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DEVELOPING EMPIRICAL RELATIONSHIPS TO PREDICT BREAKING TRENGTH OF MODIFIED CASSAVA-KODO MILLET BASED LOW GLYCEMIC FUNCTIONAL NOODLES USING DESIGNED EXPERIMENTAL APPROACH

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Abstract:

Low glycemic functional pasta products are gaining importance in the present scenario.Dietary modification is an established means of risk reduction of non-infectious diseases. Millets are important crops in semi- arid and tropical regions of the world due to their resistance to pests and diseases, short growing season, and productivity under hardy and drought conditions when major cereals cannot be relied upon to provide sustainable yields and are highly nutritious, non-glutinous and not acid forming foods. Response surface methodology (RSM) is an effective statistical technique which has been widely used to optimize processes or formulations with minimal experimental trials when many factors and their interactions may be involved. In this investigation, an attempt has been made to develop an empirical relationship to predict breaking strength of composite functional pasta. From our results, it was concluded that wheat dominates the breaking strength of the formulated pasta followed by kodo millet flour and modified cassava starch

Keywords—low glycemic functional pasta, kodo millet flour, modified cassava starch, response surface methodology, empirical relationship, breaking strength prediction

1. Introduction

Health and nutrition is the most demanding and challenging field in this era and would continue to be in the future as well. There is a considerable public interest in the capacity of foods and food components to promote health and lower risk of non –infectious diseases and the foods high in dietary fiber are a ready example. Dietary fiber represents a broad class of undigested carbohydrate components that are made up of the plant cell wall: cellulose, hemicelluloses and lignin [1]. Among food carbohydrates, starch or amylum exist in a unique position and is considered as the main foundation of carbohydrate in the human diet [2]. Recently, resistant starches (RS) starches gains importance by the researchers due to the incomplete digestion and absorption of starch in the small intestine. Resistant starches are the products of starch degradation that escapes digestion in the human small intestine of healthy individuals and may be completely or partially fermented in the large intestine as a substrate for the colonic micro flora [3]. Hence, resistant starch has evoked a considerable position in human society due to its putative and positive impacts on health [4]. Cereals form a major portion of human diet and are an important source of starch and other dietary carbohydrates (dietary fiber), which play an important role in the energy requirement and nutrient intake of human[5].Millets are important crops in semi- arid and tropical regions of the world due to their resistance to pests and diseases, short growing season, and productivity under hardy and drought conditions when major cereals cannot be relied upon to provide sustainable yields [6]. The addition of increasing levels of fiber in a long way improves the health status of vast majority of health conscious population who are the main target of this study. In this context, to improve hypoglycaemic effect, healthy functional flour is developed with the combination of whole grain cereal and millet (kodo millet and barnyard millet) based with the incorporation of modified starch (from cassava) and pulse (green gram dhal) to formulate low glycemic functional pasta products. Combination of whole wheat and millet (kodo millet) based with the incorporation of modified starch (from cassava) and pulse (green gram dhal) to formulate low glycemic functional pasta products. Extrusion cooking, as a multi-step, multi-functional and thermal process, is implied in the innovation of functional low glycemic functional food products such as, snack foods, modified starches, ready to eat cereals, baby foods, pasta and pet foods. Keeping this in view, an endeavour is made to produce low glycemic functional pasta products incorporated with modified starch for the elucidation of human health and nutritional benefits of cereal, millet based modified functional foods and diets.Response surface methodology (RSM) is an effective statistical technique [7] which has been widely used to optimize processes or formulations with minimal experimental trials when many factors and their interactions may be involved. RSM was applied in studying combined effect of various ingredients on the breaking strength of wheat and millet based noodles with modified cassava starch produced in this study.

2. Experimental work

2.1 Materials

Whole wheat (Triticumaestivum), kodo millet or varagu (Paspalumscrobiculatum), green gram dhal (Vignaradiata), salt, gingelly oil, chilli powder, pepper and soya sauce were purchased from the local departmental store and stored till use. Commercially available sodium alginate (Food grade - NDL) was purchased from S. Square and Company, Gwalior- 474001 (M.P),India and used as a stabilizer in noodle extrusion. Perishable ingredients were procured from the local market at the time of preparation of vegetable noodles. Freshly harvested cassava (Manihotesculenta) was procured from local market and used as the raw material for the starch extraction. Aluminium idly steamer, stainless steel vessels, ladles, knives and other crockery items were used for the study. BS sieve of 80 mesh size were used for sifting the functional flour blend for the development of pasta product (noodle). The BS sieves were manufactured by Geologist Syndicate (Pvt,) Ltd., Kolkata, India. Liquid petroleum Gas (LPG) was used as a heating source, Gas stove (Indane, India) was used. To knead dough and for extrusion of pasta products, Pasta making machine (M/S. La Monferrina, Italy) was used.

2.2 Preparation of noodles

The basic ingredients for the preparation of pasta product (noodles) were whole wheat flour, salt and water. Cereal (whole wheat flour), millet and pulse based cassava modified starch incorporated noodle were processed as per the standard procedures. The functional flour blend was weighed followed by addition of salt and was mixed well. The functional flour was then sifted thrice to ensure thorough blending. For pre moistening, the functional flour blend with hot water (70 ºC) was added and mixed well, followed by pre steaming in an idly steamer for 5 min. The pre moistened and pre steamed functional flour blend was fed in the barrel of extruder. Then, the blend was post moistened with of hot water (70 ºC) and was mixed thoroughly in the extruder by the shaft in the extruder. The mass was kneaded for 15 min to ensure thorough distribution of moisture. The appropriate brassdie for respective product was fixed and then extruded. After extrusion, the pasta products were post steamed for 20 min using idly steamer. The post steamed pasta products were cooled and dried in a cabinet drier for four hours at 60°C.

2.3 Design of Experiments

To standardize the formula for the preparation of pasta products like noodles, spaghetti and macaroni the following combinations of treatment schedule as trial was experimented. For the experiments, refined wheat flour, kodo millet, and modified/resistant starch are used to formulate low glycemic functional flour for pasta products and production were carried out. In all the experiments, 15 ggreen gram flour and 70 ml of water were kept in a constant level based on the taste and trails. To improve the quality of the low glycemic pasta products such as strength, elasticity and to avoid disintegration and also to reduce solid loss the Sodium Alginate in 2% of total weight (NDL), a food stabilizer which also acts as a dietary fiber was added. The considered factors and their levels are shown in Table 1.

Table 1 Functional pasta preparation factors and their levels

Factors	Unit	Levels				
		-1.68	1	0	1	1.68
Wheat flour	g	40	52	70	88	100
Kodo millet flour	g	10	20	35	50	60
Modified cassava starch	g	5	10	18	25	30

Three factor five level available in the central composite rotatable design experiments [7], consisting of 8 factorial points, 6 corner points and 6 center points was used. The combination of the three factors (whole wheat flour, kodo millet and modified cassava starch) were studied in the response surface experiment, their coded and actual values are shown in Table 2. The noodle samples were allowed to cool for about 6 h prior to use in analysis. For each trial, three samples were produced and analyzed separately.

2.4 Evaluation of Breaking Strength of Noodles

To determine breaking strength, a noodle strip of 6 cm length was taken and its ends were tied horizontally to the supporting strands about 15 cm above the ground level. Known weights (1, 2, and 5g) were dropped on the tied strip at different heights. When the strip breaks, the breaking strength of the pasta products were recorded as Y cm. It was analyzed during the initial and final days of storage and average value was considered for statistical analysis [8].

3. Results and Discussion

3.1 Developing Empirical relationship

By considering all the above conditions, the feasible limits of the parameters were chosen in such a way that pasta producing experiments were carried out to evaluate breaking strength. Central composite rotatable design of second order was found to be the most efficient tool in response surface methodology to establish the mathematical relation of the response surface using the smallest possible number of experiments without losing its accuracy.

Due to wide range of factors, it was decided to use three factors, five levels and central composite design matrix to develop mathematical model for the experimental conditions.

Table 2 Experimental Design matrix and Breaking strength results

		Factor 1	Factor 2	Factor 3	Response
Std	**Run**	**A:Wheat**	**B:kodo millet**	**C:Cassava modified starch**	**Breaking strength**
		g	g	g	cm/g
1	15	52	20	10	6.42
2	19	88	20	10	9.87
3	14	52	50	10	5.95
4	12	88	50	10	9.79
5	7	52	20	25	7.95
6	18	88	20	25	9.22
7	3	52	50	25	5.33
8	4	88	50	25	6.95
9	2	40	35	18	6.16
10	16	100	35	18	10.25
11	9	70	10	18	9
12	20	70	60	18	6.72
13	1	70	35	5	8.6
14	11	70	35	30	7.15
15	13	70	35	18	10.79
16	10	70	35	18	10.6
17	5	70	35	18	10.83

18	17	70	35	18	10.79
19	6	70	35	18	10.8
20	8	70	35	18	10.79

Central composite design is the most popular response surface method design, which has three groups of design points such as, factorial points, axial or star points and center points. In the factorial part of the design consists of all possible combinations of the upper (+1) and lower levels (-1) of the factors. The star points have all of the factors set to 0, the midpoint, except one factor, which has the value +/- Alpha (+/- 1.682) for both rotatability and orthogonality of blocks. Center points, as implied by the name, are points with all levels set to coded level 0 - the midpoint of each factor range. The center points (In this investigation, 15-20) are usually repeated 4-6 times to get a good estimate of experimental error (pure error). To summarize, central composite designs require 5 levels of each factor: -Alpha, -1, 0, 1, and +Alpha. One of the commendable of the central composite design is that its structure lends itself to sequential experimentation. Table 2 shows the 20 sets of coded conditions used to form the design matrix.

Thesecond-order polynomial (regression) equation is used to represent the response surface Y is given by,

$$\mathbf{Y = \beta_0 + \sum\beta_i X_i + \sum\beta_{ii} X_i^2 + \sum\beta_{ij}X_iX_j (1)}$$

The selected model should include the effects of main and interaction effects of all the factors. With the view of considering this criterion, for the three factors, the selected polynomial can be expressed as,

$$\mathbf{Y = b_0 + b_1(A) + b_2(B) + b_3(C) + b_{12}(AB) + b_{13}(AC) + b_{23}(BC) + b_{11}(A^2) + b_{22}(B^2) + b_{33}(C^2)(2)}$$

Where b_0 is the average of the responses and b_1, b_2, b_3,…,b_{33} are regression coefficients that depend on respective linear, interaction, and squared terms of factors. In order to estimate the regression coefficients, a number of experimental design techniques are available. In this work, central composite rotatable design was used which fits the second order response. The fitted regression equation to predict breaking strength is given below,

$$\mathbf{Breakingstrength=10.8+1.3A-89B+0.68B-0.37C+0.09AB-0.55AC-0.541BC-0.93A^2-1.1B^2-1.1\ C^2(3)}$$

Allthe coefficients were obtained applying central composite rotatable design using the Design Expert statistical software package (Version 8.07.1). The significance of each coefficient was determined by Student’s t test and p values, which are listed in Table 3. In this case, A, B, C, AB, AC, BC, A2, B2 and C2 are significant model terms, values of "Prob>F" less than 0.05 indicates that model terms are significant. After determining the significant coefficients (at 95% confidence level), the final empirical relationship was constructed using only these coefficients.

Table 3 ANOVA for Response Surface Quadratic Model for Breaking strength

Analysis of variance table [Partial sum of squares - Type III]						
	Sum of		Mean	F	p-value	
Source	Squares	df	Square	Value	Prob> F	
Model	71.41	9	7.93	581.73	< 0.0001	S*
A-Wheat	21.34	1	21.34	1564.95	< 0.0001	
B-kodo millet	6.31	1	6.31	462.41	< 0.0001	
C-Cassava modified starch	1.83	1	1.83	134.41	< 0.0001	
AB	0.069	1	0.069	5.07	0.048	
AC	2.41	1	2.41	176.89	< 0.0001	
BC	2.37	1	2.37	173.71	< 0.0001	
A^2	12.52	1	12.52	918.29	< 0.0001	
B^2	15.99	1	15.99	1172.06	< 0.0001	
C^2	15.88	1	15.88	1164.27	< 0.0001	
Residual	0.14	10	0.014			
Lack of Fit	0.1	5	0.02	3.02	0.1255	NS*
Pure Error	0.034	5	6.79E-03			
Cor Total	71.55	19				

S*- Significant, NS* - Not significant

3.2.Checking adequacy of the developed relationship

Analysis of variance (ANOVA) technique was used to check the adequacy of the developed empirical relationships. In this investigation, the desired level of confidence was considered to be 95%. The relationship may be considered to be adequate provided that (a) the calculated value of the F ratio of the model developed should not exceed the standard tabulated value of F ratio and (b) the calculated value of the R ratio of the developed relationship should exceed the standard tabulated value of R ratio for a desired level of confidence.

3.2Checking adequacy of the developed relationship

Analysis of variance (ANOVA) technique was used to check the adequacy of the developed empirical relationships. In this investigation, the desired level of confidence was considered to be 95%. The relationship may be considered to be adequate provided that . It is found that the model is adequate. The value of probability > F in Table 3 for the empirical relationships are less than

0.05, which indicates that the empirical relationships are significant. Lack of fit was not significant for all the developed empirical relationships as desired. The Fisher's F test with a very low probability value (P model > F= 0.0001) demonstrates a very high significance. The goodness of fit of the model was checked by the determination coefficient (R^2). The coefficient of determination (R^2) was calculated to be 0.9981 for response. This implies that 99.81 % of experimental data confirms the compatibility with the data predicted by the model, and the model does not explain only about 0.19 % of the total variations. The R^2 value is always between 0 and 1, and its value indicates aptness of the model

Table 4 Statistical values

Std. Dev.	0.12	R-Squared	0.9981
Mean	8.70	Adj R-Squared	0.9964
C.V. %	1.24	Pred R-Squared	0.9885
PRESS	0.82	Adeq Precision	65.624

For a good statistical model, R^2 value should be close to 1.0. The adjusted R^2 value reconstructs the expression with the significant terms. Table 4 shows all the statistical values and all are adequate values. The value of the adjusted determination coefficient (Adj. R^2=0.9964) also high to advocate for a high significance of the model. The Pred. R^2 (0.9885) that implies that the model could explain 95% of the variability in predicting new observations. This is in reasonable agreement with the Adj. R^2 of breaking strength. The value of coefficient of variation is also around 1.24 % indicates that the deviations between experimental and predicted values are low. Adequate precision measures the signal to noise ratio. A ratio greater than 4 is desirable. Relationships can be effectively used for prediction purpose. The normal probability plot of the residual breaking strength is shown in Fig. 2, which reveals that the residuals are falling on the straight line, indicating that the errors are distributed normally.

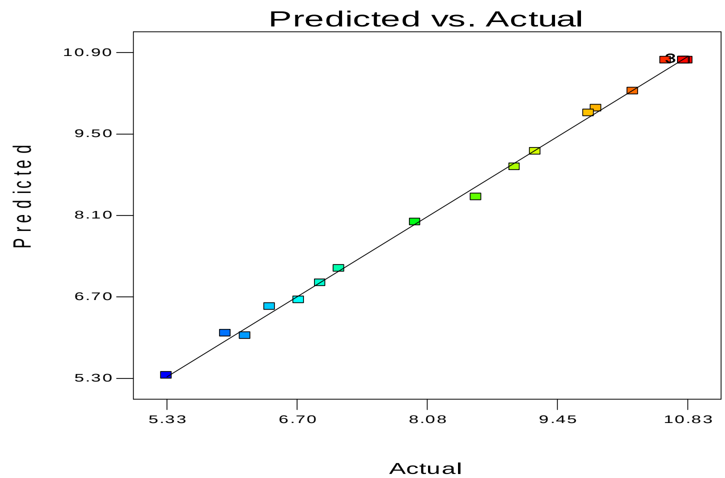

Fig. 1 Correlation graph between actual and predicted values of breaking strength

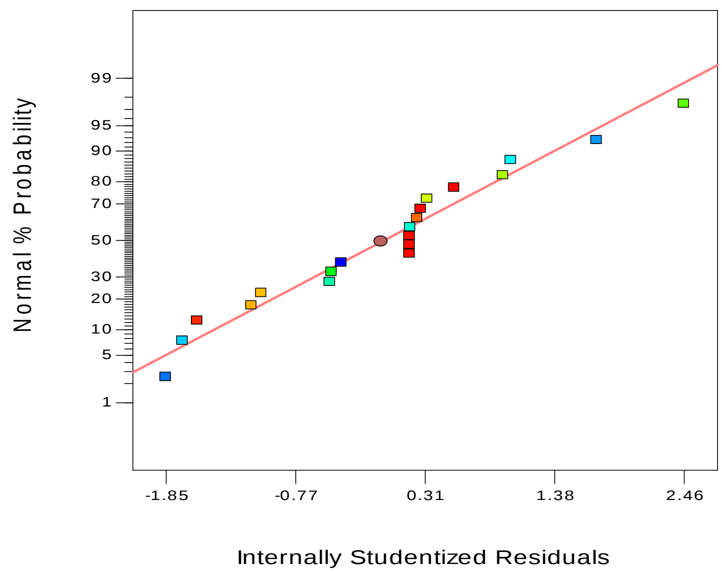

Fig.2 Normal probability chart of residuals

4. Conclusions

1. It was experimentally seen that the use of design of experiments coupled with the statistical fitting model strategy is a simple, effective, and efficient way to develop robust, highly efficient and quality experimental procedure to analyse breaking strength. Based on the experimental results, the following conclusions have been drawn.2. A mathematical model was developed using response surface methodology to predict the breaking strength of the low glycemic functional noodle. The model can be effectively used to predict breaking strength of the modified cassava starch-kodo millet based pasta within the limits of chosen factors.3. Breaking strength of the composite noodles

is influenced by wheat, kodo millet and modified cassava starch. Of the three factors considered, wheat has the highest effect (Fisher ratio = 1564.95) and modified cassava (Fisher ratio=134.41) has the lowest effect on the breaking strength of the pasta [9,10].4. Developed empirical relationships can be effectively used to predict the breaking strength of the modified cassava - kodo millet based pasta within the range of parameters considered in this investigation. However, the established procedures can possibly extend to other materials.

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