix wrapped in sal leaves or other large leaves on slow fire. Ghosh, Rao, Balasubramanyam, & Kulkarni (1998) stated that *chhana podo* should have a light brown color and a cake-like soft spongy body. It should be sweet, with a rich fat taste and a cooked flavor. Ghosh et al. (2002) attempted characterization of market samples in Odisha with respect to cake height, physical appearance and sensory characteristics as judged by panelists from Dairy Technology Department, National Dairy Research Institute (NDRI), Bangalore; the product varied greatly in all characteristics from district to district. Cake height ranged from 1.5 cm to 10 cm with most places producing *chhana podo* of 4 cm thickness. One-side as well as two-side baked *chhana podo* was produced. Product color ranged from creamy white to light brown. Products from some districts had visible semolina particles giving the product a more grainy structure; some samples were moist and had sugar syrup oozing out whereas others were drier; the texture varied from a compact and firm body to a spongy body. However, essential details like number of panelists, method of screening and training of panelists, product evaluation criteria, and form in which data was collected were not mentioned. No mathematical tool was used for analysis of the data. The sensory characteristics of *chhana podo* is expected to change on varying the ingredients in the product; effects of each ingredient in the product is as follows: water makes the product soft and spongy, fat mellows the product, sugar imparts sweetness and also aids in color and flavor development. Kumar, Khamrui, and Bandyopadhyay (2002) investigated this and enumerated the functions of different ingredients; fat in standardized milk, semolina, sugar and water, and varied the levels of these ingredients; these levels affected the sensory and textural characteristics of *chhana podo*. The most desirable product as judged by panelists had *chhana* from milk (fat: 4.5 g/100 g), 35 g/100 g sugar, 5 g/100 g semolina and 30 g/100 g added water (all ingredients were added

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by weight of *chhana*). However, details pertaining to the sensory study were not mentioned; moisture content (MC) of *chhana* was not mentioned, no optimization tool was used and no objective parameters were used for optimization.

1.2. Need of sensory evaluation of food and fuzzy logic as a data analysis tool

Sensory quality of food gives an estimation of the total impression the food creates in the mind of the person who consumes the food (Das, 2005). The quality of food products, in conformity with consumers' requirements and acceptance, is determined by their sensory attributes, chemical composition, physical properties, level of microbiological and toxicological contaminants, shelf-life, packaging and labeling (Molnar, 1995). Sensory evaluation has been defined as a scientific method used to evoke, measure, analyze, and interpret those responses to products as perceived through the senses of sight, smell, touch, taste, and hearing (Stone & Sidel, 2004). It is the ultimate criterion for the acceptance or rejection of food (Chakraborty, Das, & Das, 2011; Das, 2005) and comprises a set of techniques for measurement of human responses to foods and minimizes the potentially biasing effects of brand identity and other information that influences consumer perception. Without appropriate sensory analysis, there is a high risk of market failure (Arazi & Kilcast, 2001) because comparison and choice are fundamental to consumers (Imm, Lee, & Lee, 2011). Sensory evaluation can be divided into two categories viz. objective (wherein a product is evaluated by a trained panel of assessors) and subjective (wherein a product is evaluated by untrained consumers) (Kemp, Hollowood, & Hort, 2009). Sensory evaluation is highly subjective in nature, and is characterized by imprecision, inaccuracy and uncertain repeatability (Das, 2005). Generally, sensory evaluation data that are collected in crisp form are analyzed statistically; methods include principal component analysis, correspondence analysis and generalized canonical analysis. But due to imprecision of the variables, classical computational techniques based on statistical and factorial analysis are not efficient (Martinez, 2007). However, due to several reasons, viz. existence of non-linear relations in sensory evaluation, computing using great amount of numerical data only and inability in deriving precise physical interpretation of results, these methods are unsuitable in such computations (Zeng, Ruanb, & Koehl, 2007). Such analyses cannot provide data on the strength and weakness of a particular quality attribute in the product that may be responsible for acceptance or rejection of the product (Lazim & Suriani, 2009). Human perception is always fuzzy and the assessor's opinion by nature comes in linguistic form. Therefore, it is more realistic to carry out linguistic assessments using linguistic variables instead of numerical values (Zadeh & Kacprzyk, 1999). Ranking or scoring of samples necessarily requires acquisition, quantization, aggregation and comparison of meaning of such linguistically expressed assessments (Chakraborty, 2001). Soft computing techniques based on intelligent systems such as fuzzy logic, data aggregation, classification and clustering are required to solve such problems which include uncertainty, imprecision and vagueness (Dubois, Prade, & Yager, 1996; Zimmerman, 2001); for processing of linguistic data, there is a need for computing with words (Zadeh & Kacprzyk, 1999). Zadeh (1965) introduced Fuzzy Set Theory to compute with words (linguistic variables) and fuzzy sets provide mathematical methods that can represent the uncertainty of humans' expression (Lazim & Suriani, 2009). Chen (1988) developed a model for analysis of sensory data and fuzzy set theory has been successfully applied to deal with such linguistic data instead of averaging scores to compare the samples' attributes (Lincklaen et al., 1989). Zhang and Litchfield (1991) developed a fuzzy comprehensive model for ranking of foods and development of new food products. Fuzzy logic approach is thus a precise approach for dealing with the uncertainty, vagueness and imprecision which grows out of the complexity of human behavior; hence it can be used to draw important conclusions regarding acceptance, rejection, ranking and the strong and weak quality attributes of the food (Das, 2005; Jaya & Das, 2003; Lazim & Suriani, 2009; Rao & Das, 2003; Routray & Mishra, 2011; Sinija & Mishra, 2011; Uprit & Mishra, 2002; Zhang & Litchfield, 1991).

The present study was undertaken with the following objectives: (1) to find acceptable levels of ingredients on a dry mass basis to constitute the *chhana podo* feed-mix and (2) to conduct a sensory evaluation study of *chhana podo* samples, to analyze the sensory evaluation data using fuzzy logic and to verify if fuzzy logic could be used to validate optimization results obtained from genetic algorithm (GA) (constrained optimization technique).

2. Materials and methods

2.1. Chhana preparation for chhana podo production

De (1980) and Jagtap and Shukla (1973) reported that a minimum fat content of 4 g/100 g of cow milk was essential to obtain *chhana* of satisfactory texture; hence, branded market milk Amul Taaza® (Sumul Dairy, Surat, Gujarat, India) containing fat: 3.0 g/100 g, SNF: 8.5 g/100 g and Amul Gold® (Surat District Co-operative Milk Producers' Union Limited, Surat, Gujarat, India) containing fat: 6.0%, SNF: 9.0% were mixed in the ratio 1:1 (L/L) to ensure a fat percentage of 4.5 g/100 g in a liter of milk. The word "milk" in this paper has been used hereafter to mean this mixture of *Amul Taaza®* and *Amul Gold®*. After combining the two varieties of milk in the above ratio, following measurements were made; MC and fat content (IS-1224, 1997). Milk was heated to 95 °C before addition of acid solution for complete denaturation of whey proteins (Burton, 1988; Choudhary, Berg, Singh, & Das, 1998; Jonkman & Das, 1993). Since the majority of researchers suggested 70 °C as the most suited coagulation temperature, the same was chosen for this study (Iyer, unpublished; Jonkman & Das, 1993; Ravichandra, Mishra, & Das, 1997; Soni, Bandyopadhyaya, & Ganguly, 1980). Citric acid was used as the acidulant (IS-5162, 1980). Coagulation of milk was completed in less than a minute (Aneja, Mathur, Chandan, & Banerjee, 2002). Jonkman and Das (1993) reported acidity of the milk–acid mixture at 0.52 g/100 ml of distilled water (as lactic acid) for good quality *chhana* from cow milk; the same was selected for the acidity of milk–acid mixture in this study. Strength of the acid solution was calculated to be 1.62% using an expression obtained by Jonkman and Das (1993). Since Choudhary et al. (1998) and Sahu and Das (2008) suggested that a very fast cooling rate must be employed for acidifying the milk for maximization of milk fat and protein recovery in *chhana*, citric acid solution was prepared from 2.6 g of anhydrous citric acid in 200 ml distilled water and frozen in ice trays. These frozen cubes were added to the milk at 95 °C to bring down the temperature of the milk–acid mixture rapidly to 70 ± 1 °C. For de-wheying of *chhana*, gravity drainage of whey was employed (De, 1976; Kumar, unpublished; Vishwesharaiah & Anantakrishnan, 1985). The milk–acid mixture was given a residence time of 1 min before separating the whey through a muslin cloth which was tied into a bag and kept hanging for 20 min for excess whey to drain out under the influence of gravity. MC of *chhana* was measured with an Infrared moisture analyzer (Make: AND, Model: MX-50). The *chhana* thus prepared (Fig. 1) was used for the production of *chhana podo*.

2.2. Feed-mix composition and chhana podo production

Mukhopadhyay (2012) optimized the process parameters for the production of *chhana podo*. Independent variables and their