IJFS_18407_RA

INNOVARE JOURNAL OF FOOD SCIENCE

NNOVARE ACADEMIC SCIENCES Knowledge to Innovation

ISSN;2321;550X

Vol 5, Issue 2, 2017

Research Article

OPTIMIZATION OF MILLET-BASED IDLI FORMULATIONS USING RESPONSE SURFACE METHODOLOGY

NAZNI P[1]*, SANGEETHALAKSHMI T[2]

[1]Department of Clinical Nutrition and Dietetics, Periyar University, Salem, Tamil Nadu, India. [2]Department of Foods and Nutrition, Mother Teresa University, Kodaikanal, Tamil Nadu, India. Email: naznip@gamil.com

Received: 10 March 2017, Revised and Accepted: 15 March 2017

ABSTRACT

Objective: The barnyard millet is the fastest growing of all millet produces a crop in 6 weeks. Idli is an important staple fermented food in both developed and developing countries. This work was focused on the sensory qualities of barnyard millet idli produced by barnyard millet:dhal ratio and fermentation time at various combinations (13 combinations). Response surface methodology (RSM) was used to optimize the ingredients such as millet: dhal (3:1 to 3:1.25) and fermentation time (12 to 12.5) to formulate 13 variations of idli.

Methods: RSM was used to investigate the effects of barnyard millet:dhal ratio (a) and fermentation time (b) on the idli. Data obtained from RSM on barnyard millet idli developed were subjected to the analysis of variance and analyzed using a second order polynomial equation.

Results: Results of this study revealed that maximum desirable score that can be achieved with the desirable value of appearance was 6.93, color 6.68, flavor 7.37, texture 8.19, taste 6.42, overall acceptability scores 7.51, hardness scores 1972.4, and elasticity scores 0.191. On the basis of these calculations, good millet-based idli could be made when the millet to black gram dhal ratio is 3:1.60 (w/w), fermented time for 12.43 hrs as the best proportion of these components. This sample was considered a best optimizing source for sensory attributes.

Conclusion: Moreover, RSM was shown to be an adequate approach for modeling the organoleptic parameters and the degree of liking of good fermented barnyard millet idli. Millet-based idli formulations showed a remarkable level glycemic response and best substitute instead of rice-based foods.

Keywords: Barnyard millet, Response surface methodology, Dhal, Fermentation time.

INTRODUCTION

Fermented foods are defined as foods that have been subjected to the action of selected microorganisms by which a biochemically and organoleptically modified substrate is produced, resulting in an acceptable product for human consumption [1]. There are different types of fermented foods, in which a range of different substrates are metabolized by a variety of microorganisms to yield products with unique and appealing characteristics [2]. Fermented foods supply important nutrients, particularly proteins and amino acids. People become familiar with particular fermented foods produced in their part of the world, and many of these foods became an integral part of the local diet [3] and culture and were regarded as essential for human consumption and nutrition.

Millets are important foods in many underdeveloped countries because of their ability to grow under adverse weather conditions like limited rainfall. India has the largest millet producing country in the world with a total area of 23 million ha, and small millets alone account for about 3.5 million ha [4]. The major millets are pearl millet, foxtail millet, proso millet, and finger millet. The most important minor millets cultivated in India are barn-yard millet, kodo millet, little millet, guinea millet, and brown top millet [5]. Millets are more nutritious and they are non-glutinous and non-acid forming and easy to digest.

Millets are more nutritious and they are non-glutinous and non-acid forming and easy to digest. Millets are good sources of energy, protein, fatty acids, vitamins, minerals, dietary fiber, and polyphenols. Millet proteins contain good sources of essential amino acids except lysine and threonine but have relatively high quantity of sulfur containing amino acids (methionine and cysteine). Millets are rich sources of phytochemicals, micronutrients, and antioxidants, such as phenolic acids and glycated flavonoids [6].

Minor millets, with their low carbohydrate content, low digestibility and water soluble gum content (β-glucan) have been attributed to improve glucose metabolism. These grains release sugar slowly in the blood and also diminish the glucose absorption [7]. The dietary fiber and resistant starch of minor millets have been attributed to exhibit hypoglycemic and hypolipidemic effects [8]. Further, the antioxidative properties of minor millets against hyperglycemia and oxidative stress have also been studied, which is mainly determined by their higher reserves of phytochemicals such as phenolics, tannins, phytates, and micro minerals. [9]. The main objective of this study was to explore the effect of millet and black gram dhal and fermentation time on the sensory characteristics of idli and analyzing the instrumental texture profile parameters as a function of raw material composition and fermentation time and to find the optimum levels to maximize the desirable textural properties of idli using response surface methodology (RSM).

METHODS

Ingredients

The ingredients used for this investigation such as barnyard millet, urad dhal, fenugreek, and salt were purchased from local departmental store in Salem. All the ingredients were selected by considering its availability, nutritional, and health benefits.

Basic formulation of idlis

About 13 variations of idlis with varying proposition of ingredients and fermentation time were optimized (barnyard millet: Black gram dhal and temperature were mixed at ratios of 3:1; 12, 3:0.75; 13 and 3:1.5; 14) to the entire proposition. The composition is given in Table 1.

Optimization of the barnyard millet idly-experimental design for the process of optimization

The Central Composite Rotatable Design (CCRD) was used for selecting the level of parameters in the experiments. RSM was performed using the Design-Expert software program version 7.0. The coded and un-coded independent variables used in the RSM design are listed in Table 1. The levels of the independent parameters were based on preliminary experimental results. The experimental design was based on the CCD as shown below.

Each design point consists of the replicates. For the statistical analysis, the numerical levels are standardized to −2, −1, 0 and +1, +2. The experiments were carried out in randomized order (Gacula and Singh, 1984). The relationship between standardized variables values is given as follows.

RSM

RSM was applied to optimize the levels of two variables barnyard millet: Black gram dhal (X1) and temperature (X2). CCRD was used in selecting the levels of the four variables. The variables were standardized on the basis of their effect of responses, i.e., product weight, number of pores in a square inch in idly, carbohydrate, protein, fat, fiber, and overall acceptability. The standardized variables (X_i) were obtained using the following second order polynomial equation. The model proposed of each response of Y was:

$$Y = \beta_0 + \sum_{t=1}^{K} \beta_i X_i + \sum_{i=1}^{K} \beta_{ii} X_i^2 + \sum_{i=1}^{K-1} \sum_{j=i+1}^{K} \beta_{ij} X_i X_j + \varepsilon$$

Where: β_0 - Constant, β_i - Linear coefficient, β_{ii} - Quadratic coefficient, β_{ij} - Cross product coefficient, X_i, X_j - Levels of the independent variables, ε - Number of the factors tested. The model permitted evaluation of quadratic terms of the independent variables on the dependent variable.

Statistical analysis

Data were analyzed by the least-squares method, and response surfaces were generated using the Design Expert® 7.0.0 software (Stat Ease Inc., Minneapolis, MN, USA). Analysis of variance (ANOVA) was used to test the significance of each variable (p≤0.05) and to verify the adequacy of the model. Interaction effects were determined using LS means (p≤0.05). All experiments were carried out in triplicate.

RESULTS AND DISCUSSION

The effect experiments are conducted according to the design matrix, and corresponding results are listed in Table 4. The quadratic equation for predicting the optimum point was obtained according to the CCRD design and input variables, and then the empirical relationship between the response and the independent variables in the coded units was presented on the basis of the experimental results as follows:

Coded: Appearance (Y1) = +6.80−0.05*A+0.052*B−0.25*AB+0.16*A^2−0.34*B^2 Equation (1)

Un-coded: Appearance = −162.59+12.63*millet and dhal+25.516*time−1.38*millet and dhal*time+1.80*millet and $dhal^2$−0.93*$time^2$ Equation (2)

Where, Y is the appearance attributes, A1 and B2 is millet and dhal ratio and time, respectively.

The results of the ANOVA for the quadratic equation are tabulated in Table 4. The ANOVA indicates the equation and actual relationship between the response and significant variables represented by the equation are accurate. The significance of the coefficient term is determined by the values of F and p, and the larger the value of F and the smaller the value of p, the more significant (Amini *et al.,* 2008; Kalavathy *et al*. 2009)[10,11]. The p is lower than 0.05, suggesting the model is considered to be statistically significant (Kim *et al.* 2003)[12].

For the developed barnyard millet idli, the ANOVA results indicated the F-value for the model was 0.36, suggesting that only a 0.86^{NS} chance of a "model F value" so small could occur due to fermentation time and the most of the variation in the response could be explained by the regression equation and that the model was not significant (p>0.05). In addition, the probability p=0.86^{NS} also validated the model was not significant. On checking this model the lack of fit was not significant and the R^2 values, the "predicted R^2" of −2.35 was in reasonable agreement with the "adjusted R^2" of −0.36. "Adequacy precision" measures the signal to noise ratio. It is reported that a ratio >4 is desirable (Muthukumar *et al.* 2003) [13].

The effect experiments are conducted according to the design matrix, and corresponding results are listed in Table 4. The quadratic equation

Table 1: Coded and un-coded independent variables used in RSM design

Independent variables	Coded value		
	−1	0	+1
Barnyard millet:black gram dhal (X1)	3:1	3:0.75	3:1.5
Temperature (X2)	12	13	14

RSM: Response surface methodology

Table 2: Variation for the preparation of idli from barnyard millet

Variations	Barnyard millet:black gram dhal	Temperature
V_0	3:1 (rice:dhal)	12
V_1	3:1	12
V_2	3:1.5	12
V_3	3:1	13
V_4	3:1.5	13
V_5	3:0.89	12.5
V_6	3:1.60	12.5
V_7	3:1.25	11.79
V_8	3:1.25	13.20
V_9	3:1.25	12.5
V_{10}	3:1.25	12.5
V_{11}	3:1.25	12.5
V_{12}	3:1.25	12.5
V_{13}	3:1.25	12.5

Table 3: Methods of preparation ingredients

Ingredient	Weight (g)
Barnyard millet	100
Black gram dhal	25
Fenugreek	5
Salt	To taste
Water	As requirement

Table 4: Effect of barnyard millet, dhal and fermentation time on appearance attribute of developed idli

Source	Coefficient estimate	Sum of squares	Mean square	F value	p value
Model	6.80	1.39	0.28	0.36	0.86^{NS}
A	−0.052	0.021	0.021	0.028	0.872
B	0.052	0.021	0.021	0.028	0.872
AB	−0.25	0.25	0.25	0.33	0.586
A^2	0.16	0.18	0.18	0.24	0.639
B^2	−0.34	0.79	0.79	1.03	0.343
Residual		5.38	0.77		
Lack of fit		2.58	0.86	1.23	0.408^{NS}
R^2	0.20				
Adjusted R^2	−0.36				
Predicted R^2	−2.35				

A: Millet and dhal, B: Time

for predicting the optimum point was obtained according to the CCRD design and input variables, and then the empirical relationship between the response and the independent variables in the coded units was presented on the basis of the experimental results as follows:

Coded: Color (Y2)=+7.40−0.20*A+0.23*B+0.25*AB−0.33*A^2−0.57*B^2 Equation (3)

Uncoded: Color (Y2)=−233.46−8.77*millet and dhal+38.82*time +1.38*millet and dhal*time−3.61*millet and $dhal^2$−1.59*$time^2$ Equation (4)

Where, Y is the appearance attributes, A1 and B2 is millet and dhal ratio and time, respectively.

For the developed barnyard millet idli's color attribute, the ANOVA results indicated the F-value for the model was 0.65, suggesting that only a 0.66^{NS} chance of a "model F value" so small could occur due to fermentation time and the most of the variation in the response could be explained by the regression equation and that the model was not significant (p>0.05). In addition, the probability p=0.66^{NS} also validated the model was not significant. On checking this model, the lack of fit (0.25^{NS}) was not significant and the R^2 value was 0.31 means 31% of acceptable, the "predicted R^2" of −2.32 was in reasonable agreement with the "adjusted R^2" of −0.16.

The quadratic equation for predicting the optimum point was obtained according to the CCRD design and input variables, and then the empirical relationship between the response and the independent variables in the coded units was presented on the basis of the experimental results as follows:

Coded: Flavor=+7.40+0.30*A+0.12*B−0.75*AB−0.45*A^2−0.70*B^2 Equation (3)

Uncoded: Flavor=−381.93270+66.50592*millet and dhal+ 54.62500*time−4.16667*millet and dhal*time−5.00000*millet and $dhal^2$−1.94444*$time^2$ Equation (4)

Where, Y is the appearance attributes, A1 and B2 were barnyard millet and dhal ratio and fermentation time, respectively.

For the developed barnyard millet idli's flavor attribute, the ANOVA results indicated the F value for the model was 1.94, suggesting that only a 0.205^{NS} chance of a "model F value" so varied could occur due to fermentation time and the most of the variation in the response could be explained by the regression equation and that the model was not significant (p>0.05). In addition, the probability p=0.205^{NS} also validated the model was not significant. On checking this model, the lack of fit (0.98^{NS}) was not significant and the R^2 value was 0.58 means 58% of acceptable, the "predicted R^2" of 0.28 was in reasonable agreement with the "adjusted R^2" of 0.28.

The effect experiments are conducted according to the design matrix and corresponding results are listed in Table 7. The quadratic equation for predicting the optimum point was obtained according to the CCRD design and input variables, and then the empirical relationship between the response and the independent variables in the coded units was presented on the basis of the experimental results as follows:

Coded: Texture=+7.80+0.60*A+5.677E−016*B−1.254E−015*AB−0.15*A^2−0.65*B^2 Equation (3)

Uncoded: Texture=−284.28206+6.34518*millet and dhal+ 45.50000*time−5.84885E−013*millet and dhal*time−1.66667*millet and $dhal^2$−1.80556*$time^2$ Equation (4)

Where, Y is the appearance attributes, A1 and B2 was barnyard millet and dhal ratio and fermentation time, respectively.

Table 5: Effect of barnyard millet, dhal and fermentation time on color attribute of idli

Source	Coefficient estimate	Sum of squares	Mean square	F value	p value
Model	7.40	3.72	0.74	0.65	0.66^{NS}
A - Millet and dhal	−0.20	0.31	0.31	0.28	0.615
B - Time	0.23	0.42	0.42	0.37	0.563
AB	0.25	0.25	0.25	0.22	0.653
A^2	−0.33	0.73	0.73	0.65	0.448
B^2	−0.57	2.30	2.30	2.02	0.198
Residual		7.97	1.14		
Lack of fit		4.77	1.59	1.99	0.25^{NS}
R^2	0.31				
Adjusted R^2	−0.16				
Predicted R^2	−2.32				

Table 6: Effect of barnyard millet, dhal and fermentation time on flavor attribute of idli

Source	Coefficient estimate	Sum of squares	Mean square	F value	p value
Model	7.40	7.42	1.48	1.94	0.205^{NS}
A - Millet and dhal	0.30	0.73	0.73	0.95	0.361
B - Time	0.12	0.12	0.12	0.16	0.69
AB	−0.75	2.25	2.25	2.95	0.12
A^2	−0.45	1.41	1.41	1.84	0.21
B^2	−0.70	3.41	3.41	4.46	0.07
Residual		5.35	0.76		
Lack of fit		0.15	0.049	0.038	0.98^{NS}
R^2	0.58				
Adjusted R^2	0.28				
Predicted R^2	0.28				

Table 7: Effect of barnyard millet, dhal and fermentation time on texture attribute of idli

Source	Coefficient estimate	Sum of squares	Mean square	F value	p value
Model	7.80	5.88	1.18	2.85	0.10^{NS}
A - Millet and dhal	0.60	2.91	2.91	7.07	0.03
B - Time	5.677	8.882	8.882	2.15	1.00
AB	−1.254	0.000	0.000	0.000	1.00
A^2	−0.15	0.16	0.16	0.38	0.55
B^2	−0.65	2.94	2.94	7.13	0.03
Residual		2.89	0.41		
Lack of fit		2.09	0.70	3.48	0.13^{NS}
R^2	0.67				
Adjusted R^2	0.43				
Predicted R^2	−0.83				

For the developed barnyard millet idli's texture attribute, the ANOVA results indicated the F value for the model was 2.85, suggesting that only a 0.10^{NS} chance of a "model F value" so varied could occur due to millet and dhal and fermentation time ratio and the most of the variation in the response could be explained by the regression equation and that the model was not significant. In addition, the probability p=0.10^{NS} also validated the model was not significant (p>0.05). On checking this model, the lack of fit (0.13^{NS}) was not significant and the R^2 value was 0.67 means 67% of acceptable, the "predicted R^2" of 0.43 was in reasonable agreement with the "adjusted R^2" of −0.83.

The effect experiments are conducted according to the design matrix and corresponding results are listed in Table 8. The quadratic equation for predicting the optimum point was obtained according to the CCRD design and input variables, and then the empirical relationship between the response and the independent variables in the coded units was presented on the basis of the experimental results as follows:

Coded: Taste=+6.60−0.55*A−0.052*B−0.25*AB+0.2*A^2+0.26*B^2 Equation (3)

Uncoded: Taste=+108.02001+8.07741*millet and dhal−16.65574*time−1.38889*millet and dhal*time+2.91667*millet and $dhal^2$+0.72917*$time^2$ Equation (4)

Where, Y is the appearance attributes, A1 and B2 were barnyard millet and dhal ratio and fermentation time, respectively.

For the developed barnyard millet idli's color attribute, the ANOVA results indicated the F value for the model was 0.93, suggesting that only a 0.51^{NS} chance of a "model F value" so varied could occur due to millet and dhal and fermentation time ratio and the most of the variation in the response could be explained by the regression equation and that the model was not significant. In addition, the probability p=0.51^{NS} also validated the model was not significant (p>0.05). On checking this model the lack of fit (0.51^{NS}) was not significant and the R^2 value was 0.39 means 39% of acceptable, the "predicted R^2" of −1.28 was in reasonable agreement with the "adjusted R^2" of −0.03.

The effect experiments are conducted according to the design matrix, and corresponding results are listed in Table 9. The quadratic equation for predicting the optimum point was obtained according to the CCRD design and input variables, and then the empirical relationship between the response and the independent variables in the coded units was presented on the basis of the experimental results as follows:

Coded: OVA=+7.60+0.18*A+0.073*B+0.50*AB−0.050*A^2−0.55*B^2 Equation (3)

Uncoded: OVA=−192.69261−32.96630*millet and dhal+35.01093*time+2.77778*millet and dhal*time−0.55556*millet and $dhal^2$−1.52778*$time^2$ Equation (4)

Where, Y is the appearance attributes, A1 and B2 were barnyard millet and dhal ratio and fermentation time, respectively.

For the developed barnyard millet idli's OVA attribute, the ANOVA results indicated the F-value for the model was 0.93, suggesting that only a 0.51^{NS} chance of a "model F value" so varied could occur due to millet and dhal and fermentation time ratio and the most of the variation in the response could be explained by the regression equation and that the model was not significant. In addition, the probability p=0.51^{NS} also validated the model was not significant (p>0.05). On checking this model, the lack of fit (0.51^{NS}) was not significant and the R^2 value was 0.39 means 39% of acceptable, the "predicted R^2" of −1.28 was in reasonable agreement with the "adjusted R^2" of −0.03.

The effect experiments are conducted according to the design matrix, and corresponding results are listed in Table 10. The quadratic equation for predicting the optimum point was obtained according to the CCRD design and input variables, and then the empirical relationship between the response and the independent variables in the coded units was presented on the basis of the experimental results as follows:

Coded: Hardness=+2672.80−381.59*A−184.28*B+19.75*AB−348.12*A^2−217.99*B^2 Equation (3)

Un-coded: Hardness=−92678.73528+7402.29275*millet and dhal+14809.79722*time+ 109.72222*millet and dhal*time−3867.98611*millet and $dhal^2$− 605.53819*$time^2$ Equation (4)

Where, Y is the appearance attributes, A1 and B2 were barnyard millet and dhal ratio and fermentation time, respectively.

Table 8: Effect of barnyard millet, dhal and fermentation time on taste attribute of idli

Source	Coefficient estimate	Sum of squares	Mean square	F value	p value
Model	6.60	3.56	0.71	0.93	0.51^{NS}
A - Millet and dhal	−0.55	2.44	2.44	3.18	0.11
B - Time	−0.052	0.021	0.021	0.028	0.87
AB	−0.25	0.25	0.25	0.33	0.58
A^2	0.26	0.48	0.48	0.63	0.45
B^2	0.26	0.48	0.48	0.63	0.45
Residual		5.37	0.77		
Lack of fit		2.17	0.72	0.90	0.51^{NS}
R^2	0.39				
Adjusted R^2	−0.03				
Predicted R^2	−1.28				

Table 9: Effect of barnyard millet, dhal and fermentation time on overall acceptability attribute of developed idli

Source	Coefficient estimate	Sum of squares	Mean square	F value	p value
Model	7.60	3.40	0.68	0.69	0.6475^{NS}
A - Millet and dhal	0.18	0.25	0.25	0.25	0.6302
B - Time	0.073	0.043	0.043	0.043	0.8408
AB	0.50	1.00	1.00	1.01	0.3476
A^2	−0.050	0.017	0.017	0.018	0.8981
B^2	−0.55	2.10	2.10	2.13	0.1876
Residual		6.91	0.99		
Lack of fit		1.71	0.57	0.44	0.7384^{NS}
R^2	0.3299				
Adjusted R^2	−0.1487				
Predicted R^2	−0.9660				

Table 10: Effect of barnyard millet, dhal and fermentation time on hardness attribute of developed idli

Source	Coefficient estimate	Sum of squares	Mean square	F value	p value
Model	2672.80	2.492	4.98	2.58	0.124^{NS}
A - Millet and dhal	−381.59	1.165	1.165	6.03	0.04
B - Time	−184.28	2.717	2.717	1.41	0.274
AB	19.75	1560.25	1560.25	8.077	0.93
A^2	−348.12	8.430	8.430	4.36	0.075
B^2	−217.99	3.306	3.306	1.71	0.23
Residual		1.352	1.932		
Lack of fit		1.328	4.427	73.11	0.00**
R^2	0.64				
Adjusted R^2	0.39				
Predicted R^2	−1.46				

For the developed barnyard millet idli's hardness attribute, the ANOVA results indicated the F value for the model was 2.58, suggesting that only a 0.124^{NS} chance of a "model F value" so varied could occur due to millet and dhal and fermentation time ratio and the most of the variation in the response could be explained by the regression equation and that the model was not significant. In addition, the probability p=0.124^{NS} also validated the model was not significant (p>0.05). On checking this model the lack of fit (0.00**) was significant and the R^2 value was 0.64 means 64% of acceptable, the "predicted R^2" of −1.46 was in reasonable agreement with the "adjusted R^2" of 0.39.

The effect experiments are conducted according to the design matrix, and corresponding results are listed in Table 11. The quadratic equation for predicting the optimum point was obtained according to the CCRD

Table 11: Effect of barnyard millet, dhal and fermentation time on elasticity attribute of developed idli

Source	Coefficient estimate	Sum of squares	Mean square	F value	p value
Model	0.40	0.19	0.03	6.14	0.01**
A - Millet and dhal	−0.052	0.02	0.02	3.47	0.10
B - Time	−0.025	5.00	5.00	0.82	0.39
AB	0.050	0.01	0.01	1.63	0.24
A^2	−0.15	0.15	0.15	24.53	0.00
B^2	−0.034	8.22	8.22	1.34	0.28
Residual		0.043	6.11		
Lack of fit		0.043	0.01		
R^2	0.81				
Adjusted R^2	0.68				
Predicted R^2	−0.31				

Table 12: Predicted optimization of process parameters by desirability approach

Process parameters	Target	Experimental design		Optimum values
Millet and dhal ratio	In range	3:1.00	3:1.60	3:1.60
Time	In range	12.00	13.20	12.43
Responses				
Appearance	Maximum	6	8	6.93
Color	Maximum	6	9	6.68
Flavor	Maximum	6	8	7.37
Texture	Maximum	6	9	8.19
Taste	Maximum	6	8	6.42
OVA	Maximum	6	9	7.51
Hardness	Maximum	1500	3000	1972.4
Elasticity	Maximum	0.1	0.5	0.191

design and input variables, and then the empirical relationship between the response and the independent variables in the coded units was presented on the basis of the experimental results as follows:

Coded: $Elasticity=+0.40-0.052*A-0.025*B+0.050*AB-0.15*A^2-0.034*B^2$ Equation (3)

Un-coded: $Elasticity=-12.21912+0.57133*millet\ and\ dhal\ ratio+2.00347*time+0.27778*millet\ and\ dhal\ ratio*time-1.63194*millet\ and\ dhal\ ratio^2-0.095486*time^2$ Equation (4)

Where, Y is the appearance attributes, A1 and B2 were barnyard millet and dhal ratio and fermentation time, respectively.

For the developed barnyard millet idli's elasticity attribute, the ANOVA results indicated the F-value for the model was 6.14, suggesting that only a 0.01** chance of a "model F value" so varied could occur due to millet and dhal and fermentation time ratio and the most of the variation in the response could be explained by the regression equation and that the model was significant. In addition, the probability p=0.01** also validated the model was significant (p>0.01). On checking this model, the R^2 value was 0.81 means 81% of acceptable, the "predicted R^2" of −0.31 was in reasonable agreement with the "adjusted R^2" of 0.68.

Optimization of extraction parameters of idli

The relationship between independent and dependent variables was graphically represented by three-dimensional (3D) response surface generated by the model (Figs. 1-8). Fig. 1 showed the interaction between barnyard millet: Dhal (a) and fermentation time (b) on the yield of 13 variations of idli. This 3D figure showed some interactions between barnyard millet: dhal and fermentation time for appearance of idli. The sensory value of appearance increase to a certain point and get decreased at a level of about 6.93 due to the interactions of fermentation.

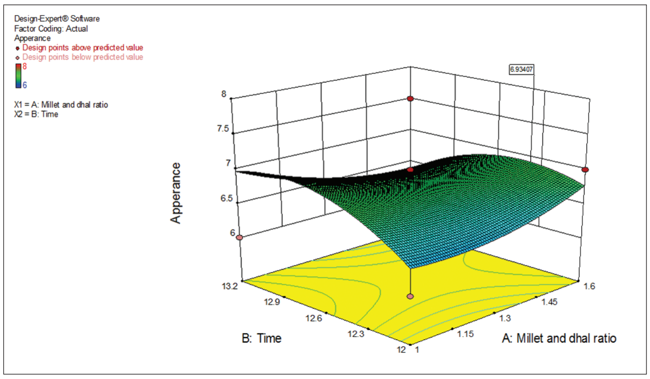


Fig. 1: Response surface plot of the effects of barnyard millet: Dhal (a) and fermentation time (b), on the appearance of idli

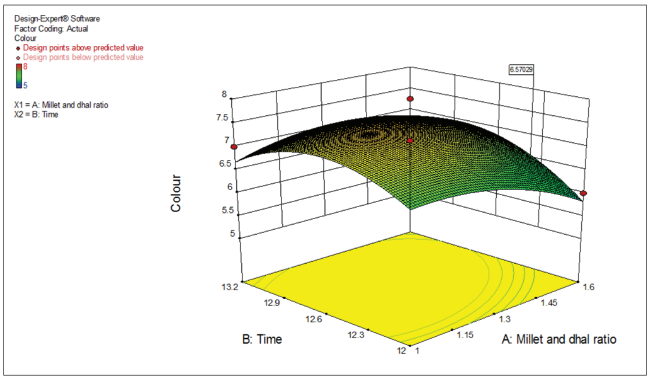


Fig. 2: Response surface plot of the effects of barnyard millet: Dhal (a) and fermentation time (b), on the color of idli

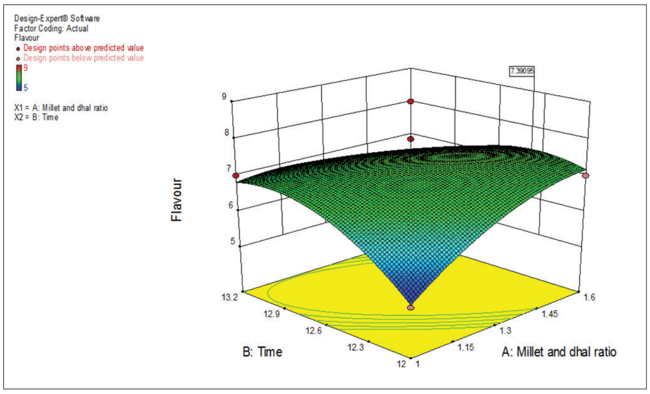


Fig. 3: Response surface plot of the effects of barnyard millet: Dhal (a) and fermentation time (b), on the flavor of idli

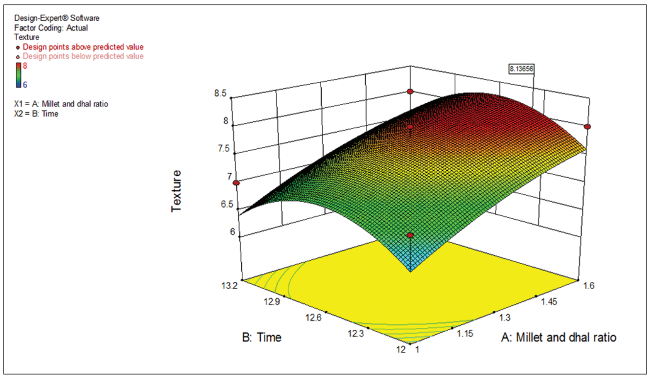


Fig. 4: Response surface plot of the effects of barnyard millet: Dhal (a) and fermentation time (b), on the texture of idli

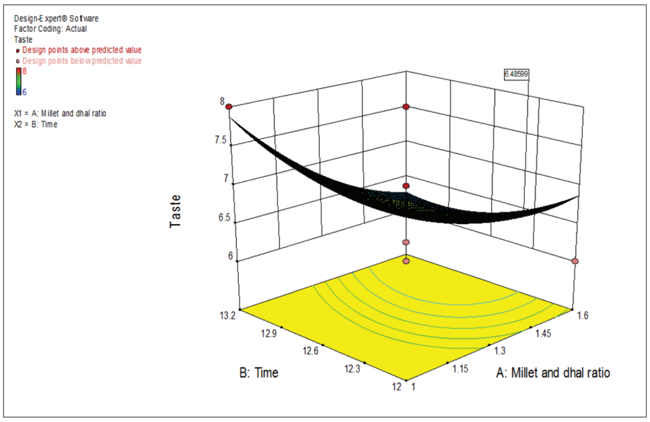


Fig. 5: Response surface plot of the effects of barnyard millet: Dhal (a) and fermentation time (b), on the taste of idli

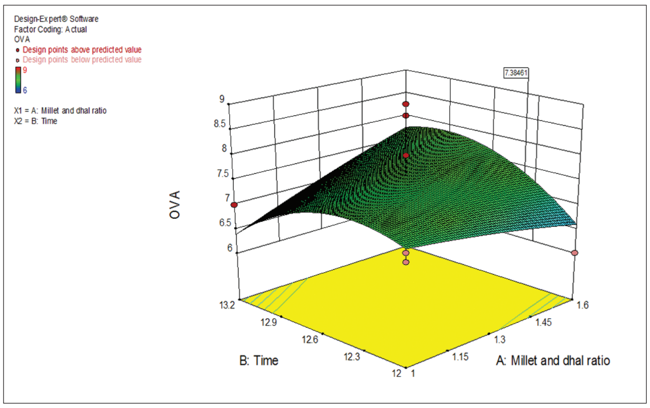


Fig. 6: Response surface plot of the effects of barnyard millet: Dhal (a) and fermentation time (b), on the OVA of idli

The same study was done by Ghosh and Chattopadhyay [14] which states that the changes during fermentation affect the physical properties such as appearance, texture, aroma, flavor, and overall acceptability and these parameters are vital to assess the acceptability of the product in the consumer point of view.

In Fig. 2, the interaction between barnyard millet: Dhal (a) and fermentation time (b) on color of developed idli. The color of the idli varied with the difference in ratios of the ingredients and change in fermentation time. In Fig. 3, the flavor attribute of idli was varied between the independent and dependent variables. The sensory point was gradually raised to the center point and sudden fall was seen in plot. The changes in fermentation depend on the available nutrients in the starting materials, the unique metabolic abilities of the fermenting microorganisms and possible interactions among all of these elements [15]. The response surface graph reveals that fermented aroma increased with increase in fermentation time.

Fig. 4 plots denote sudden decrease in the variable interaction from its center point. The texture of idli is influenced by many variables such as raw material, quantity, soaking time, grinding conditions, fermentation temperature, and time and adjuncts on quality of idli [16-18]. The fluffiness and sponginess increased with increase in the ratio of black gram dhal and fermentation time. The maximum score for fluffiness is 11.4 for the idli made of ratio 3:2 at 12 hrs fermentation time.

Fig. 5d shows that taste decreased with increase in fermentation time. In this study, the taste was high (6.42) for the idli made of ratio 3:1.78 at 13.42 hrs fermentation time. As sourness at an optimum level is preferred, an optimum temperature will favor the product.

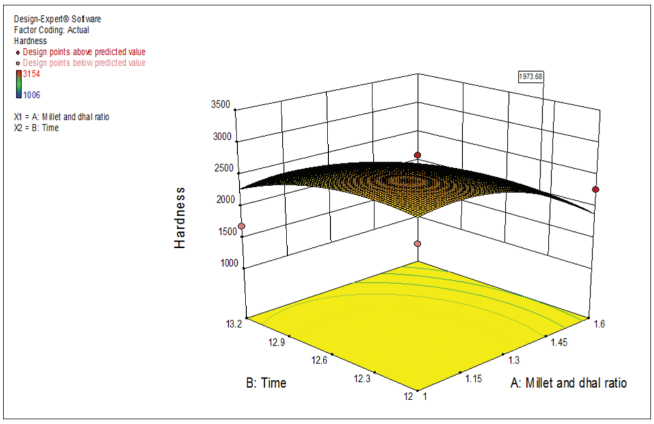


Fig. 7: Response surface plot of the effects of barnyard millet: Dhal (a) and fermentation time (b), on the hardness of idli

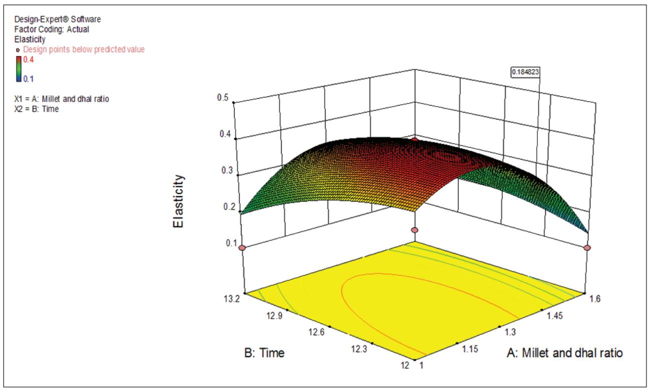
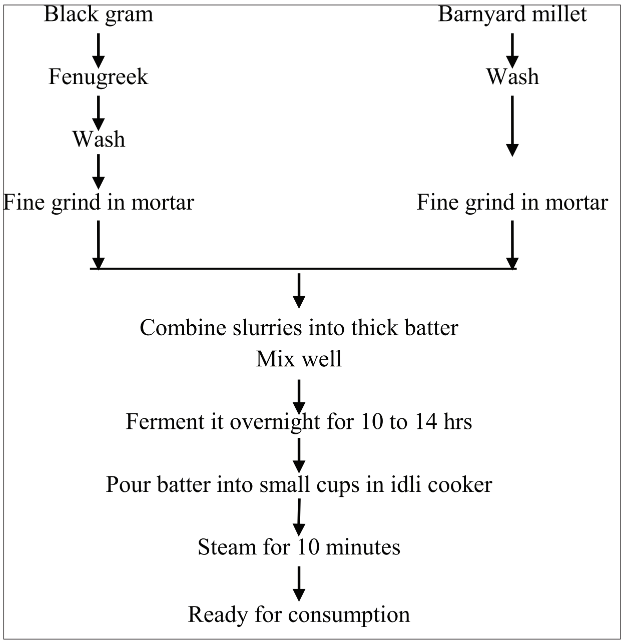


Fig. 8: Response surface plot of the effects of barnyard millet: Dhal (a) and fermentation time (b), on the elasticity of idli



Flow Chart 1: Idli preparation, Adapted from Steinkraus, 1983a [19]

Fig. 6d showed the overall acceptability of the developed idli showed maximum score of 7.51. The plots showed a raise in the overall scores to central value when the fermentation time increases and a gradual decrease was present due to the millet:dhal ratio.

Predicted optimization was performed for sensory attributes parameters such as appearance, color, flavor, texture, taste, overall quality, hardness, and texture by imposing desirability constraints. Table 12 shows the constraints imposed for idli with better sensory attributes with the desirable value for both independent and dependent variables. The maximum desirable score that can be achieved with the desirable value of appearance was 6.93, color 6.68, flavor 7.37, texture 8.19, taste 6.42, overall acceptability scores 7.51, hardness scores 1972.4 and elasticity scores 0.191. On the basis of these calculations good millet based idli could be made when the millet to black gram dhal ratio is 31.60 (w/w), fermented time for 12.43 hrs. The optimum results were validated by performing the experiment at the optimized ratio and fermentation time by comparing the observed and the predicted values. The observed and predicted values were not significantly different ($p>0.05$) which confirmed the optimization results and proved the predicted model to be correct.

CONCLUSION

RSM was successfully optimized the ingredient formulation and processing parameter of developed millet idli. The optimum results indicated that the optimum ratio millet: dhal was 3:1.60 with fermentation time −12.43 hrs. The optimum textural characteristics of the developed idli showed with hardness of 1972.4 and elasticity scores 0.191. In conclusion, the present studies showed that millet based idli developed by incorporating barnyard millets were acceptable, and they markedly reduce the glycemic responses. Similar kinds of result could be expected in rice based other foods after substituting with barnyard millets.

REFERENCES

1. Tamang JP. Role of microorganisms in traditional fermented foods. Indian Food Ind 1998;17:162-7.
2. Campbell-Platt G. Fermented foods - A world perspective. Food Res Int 1994;27(3):253-7.
3. Caplice E, Fitzgerald GF. Food fermentations: Role of microorganisms in food production and preservation. Int J Food Microbiol 1999;50(1-2):131-49.
4. Stanly JM, Shanmugam A. A study on millets based cultivation and consumption in India. Int J Mark Financ Serv Manage Res 2013;2(4):49-58.
5. Yang X, Wan Z, Perry L, Lu H, Wang Q, Hao C, *et al*. Early millet use in northern China. Proc Natl Acad Sci USA 2012;5(4):1-5.
6. Singh KP, Mishra A, Mishra HN. Fuzzy analysis of sensory attributes of bread prepared from millet-based composite flours. Food Sci Technol 2012;48(2):276-82.
7. Anderson JW, Hamilton CC, Horn JL, Spencer DB, Dillon DW, Zeigler JA. Metabolic effects of insoluble oat fibre in lean men with Type II diabetes. Cereal Chem 1991;68(5):291-4.
8. Pathak P, Srivastava S. Development and evaluation of food formulation based on foxtail millet for their suitability in diabetic diet. Proceedings of Nutritional Society of India: NIN; 1998. p. 59.
9. Hegde P, Rajasekaran N, Chandra T. Effect of the antioxidant properties of millet species on oxidative stress and glycemic status in alloxan-induced rats. Nutr Res 2004;25(12):1109-20.
10. Amini M, Younesi H, Bahramifar N, Lorestani AA, Ghorbani F, Daneshi A, *et al*. Application of response surface methodology for optimization of lead biosorption in an aqueous solution by *Aspergillus niger*. J Hazard Mater 2008;154(1-3):694-702.
11. Kalavathy MH, Regupathi I, Pillai MG, Miranda LR. Modelling, analysis and optimization of adsorption parameters for H3PO4 activated rubber wood sawdust using response surface methodology (RSM). Colloids Surf B 2009;70(1):35-45.
12. Kim HK, Kim JG, Cho JD, Hong JW. Optimization and characterization of UV-curable adhesives for optical communications by response surface methodology. Polym Test 2003;22:899-906.
13. Kundu S, Ghosh R, Choudhary P, Prakash A. Health benefits of various Indian culinary herbs and comparative statistical analysis for organoleptic properties of Indian teas by using analysis of variance (ANOVA). Int J Pharm Pharm Sci 2014;6(4):621-5.
14. Ghosh D, Chattopadhyay P. Application of principal component analysis (PCA) as a sensory assessment tool for fermented food products. J Food Sci Technol 2011. DOI: 10.1007/s13197-011-0280-9.
15. Mcfeeters RF. Effects of fermentation on the nutritional properties of food. In: Karmas E, Harris RS, editors. Nutritional Evaluation of Food Processing. 3rd ed. Ch. 16. New York: Van Nostrand Reinhold Company; 1988. p. 423-46.
16. Desikachar HS, Radhakrishnamurty R, Rao GR, Kadkol SB. Studies on idli natural fermentation: Part-1-some accompanying changes in the batter. J Sci Ind Res 1960;19C:168-72.
17. Radhakrishnamurty R, Desikachar HS, Srinivasan M, Subrahmanyan V. Studies on idli fermentation. II. Relative participation of black gram flour and rice semolina in the fermentation. J Sci Ind Res (C) 1961;20C:342-5.
18. Chauhan A, Tanwar B. Development of value added products (bun, muffin, noodles, and nuggets) by substitution with *Carissa spinarum* and *Ficus carica* powder. Asian J Pharm Clin Res 2016;9(1):130-6.
19. Steinkraus KH. Handbook of Indigenous Fermented Foods. New York, NY: Marcel Dekker; 1983a. p. 671.