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PREDICTION AND OPTIMIZATION TO MAXIMIZE BREAKING STRENGTH OF MODIFIED CASSAVA-KODO MILLET BASED LOW GLYCEMIC FUNCTIONAL NOODLES USING RESPONSE SURFACE METHODOLOGY APPROACH

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Abstract-

Functional Food products are achieving importance in the recent world.Pasta is the generic term for any variety of flour based noodles with low glycemic index. Modification in diets is an established means of risk reduction of metabolic disorders. It is very important to select and control the ingredients to enhance the breaking strength of the pasta products. 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 predict and optimize to maximize the breaking strength of composite functional pasta. From the results, it was concluded that wheat pre dominates the breaking strength of the developed pasta product followed by kodomillet flour and modified cassava starch.

Key words:

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 related to diet and life style. Dietary modification is an established means of risk reduction 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. Cassava starch has been modified by adopting physical modification technique 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. 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 [10]. 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 hypoglycemic effect, healthy functional flour is developed with the combination of whole grain cereal (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 [4]. 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 which has been widely used to optimize processes or formulations with minimal experimental trials when many factors and their interactions may be involved. Although optimization has become popular in many sectors of the Food Industry, it is a procedure for developing the best possible product in its class [5]. The intention of optimization is to provide a more precise map of the path that has the highest probability of leading to a successful food product [6].

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 pasta products extrusion. Onion, tomato, green chillies, capsicum, carrot, beans, cabbage and coriander leaves were procured from the local market at the time of preparation of vegetable pasta products. Freshly harvested cassava (*Manihotesculenta),* was procured from local market and used as the raw material for the starch extraction.green chillies, capsicum, carrot, beans, cabbage and coriander leaves were procured from the local market at the time of preparation of vegetable pasta products. Freshly harvested cassava (*Manihotesculenta),* was procured from local market and used as the raw material for the starch extraction

2.2 Preparation of Pasta products

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. 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. 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

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 gms green 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 [7] was added. The considered factors and their levels are shown in Table 1. pasta products and production were carried out. In all the experiments, 15 g green 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 [7] was added. The considered factors and their levels are shown in Table 1.

Table 1 Important factors and their levels

Factors	**Units**	**Levels**				
		-1.68	**1**	**0**	**1**	**1.68**
Wheat flour	g	40	52	70	88	100
Kodo millet	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 [8] consisting of 8 factorial points, 6 corner points and 6 center points was used. The combination of the three factors (wheat flour, kod millet and modified casava) were studied in the response surface experiment, their coded and actual values are shown in Table 2. The noodles 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.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 [9].

3. Results and Discussion

3.1 Developing Empirical relationship

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 shows the 20 sets of coded conditions used to form the design matrix. The second-order polynomial (regression) equation is used to represent the response surface Y is given by,

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

The fitted regression equation to predict breaking strength is given below,

$$Breaking\ strength = 10.8+1.3A-689B+0.68B-0.37C+0.09AB-0.55AC-0.541BC-0.93A^2-1.1B^2-1.1C^2 \quad (2)$$

Table 2 Experimental Design matrix and Breaking strength result

		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

Table 3 ANOVA for Response Surface Quadratic Model for Breaking strength

	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	1564.9	< 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	1172.0	< 0.0001	
C^2	15.88	1	15.88	1164.2	< 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

All the 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 as discussed by [8]. which are listed in Table 3. The adequacy of the developed model checked by ANOVA analysis and model aptness was checked by analyzing the R^2 and Adjusted R^2 values. Adequate Precision shows the suitability of the model.

3.2 Optimizing the ingredients of low glycemic functional pasta

To obtain the influencing tendency of the process parameters on early breaking strength of the modified cassava based kodo millets composite noodles, the described conditions were adopted as shown in Fig.1. Response surface methodology approach optimisation results are shown Table 1. Further, the three and two dimensional diagrams are plotted under certain processing conditions using the Eqn. (2) are plotted in Fig. 2 and Fig. 3 as surface plots and contour plots for each of the process parameters

Fig. 1 optimization criteria for breaking strength of noodles

Table 4 Optimisation results suggested by Design Expert software

Constraints						
Name	Goal	Lower Limit	Upper Limit	Weight	Weight	Importance
Wheat in gms	is in range	52.16	87.8381	1	1	3
kodo millet in gms	is in range	20.13	49.8651	1	1	3
Cassava modified starch in gms	is in range	10.07	24.9325	1	1	3
Breaking strength	maximize	5.33	10.8298	1	1	3
Solutions						
Number	Wheat	Kodo millet	Modified Cassava starch	Breaking strength	Desirability	
1	74	26	13	10.27	1	
2	85	37	17	11.09	1	
3	82	27	12	10.94	1	
4	72	28	19	10.95	1	
5	87	38	18	10.85	1	
6	82	26	19	11	1	
7	**84**	**36**	**13**	**11.27**	**1**	**Selected**
8	86	42	15	10.86	1	
9	82	36	13	11.25	1	
10	76	36	15	11.09	1	
11	81	28	19	11.13	1	
12	84	40	16	10.99	1	
13	79	27	17	11.21	1	
14	81	35	11	11	1	
15	83	37	16	11.18	1	
16	82	38	17	11.06	1	
17	74	28	16	11.04	1	
18	77	31	13	11.12	1	
19	84	33	18	11.15	1	
20	78	30	17	11.25	1	
21	77	34	15	11.23	1	
22	73	32	17	11.1	1	
23	74	34	15	11.09	1	
24	82	26	17	11.21	1	
25	80	31	13	11.18	1	
26	71	30	17	10.97	1	
27	77	31	14	11.17	1	

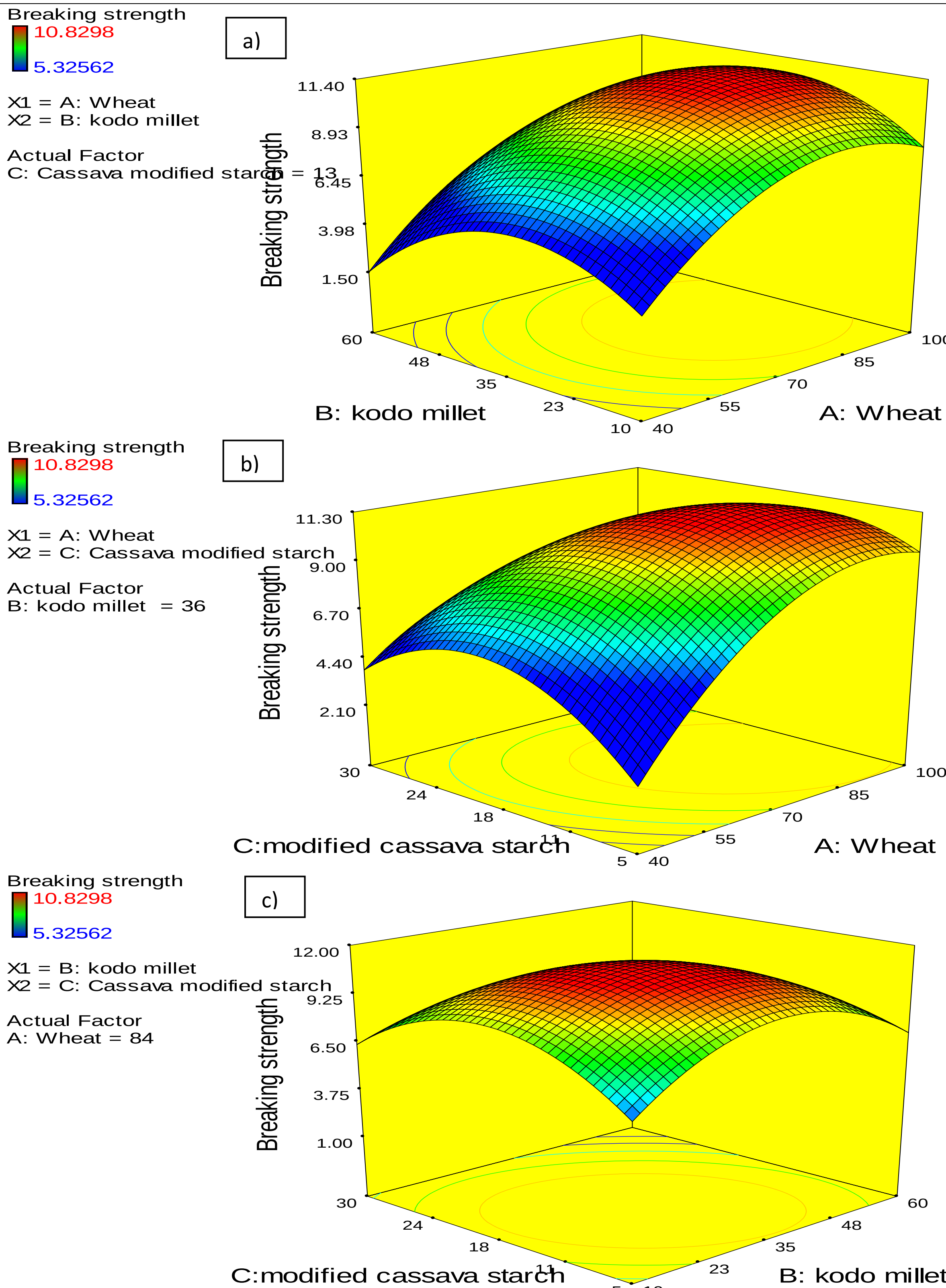


Fig. 2 3-D Response surface plots for breaking strength; (a) wheat and kodo millet; (b) wheat and modified cassava starch; (c) kodo millet and modified cassava starch.

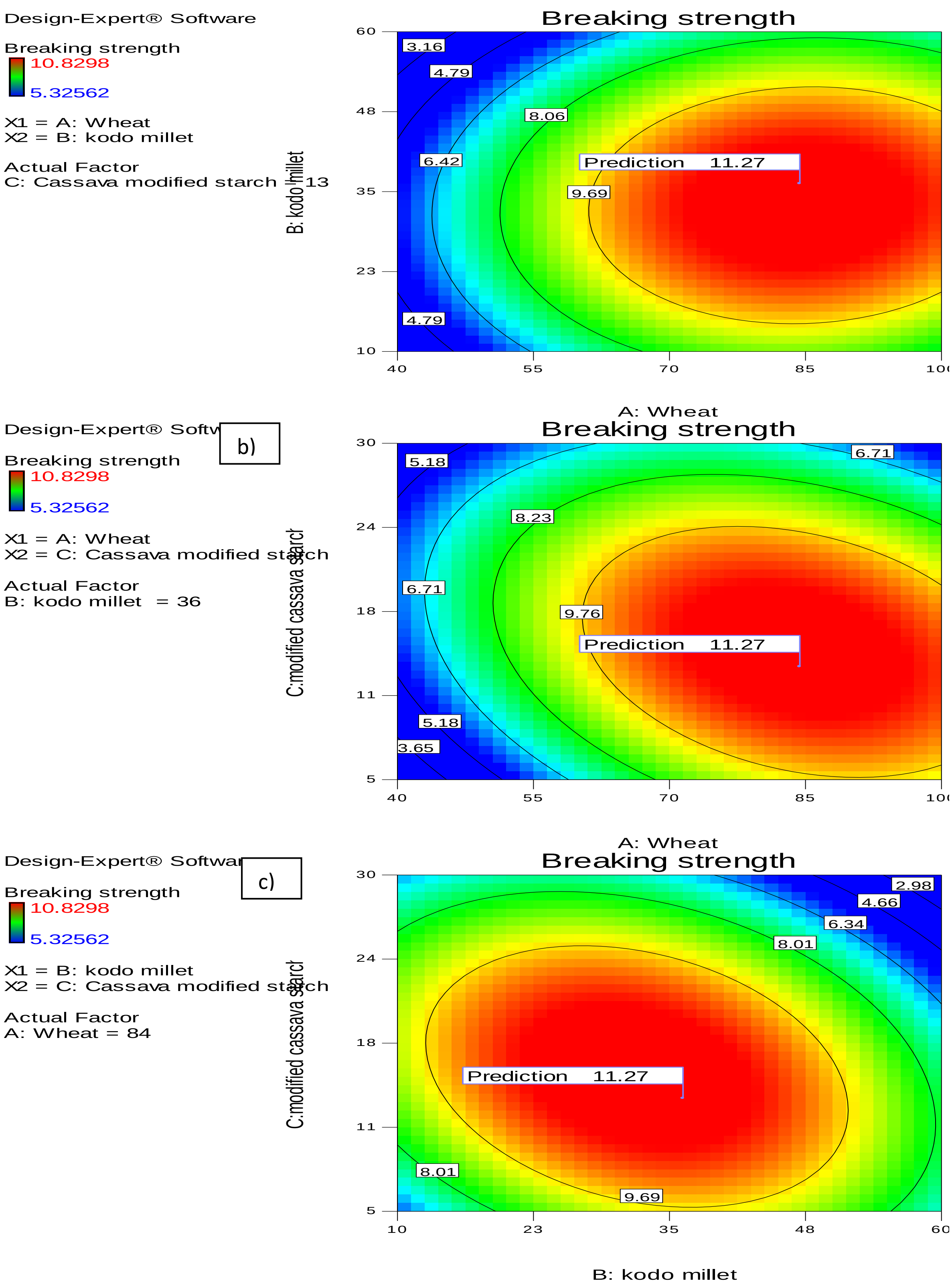
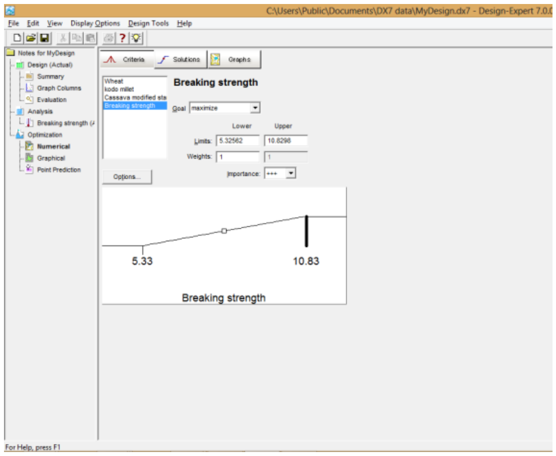


Fig. 3 2-D Contour plots for breaking strength; (a) wheat and kodo millet; (b) wheat and modified cassava starch; (c) kodo millet and modified cassava starch



It is clear from the Fig. 2(a-c) that the breaking strength increases and falls with the increase in experimental parameters content such as wheat, kodo millet and modified cassava starch. The apex of the 3 D response plot gives the maximum breaking strength. These response contours can help in the prediction of the response (breaking strength) at any zone of the experimental domain. A contour plot is produced to visually display the region of optimal factor settings. For second order response surfaces, such a plot can be more complex than the simple series of parallel lines that can occur with first order models. Once the stationary point is found, it is usually necessary to characterize the response surface in the immediate vicinity of the point. Characterization indicates to identify whether the stationary point found is a minimum response or a maximum response or a saddle point. To classifythis, the most straightforward way is to examine through a contour plot. From the Figs. 2 and 3, it is understood that the breaking strength of pasta product decreased as the modified cassava starch weight increased (Table 4). With respect to the content, the level of incorporation of kodo millet flour increased, the breaking strength of the pasta product increased. The incorporation of the kodo millet improved the breaking strength, which indicated that breaking strength is highly related to the protein content of the product. A slight decrease in the breaking strength of cassava modified starch substituted pasta products was recorded.Contour plots play (Figs. 3 (a-c)) very important role in the study of the response surface. By solving Eqn. (2) and analyzing the profile of the response surface and the corresponding contour plot, the value of breaking strength obtained is 11.27 cm/gm, which is found to be maximum and is located at the wheat content of 84 g, kodo millet of 36 g, and modified cassava starch of 13 g at the peak of the response surface plot and the corresponding domain in the contour plot. Most of the contours plots show multiple asymmetric saddling, indicating a rather complex relationship between the dependent and independent variables. This directly reflects the complexity of various changes that modified pasta properties during preparation. Three confirmation experiments were conducted to compare the experimental results with the prediction under the optimal conditions. The mean experimental breaking strength was obtained as 11.25 cm/gm. The error percentage of 4.15% showed an excellent prediction of the model.

4. Conclusions

Based onthe experimental results, the following conclusions have been drawn,

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 and optimize the breaking strength2. 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-kodo millet based pasta within the limits of chosen factors.3. The maximum breaking strength of 11.27 cm/gm is obtained at the wheat content of 84 g, kodo millet of 36 g, and modified cassava starch of 13 g at the peak of the response surface plot by optimizing experimental ingredients parameters. 4. Prediction and optimization of breaking strength of the modified cassava-kodo millet based pasta was analyzed and optimized experimental contents were obtained using the response surface methodology concept available in the design of experiments (DOE) concept. However, the established procedures can possibly extended to other materials

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