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ORIGINAL ARTICLE

Spreadsheet aided fuzzy model for prediction of chapati making quality

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Abstract A spreadsheet aided fuzzy logic model for predicting chapati making quality characteristics of Indian wheat varieties was created. Data collected from 19 randomly selected wheat varieties were used. Starch damage, Farinograph water absorption as input variables and chapati overall score as output variable were fuzzified by the use of excel spreadsheet and defuzzification was carried out using weighted average method. Fuzzy model was compared with the regression model of measured data for its error levels and ease of application. Standard error of estimate of fuzzy model was smaller (1.825) than measured (2.895) chapati quality score regression model.

Keywords Chapati · Spreadsheet · Fuzzy logic

Wheat is the basic raw material for the preparation of chapati and its culinary variants such as *roti, phulka* and *parotha* (Haridas Rao et al. 1986). Chapati is the staple diet of a majority of people living in India and its subcontinent. Chapati is made from whole-wheat flour, circular in shape, 10–15 cm diameter and 2–3 mm thick. Puffing, soft and pliable textures are the important quality attributes of chapati. Damaged starch and water absorption of flour are the dominant factors, which affect chapati-making quality (Prabhasankar and Manohar 2002). Physico chemical and functional properties of flour also affect chapati-making property (Sandhu et al. 2007). Considerable work has been reported on the influence of quality and quantity of protein fractions on chapati characteristics. Prediction modeling studies like Electrophoretic and immunologically based methods (Prabhasankar 2002) and multiple regression analysis (Prabhasankar and Manohar 2002) were proposed to predict the chapati making quality. Fuzzy logic is a simple yet very powerful problem solving technique with extensive applicability (Murtha 1995). Vague and imprecise data can be analyzed and important conclusions regarding acceptance, rejection and ranking can be drawn (Das 2005). Fuzzy logic method is suited to systems that require the ability to handle uncertainties (Pham et al. 2005). Fuzzy approach is more suitable for the data associated with some error (Akkurt et al. 2004). Fuzzy logic can be defined as a mathematical model to study and define uncertainties (Cengiz kayacan et al. 2004). Fuzzy identifiers provide a natural framework, to incorporate human linguistic descriptions about the unknown non-linear system (Barea et al. 2006). Fuzzy sets are not confined to a deterministic value as human expectations on feeling for foods are fuzzy (Lee and Kwon 2007). Inaccurate or incomplete expert knowledge is formulated with the help of a set of 'if-then' rules and each rule reflects a non-linear relationship between independent variable (inputs) and dependent variables (outputs) of the process or system under consideration (Aluclu et al. 2008). Processing of the linguistic uncertainties by the fuzzy sets has opened a wide range of implicational areas such as estimation, prediction, control, approximate reasoning, optimization, chemical, industrial engineering, robotics (Morteza et al. 2007) environmental protection, economy, power systems, telecommunication, medicine etc.,(Claudio moraga 2005). Fuzzy logic was successfully used to determine field trafficability, to predict the yield for precision forming, to control start up and shut down of food extrusion processes, to steer a sprayer automatically, to predict corn breakage grain losses from a combine and to manage a food supply. Comparison between the fuzzy logic and linear discriminant analysis

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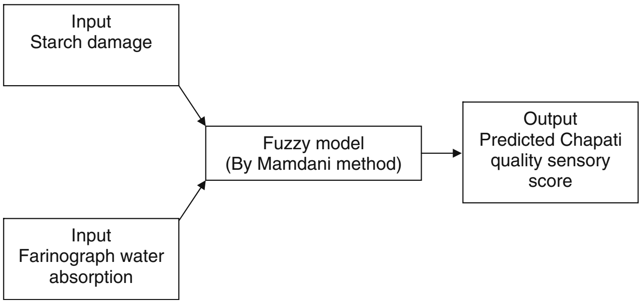

Fig. 1 Fuzzy logic model for prediction of chapati quality sensory score

(LDA) in predicting peanut maturity resulted in better prediction by fuzzy model compared to LDA (Shahin et al. 2000). Classification of plant standard was done by fuzzy logic and found good agreement results between the fuzzy prediction and human experts (Chen and Roger 1994, Simonton and Graham 1996). Fuzzy logic based programmes for various applications are available, which require dedicated softwares to run on computers. Excel spreadsheet is used by many users because of its computational and graphical capabilities. Spreadsheet aided fuzzy logic application for bank software development project has been reported (Barron 1993). However, no work dealing with the prediction of chapati making quality using spreadsheet aided fuzzy model has been reported in the literature. Thus, the aim of the present study was to develop a spreadsheet aided fuzzy model, which runs under MS Excel to predict the chapati making quality.

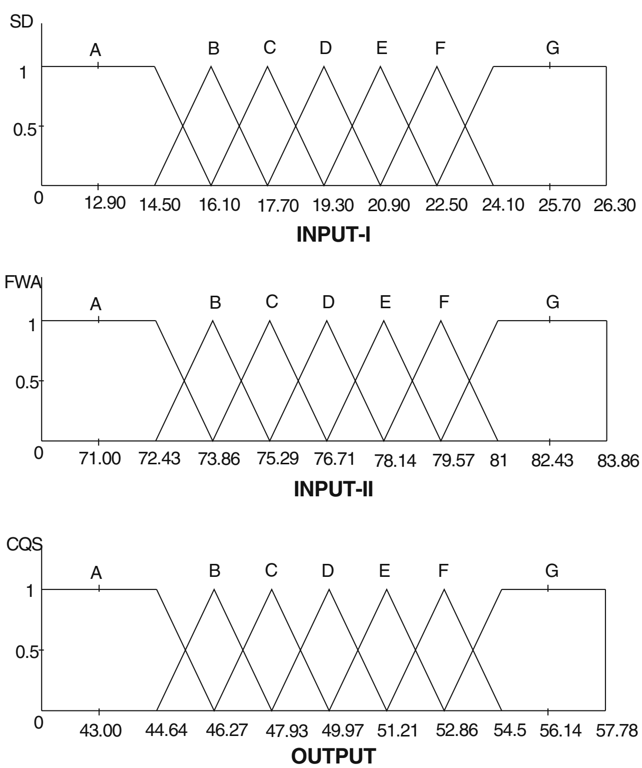

Fig. 2 Membership functions for input and output parameters used for fuzzy model. SD: Starch damage, FWA:Farinograph water absorption, CQS: Chapati quality overall sensory score, A:Moderately low, B:Low, C:Moderately medium, D:Medium, E:Moderately high, F:high, G:Very high

Table 1 Randomly selected rules

Sl. No.	Starch damage (%)	Farinograph water absorption (%)	Chapati quality overall sensory score
1	A	B	B
2	B	C	A
3	C	D	A
4	D	E	D
5	E	C	F
6	F	D	F
7	G	E	D

A Moderately low, *B* Low, *C* Moderately medium, *D* Medium, *E* Moderately high, *F*High, *G*Very high

Materials and methods

The fuzzy model consisted of starch damage values as per AACC method (AACC 76-30A), Farinograph water absorption values as per AACC method (AACC 54-21) as input variables and chapati quality overall sensory score (Haridas Rao et al 1986) as output variable (Fig. 1). Real values of overall sensory score of chapati for comparison with those obtained by fuzzy logic were taken from experimental study result of Prabhasankar et al. 2002. Twenty eight *aestivum* wheat varieties from Mahatma Phule Krishi Vidyapeeth Agricultural Research Station, Nasik and University of Agricultural Sciences, Dharwad were used in the experimental study. The total number of data sets considered was 28, in which 19 sets reported were used for model testing. Built-in functions of Excel were used for logic and mathematical calculations. Multiple regression analysis was carried out to predict the overall chapati quality score.

A fuzzy set is defined as $D = \{(x, \mu_D(x))/x \in X\}$ (1)

where "X" represents the universal set, "D" is a fuzzy subset in "X" and "$\mu_D(x)$" is the membership function of fuzzy set "D". For any set degree of membership ranges from 0 to 1 and Value of "1" and "0" represent 100% and 0% membership respectively. The numbers of input / output membership functions and base widths were obtained using the experimental results (Fig. 2). Fuzzy logic rule base was developed to determine the effect of relationships between the input membership functions and the result. There were a total of 49 fuzzy rule sets and randomly selected 7 were listed in Table 1. The rule base consisted of set of rules of the 'if-then'

Table 2 Testing data for comparison of regression and fuzzy logic models score of different Indian wheat varieties

Sl. No.	Data used in model construction			Comparison of Regression and Fuzzy models			
	Starch damage (%)	Water absorption (%)	Observed overall sensory score (60)	Regression model	Fuzzy model	Regression error (%)	Fuzzy error (%)
1	14.9	81	54.5	55.1	53.2	1.10	2.39
2	19.5	77.5	53	51.1	49.6	3.58	6.42
3	23.3	80	53	51.4	50.8	3.02	4.15
4	21.3	78	52.5	50.8	52.9	3.24	0.76
5	15.5	78.5	51	53.2	52.2	4.31	2.35
6	24.1	80	49	51.1	50.6	4.29	3.27
7	21.3	76.5	47	49.8	52.9	5.96	12.55
8	14.6	72.5	44.5	49.6	47.4	11.46	6.52
9	21.3	74	43	48.2	48.5	12.09	12.79
10	18.5	73	53	48.5	50.5	8.49	4.72
11	17.9	73	51.5	48.7	52.3	5.44	1.55
12	20.0	74	51	48.6	48.3	4.71	5.29
13	13.0	71	47	49.1	46.3	4.47	1.49
14	12.9	72	50	49.8	46.3	0.40	7.40
15	13.7	76	54.5	52.2	50.4	4.22	7.52
16	13.9	74	49.5	50.8	46.3	2.63	6.46
17	14.3	74	53	50.7	46.3	4.34	12.64
18	14.7	73	49.5	49.8	47.8	0.61	3.43
19	15.0	74	52.5	50.4	47.5	4.00	9.52

form. "If" portion referred to the degree of membership in one of the fuzzy sets and "then" portion referred to the associated system output of fuzzy set. Typical rule of the form was "if (Starch damage medium) and (Farinograph water absorption high) then overall score medium". "AND", "OR" and "COMPLIANCE" are the three primary set operators used in fuzzy logic which are shown in Eqs. 2, 3 & 4.

$$\text{AND}: \mu_{c\cap D} = \left(\mu_{c\wedge}\mu_D\right) = \min(\mu_c, \mu_D) \qquad (2)$$

$$\text{OR}: \mu_{cUD} = \left(\mu_{c\,v}\,\mu_D\right) = \min(\mu_c, \mu_D) \qquad (3)$$

$$\text{COMPLIANCE}: 1-\mu_D \qquad (4)$$

where μ_c and μ_D are membership functions of fuzzy sets C and D, respectively.

Minimum method by Eq. 2 was used to combine the membership degrees from each rule established. Weighted average (WA) method was used to de-fuzzify and translate the conglomerated outputs into crisp value by Eq. 5.

$$WA = \frac{\sum_i^s \mu(Kxi)\ Kxi}{\sum_i^s \mu(Kxi)} \qquad (5)$$

where Kxi is the output value in the i subset, and μ(Kxi) is the membership value of the output value in the i^{th} subset. The percentage error for measured data regression model and fuzzy model was computed using Eq. 6.

$$\%Error = \frac{[Z_{Predicted} - Z_{Actual}] \times 100}{Z_{Actual}} \qquad (6)$$

Where Z is chapati quality overall sensory score

Statistical analysis Multiple regression analysis and RMSE (Root mean square error) were carried out by standard methods using Excel'97 software.

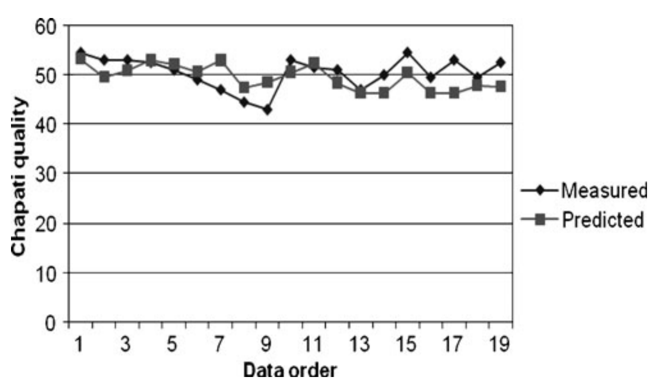

Fig. 3 Comparison of observed chapati quality overall sensory score and predicted quantities by the fuzzy model

Table 3 Regression analysis of observed and fuzzy predicted chapati making quality overall sensory score

Sl. No.	Chapati quality overall sensory score	R	R^2	Adjusted R^2	F(2,16)	Significance (p)	Standard error
1	Observed	0.535	0.286	0.197	3.202	0.067	2.895
2	Fuzzy predicted	0.722	0.521	0.462	8.714	0.002	1.825

Results and discussion

Prediction results of observed data by the developed fuzzy model and the regression model were presented in Table 2 and Fig. 3 indicated that the spreadsheet aided fuzzy model predicts the measured data successfully. Regression summary statistics of observed and fuzzy predicted chapati quality overall sensory score were shown in Table 3. Results indicated that prediction power of fuzzy model was high and significant at $p=0.05$ level. Coefficient of determination (R^2) value of fuzzy predicted model was higher (0.462) and standard error of estimate value was lower (1.825) than those of observed chapati quality overall sensory score. About 52% of the variance in the fuzzy model prediction of chapati quality overall sensory score could be accounted for by starch damage and Farinograph water absorption, which was found to be statistically significant, compared to 28% of the observed chapati quality overall sensory score. Lower (1.825) standard error estimate of fuzzy model than the measured (2.894) chapati quality overall sensory score of regression model indicated that fuzzy model provided better prediction results. RMSE and mean absolute error were computed for each model and shown in Table 4 to make an objective comparison of the models. Regression model produced an average absolute percentage error of 4.65% (RMSE 5.56). The fuzzy model could have produced lower percentage errors than 5.85% (RMSE 6.94) when constructed with more than 2 input parameters. (Akkurt et al. 2004). Fuzzy logic is associated with the human thoughts in generating verbal fuzzy rules. The advantages of fuzzy model for predicting chapati quality could save chapati preparation time and manpower reduction for quality evaluation. Product can be tailored to the specific requirements by adjusting membership functions, the logic or fuzzy approximate reasoning in fuzzy model. Hence, fuzzy approach is well suited for prediction of chapati making quality.

Table 4 Error comparison for the fuzzy and regression models

Model type		Fuzzy	Regression
RMSE		6.94	5.56
MAE	Min	0.76	0.40
	Average	5.85	4.65
	Max	12.79	12.09

RMSE Root mean square error

MAE Mean average error

Conclusion

The development of spreadsheet aided fuzzy model with logical functions for predicting chapatti making quality has been outlined. A fuzzy logic model was created to predict chapatti making quality of different wheat varieties. Input parameters used in fuzzy model construction were starch damage and Farinograph water absorption. Multiple regression analysis model was used to compare the fuzzy model prediction strength. The coefficients of determination (R^2) values for regression model of observed chapati quality score and fuzzy model were 28.6% and 52.1%, respectively. R^2 of the fuzzy model was 82% higher than regression model. Successful predictions of chapati making quality score by the model indicate that fuzzy logic could be a useful tool for engineers and research scientists in the area of baking and milling technology. Even though the fuzzy model yielded slightly higher error than multiple regression model, professionals can use because of its simplicity, ease of application and explicit in nature. Chapati quality parameters are always associated with human evaluation, which makes fuzzy approach as more suitable prediction technique.

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