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Some Studies on Formulation of Rice Based Functional Cookies for Celiacs

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Abstract: July 8, 2009July 8, 2009July 8, 2009Gluten is a protein found in all forms of wheat, rye, oats, barley and related grain hybrids. People with celiac disease when consume gluten, the absorptive villi in the small intestine are damaged and thus preventing the absorption of many important nutrients. The long-term effect of untreated celiac disease can be life threatening. Present investigation aims at development of cookies from gluten free composite flour. The effect of broken rice flour on cookies quality was studied. The compositional variations resulted in the 13 minutes baking as optimum time in a condition of 170±1°C as upper burner and 185±1°C as lower burner temperature. The textural and colour characteristics of optimized cookies resulted in the sensory acceptability as "extremely acceptable". The composite flour free from gluten may give a viable alternative to introduce a variety in cookies so as to increase the food choice range for the person suffering from celiac disease.

Key words: Gluten · Baking · Dough · Celiac disease · Cookies

INTRODUCTION

Gluten is a protein found in all forms of wheat, rye, oats, barley and related grain hybrids. Gluten is an essential structure-building protein used through white wheat flour in bakery products, which affect the appearance, mouth feel, colour and texture of final products. Among all bakery products, cookies are predominant, with vast combinations of texture and taste giving them a universal appeal. Cookies are considered as the lowest cost processed foods in the country, when compared to Indian sweet meats, salted snacks, wafers and savoury items. Apart from offering nutrition and taste, they can be packed in a variety of sizes.

Celiac disease (CD) is an immune-mediated enteropathy triggered by the ingestion of gluten-containing grains (including wheat, rye and barley) in genetically susceptible individuals. According to the revised criteria for the diagnosis of celiac disease, the European Society for Pediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN), the finding of an "initial characteristic small intestinal mucosal biopsy abnormality and response to gluten free diet (GFD) should be regarded as essential" [1]. The development of CD is a dynamic process whereby mucosal damage to the small intestine develops in three subsequent phases: (a) infiltrative phase, characterized solely by an increased number of intraepithelial lymphocytes (IELs); (b) hyperplastic phase, characterized by crypt hypertrophy; and (c) destructive phase, which is characterized by progressive villous atrophy (VA) ultimately leading to the flattening of the mucosa (Fig 1) [2,3]. Population-based screening studies have shown that celiac disease is very common and affects about one in 120 [4]. The long-term effect of untreated celiac disease can be life threatening. Strict avoidance of gluten in the diet is recommended to control the disease activity and early diagnosis in such patients may improve their overall prognosis [5].

In recent years there has been increasing interest on gluten-free bakery products. The application of gums to dough has been reported to give increased yields as well as give the dough a greater resilience with less flabby appearance. The baked products were also said to have a better texture as well as longer shelf life. A well mixed dough containing guar gum has excellent sheeting properties. Rolls and bread augmented with guar gum had a soft texture and improved shelf life [6]. In contrast to bread, in cookies the gluten network is restricted to

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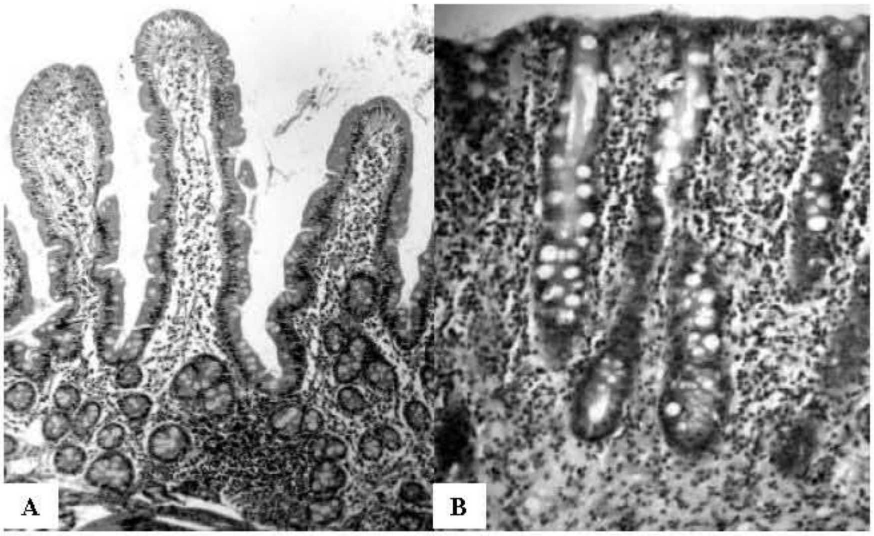

Fig. 1: Photomicrograph showing normal [A] duodenal mucosa and characteristic crypt hyper-plastic subtotal villous atrophy in celiac disease [B] (H&E X200)

develop for the dough to be cohesive without being too elastic [7]. Cohesive dough with low elasticity can also be formed from gluten-free composite flours. Therefore it was considered desirable to replace the wheat flour by broken rice and corn starch composite flour to develop low cost functional gluten free cookies.

MATERIALS AND METHODS

Present study was carried out using broken rice (*Oryza sativa*) genotype PR-106 grins, Corn starch, Guar gum, Skim milk Powder, shortening, sugar, liquid glucose, salt, baking powder and flavour were procured from local market. Analytical grade chemicals and reagents from BDH, Qualigens, Ranbaxy and Emerck were used in the present investigation.

Broken rice grains were cleaned manually to remove whole seeds, dust particles and other impurities if any. The cleaned broken rice was stored under refrigerated condition (4±2°C) in a closed container prior to their use in the actual experiment. Cleaned broken rice grains were tempered at 14 % moisture (wet basis). Tempered broken rice grains were milled in dry grinder. The flour sample thus obtained was sieve through standard mesh Size sieve (100µ) and the obtained sieved flour was stored in an airtight container under refrigerated condition (4 ± 2°C) prior to their use (Fig. 2).

Starch was isolated from broken rice grains following modified method described [8,9]. Cleaned broken rice grains were steeped in distilled water (1:2, w/v) for 12 hours. The steeped grains were washed thoroughly with

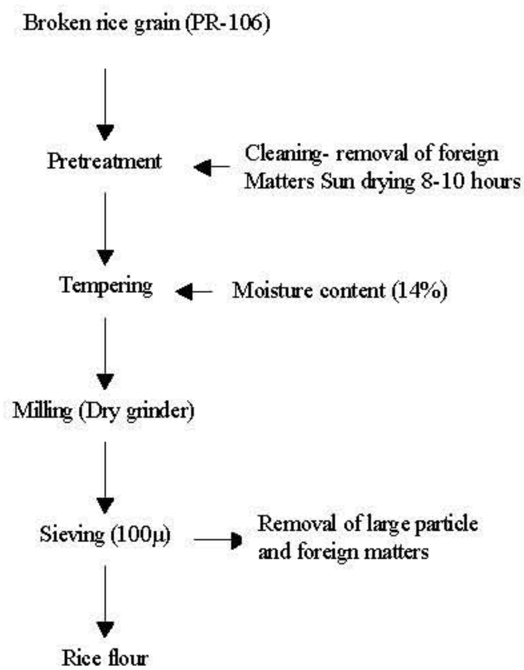

Fig. 2: Flow diagram for the preparation of rice flour

distilled water and then subjected to ground in a wet grinder to make slurry. The resultant slurry thus obtained was filtered through muslin cloth followed by sieving through standard mesh sieve (100µ). Then, supernatant was mixed well using shaker for 5 minute with eight times volume of distilled water and kept under refrigerated condition (4 ± 2°C) for 8 hour. After that, the water containing water-soluble protein was removed by

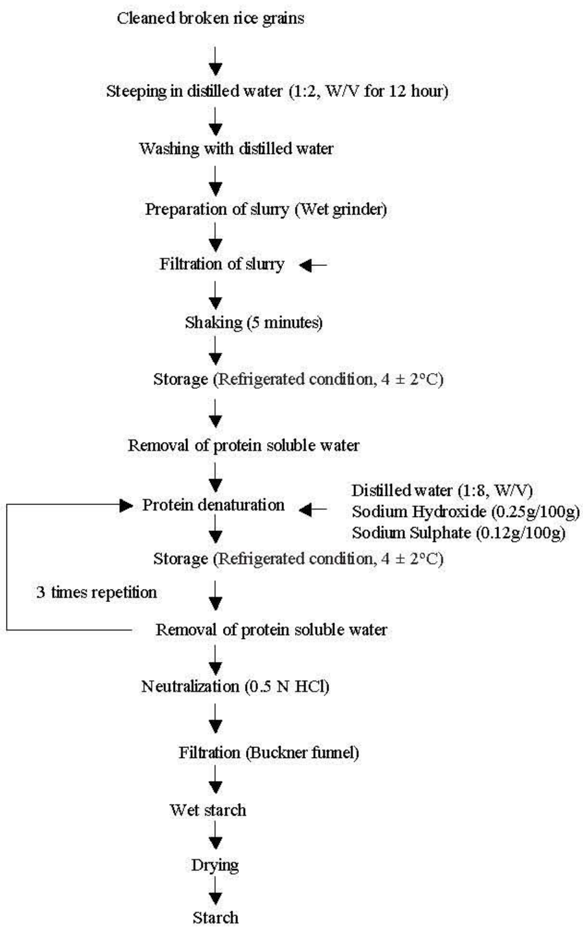

Fig. 3: Flow diagram for isolation and purification of starch from broken rice grains

decanting the supernatant carefully. The starch paste prepared by mixing residue with the remaining water was then mixed with eight times volume of sodium hydroxide solution (0.25g/100g) containing sodium sulphate (0.12g/100g) and kept under refrigerated condition (4 ± 2°C) for 8 h. The supernatant was decanted off after the completion of soaking time. The isolation step was repeated three times. Then, the paste was neutralized with 0.5 (N) HCl. The starch solution thus obtained was filtered through Buckner funnel under vacuum to remove the washed water during each step of washing. The filtered cake (starch) was dried at 50°C to less than 12 % moisture content, ground, passed through 100μ sieve and stored in zip-type plastic bag (Fig. 3)

The process of cookie preparation either from white wheat flour or rice flour is presented in Fig. 4. The compositional variations in the preparation of cookies (Table 1) were adopted. The production process consisted of dough mixing, dough sheeting, dough-

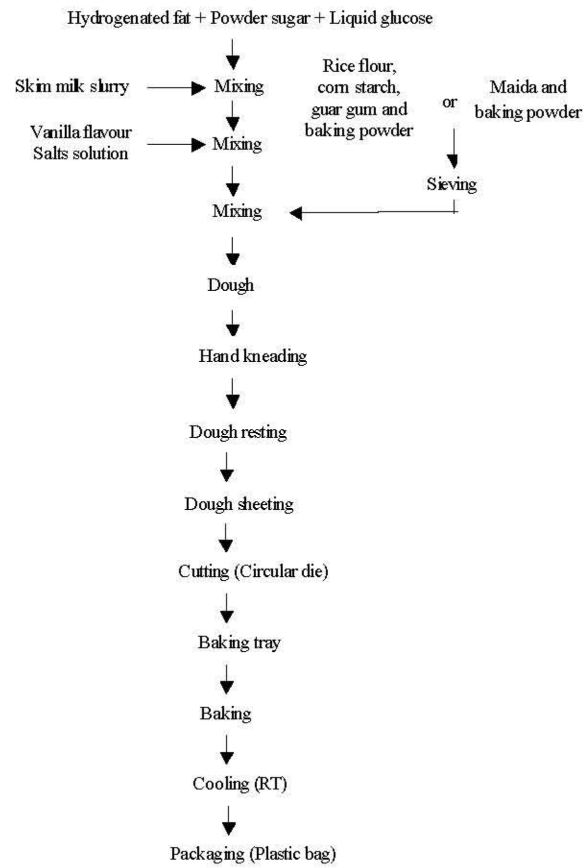

Fig. 4: Flow diagram for preparation cookies

Table 1: Central composite rotatable design for preparation of cookies

	Coded values		Un-coded values	
	Corn starch	Rice flour	Corn starch	Rice flour
Exp. No.	---	---	(gm)	(gm)
1	-1	-1	7.32	157.32
2	1	-1	42.68	157.32
3	-1	1	7.32	192.68
4	1	1	42.68	192.68
5	-1.414	0	0	175
6	1.414	0	50	175
7	0	-1.414	25	150
8	0	1.414	25	200
9	0	0	25	175
10	0	0	25	175
11	0	0	25	175
12	0	0	25	175
13	0	0	25	175

relaxation, baking and cooling. Initially the shortening was liquefied in the microwave (Samsung Microwave oven, Model M197DN-5) for sufficient time (35-45 s). Sodium bicarbonate, ammonium chloride, common salt and skim milk powder were dissolved in a portion of dough water. Rice flour, corn starch, guar gum and baking powder were sieved (100μ) for proper aeration and thoroughly mixing in 2 to 3 times. Liquefied hydrogenated fat, liquid glucose and sugar were mixed in the mixer (Continental India, Kitchen Aid, St. Joseph, Michigan, USA) thoroughly for 90 s at number three speed initially, then at number 5 speed for 150 s to get homogeneous mass of hydrogenated fat, powdered sugar and liquid glucose. Further skim milk was added and mixed for 120 s at number four speed. Then added salt solution and mixed at same speed for 40 s. Final creaming for 300 s was performed after adding ammonium chloride, sodium bicarbonate and vanilla flavour at number five speed. Rice flour, corn starch, guar gum and baking powder or maida and baking powder were mixed for 100-150 s at same speed. Every minute the dough was scraped from the sides of the bowl to avoid an unequal distribution of one of the ingredients. The final cookie dough was then removed from the bowl and kneaded by hand for 3 min. After 20 min relaxation time the dough was sheeted to a thickness of 0.5 cm. The sheet was then allowed to relax for another 15 min. The dough pieces were cut out with a cutting circular die of 5.5 cm diameter and weighed. They were then placed on a tray and baked for 11 to 15 minute in the oven (Continental India, Medium type electric baking oven.) of preset temperature 170±5°C as upper burner and 185±5°C as lower burner. The baked cookies were allowed to air cool for 15 minutes under dehumidified atmosphere at room temperature and placed in air tight container under refrigerated condition till analysed for physical, chemical and sensory characteristics.

A physical property of cookies was determined for diameter (width), thickness, spread factor, bulk density and moisture loss during baking. Proximate analysis was carried out for the moisture, protein, fat and ash content [10]. The carbohydrate content was determined using Phenol-H_2SO_4 method suggested [11] and modified [12]. Starch content was estimated by anthrone reagent method. Aqueous washing technique was used to determine the gluten content of prepared dough of refined wheat flour.

Three-point bend test or snap test of cookies was performed by using Texture Analyzer (TA-XT2i), Stable Microsystems, Surrey, U.K. using three point bend ring-HDP/3PB support setup (Fig. 5).

The cookies were placed centrally on 2-side-blade-support placed 30mm apart. The upper blade test speed was 0.5 mm/s. maximum force for break the cookie and

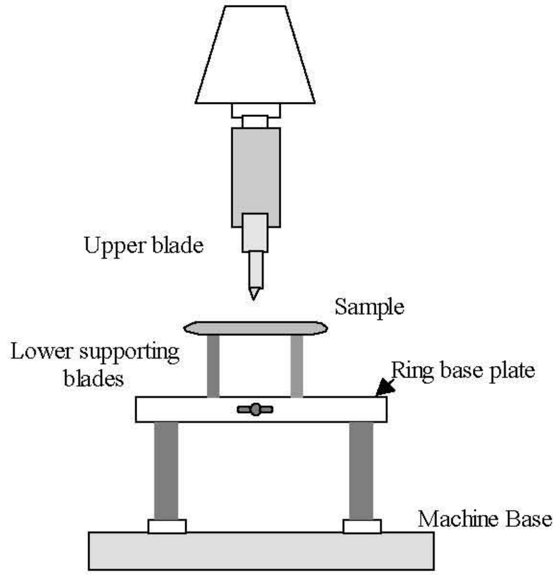

Fig. 5: Support Setup, 3-Point Bending Ring HDP/3P for measuring resistance of cookies to Bend

number of fracture before final break was measured in a test run using the data acquisition (200 pps) system and analyzed using Texture expert v 1.22 software of Stable Microsystems, Surrey, U.K. Following conditions were maintained for acquisition of texture data.

Mode: Measure force in compression
Option: Return to start
Pre-test Speed: 2.0 mm/sec.
Test Speed: 0.5 mm/sec.
Post Test Speed: 10.0mm/sec.
Rupture Test Distance: N/A
Distance: 5.0mm
Time: 3.00s
Set Height: 0.00mm
Trigger Type: Auto
Trigger Force: 0.20N
Data Acquisition Rate: 200.00 pps
Probe: Three point bend ring (HDP/3PB)

The color characteristics of cookies were assessed using a Colour Spectrophotometer (Gretag Machbeth, Model No. i5, USA) to determine L value (light-dark), a value (red-green) and b value (yellow-blue), which is shown by Hunter Lab colour space (Fig. 6). The colorimeter was calibrated with white standard L, a and b measurements were evaluated from triplicate samples and the values were averaged. Colour was also evaluated as the total colour difference (ΔE) (Eqn 3).

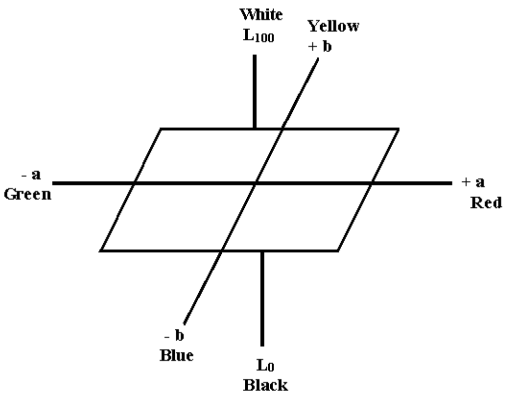

Fig. 6: Hunter Lab colour space

$$\triangle E = \sqrt{(L_o - L)^2 + (a_o - a)^2 + (b_o - b)^2} \quad (3)$$

Where, L_o, a_o and b_o represented the reading at time zero and L, a and b represented the instantaneous individual reading during baking.

The sensory quality and overall acceptability of the cookies were carried out on a 9 points hedonic rating scale, where, 9-like extremely, 8-like very much, 7-like moderately, 6-like slightly, 5-neither like nor dislike, 4-dislike slightly, 3-dislike moderately, 2-dislike very much and 1-dislike extremely. A panel of 30 semi-trained panelists was formed from the department of Food Engineering and Technology of the institute. Panelists evaluated the samples for colour, flavour, texture, appearance and overall acceptability.

A central composite rotatable design (CCRD) was used to evaluate the combined effect of rice flour and corn starch on various parameters for the preparation of cookies. The design matrix (Table 1) is a 2^2 factorial design combined with 5 central points and 4 axial points, where one variable is set at an extreme level (±1.414) while other variables are set at their central points [13].

Response surface methodology (RSM) is commonly an employed tool in analyzing experimental data resulting in the optimization of processes or products. It is used for designing the experiments [14] or may be defined as an empirical statistical modeling technique employed for multiple regression analysis using quantitative data obtained from properly designed experiments to solve multivariate equations simultaneously. A mathematical function was assumed for describing the relationship between each of the response variables, Y_i and the factors X_i, such as

$$Y_i = f(X_1, X_2, X_3, \ldots\ldots)$$

The exact mathematical representation of the function (f) is either unknown or extremely complex. However, a second order polynomial equation of the following form was assumed to relate Y_{kij} and X_i.

$$Y_{kij} = \beta_{ko} + \sum_{i=1}^{4} \beta_{ki} X_i + \sum_{i=1}^{4} \beta_{kii} X_i^2 + \sum_{i=1}^{3} \sum_{j=i+1}^{4} \beta_{kij} X_i X_j + \varepsilon_{kij} \quad (4)$$

Where, β_{k0}, β_{ki}, β_{kii}, β_{kij} are regression coefficients and ε_{kij} is pure error. X's are the coded independent variables linearly related to real variables. Standard version of SYSTAT (version 8.0) of SPSS Inc. was used to fit the second order polynomial equation to the experimental data. Non-linear regression equation relating the coded values of the factors with that of the response variable were developed. Despite the fact that in general full model appears to reasonably represent the data, better fit can be obtained with reduced model.

The adequacy of the derived model was evaluated using F-value and correlation coefficient (R) which was represented at 1 %, 5 % and 10 % level of significance as per the results of analysis of variance (ANOVA). The response contour plot was drawn using the software package (Surfer 6.04, Golden Software Inc. and U.S.A).

To study the effect of rice flour and corn starch on the dough rheology and prepared cookies moisture kinetics, textural, colour, physico-chemical and sensory properties of cookies, 13 experiments were conducted as per central composite rotatable design (Table 1). The independent variables affecting the quality of the product were the varied levels of corn starch (X_1) and rice flour ratio (X_2). All the experiments were carried at least twice.

RESULTS AND DISCUSSION

The chemical analysis was carried out for white wheat flour (*maida*) and rice flour of PR-106 genotype, which revealed that the moisture 13.02 ± 0.04 % and 12.87 ± 0.09 %, protein 10.65 ± 0.02% and 7.27 ± 0.02%, fat 0.99 ± 0.01 % and 0.85 ± 0.04 %, carbohydrate 74.59 ± 0.04 % and 77.95 ± 0.08 %, ash 0.75 ± 0.03 % and 1.37 ± 0.01 %, respectively. Gluten content resulted in 8.98 ± 0.04 % in white wheat flour. The starch content resulted in 73.97 ± 0.05 % for white wheat flour and 77.51 ± 0.04 % for broken rice flour.

The objective colour values for plain and rice cookies were evaluated using Hunter Colour lab for L, a, b values during entire baking up to 15 minutes (Fig 7 and 8). The lightness (L value) decreased from

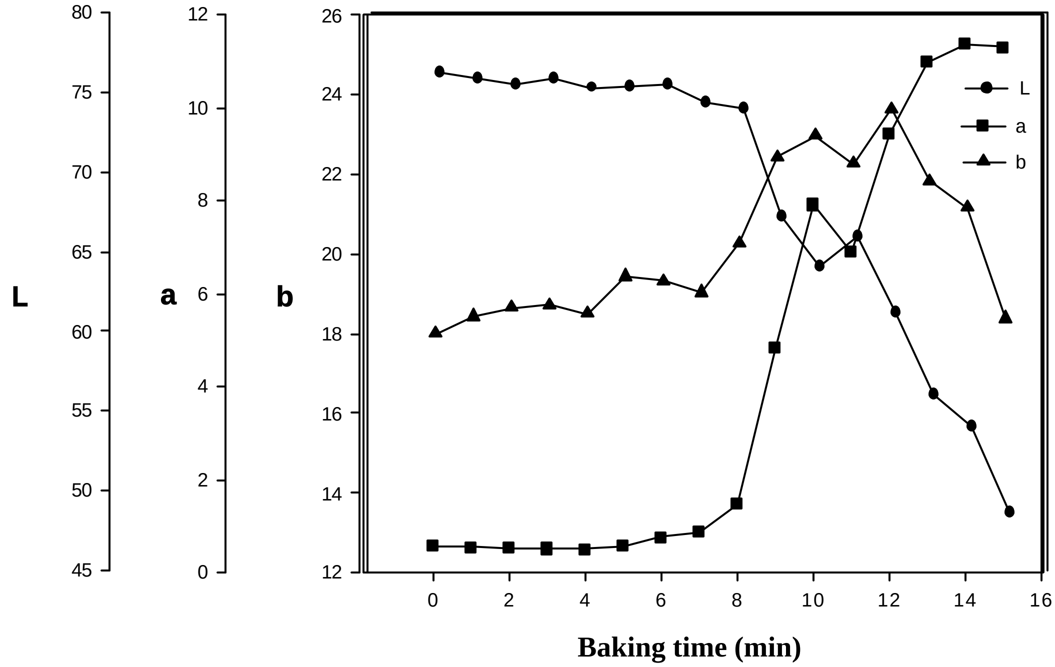

Fig. 7: Effect of baking time on colour characteristics of plain cookies

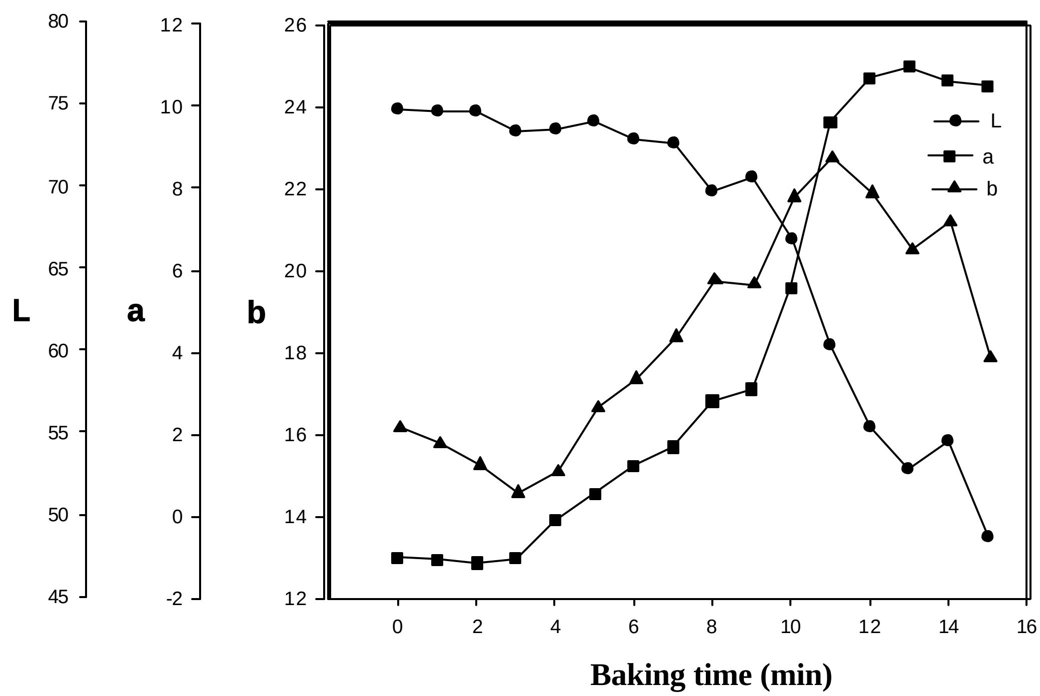

Fig. 8: Effect of baking time on colour characteristics of gluten free cookies

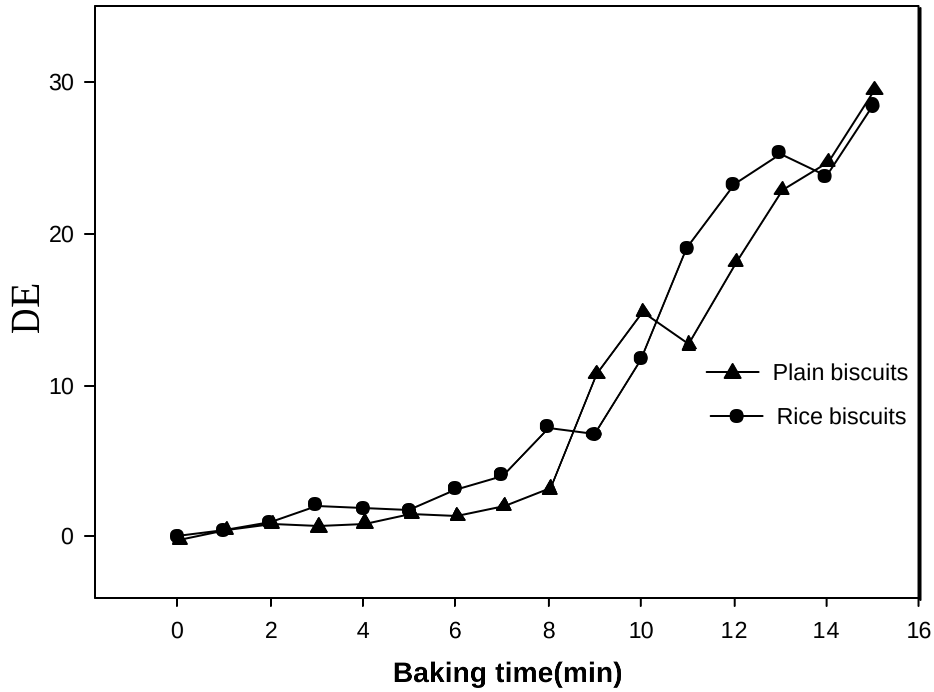

Fig. 9: Effect of baking time on ?E colour characteristics of cookies

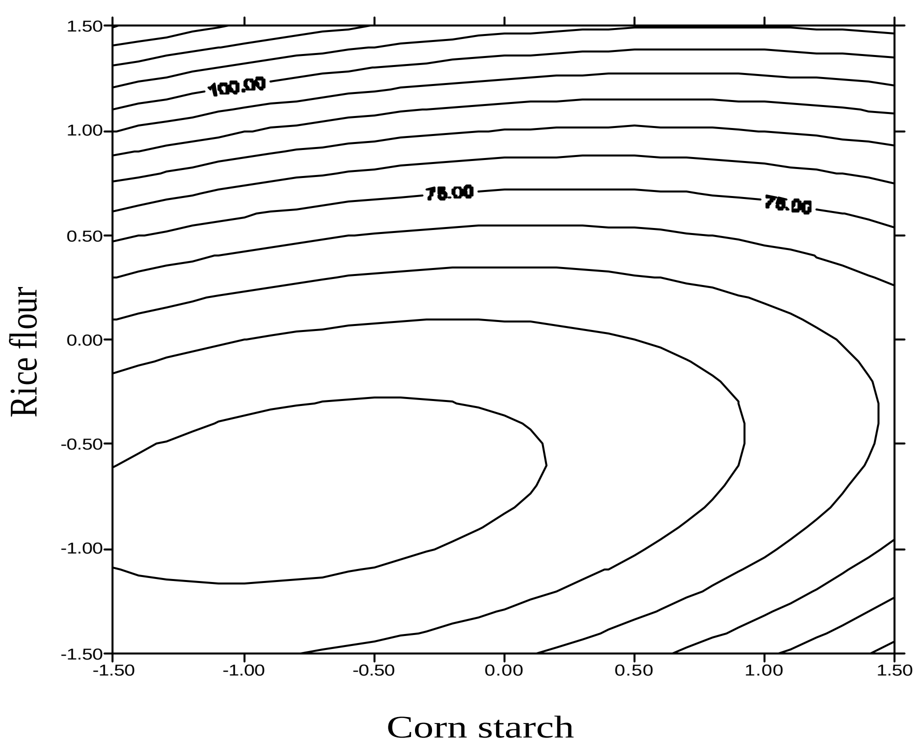

Fig. 10: Contour plot for cookies hardness baked at 13 minute as a function of corn starch and rice flour

76.21 to 48.57 and 74.61 to 48.65 in plain cookies and rice cookies, respectively during baking. Change in the 'a value' was found increasing in cookies from 0.51 to 11.37 and 1.13 to 10.49 for plain and rice cookies, respectively, which is evident from Fig 6 and 7. The 'b value', which is an indication of change in the yellowness increased from 18.00 to 23.64 during initial baking up to 12 minutes and further decreased to 18.39 for plain cookies. The similar trend was observed for rice cookies where the b value increased from 16.17 to 21.89 till 12 minutes baking and further decreases to 17.87 (Fig 8). The total colour difference (ΔE) value increased from 0.00 to 29.66 and 28.44 for the plain and rice cookies, respectively (Fig 9), which revealed that there is no significant ($P \leq 0.05$) difference at 13 minutes and 14 minutes baking time. Thus, on the basis of baking state cookies were classified as unbaked (0-9 minutes), partially baked (10-11minutes), baked (12-14 minutes) and over baked (15 minutes).

The hardness of the baked cookies at 12, 13 and 14 min baking time ranged from 36.03 to 74.53 N, 47.05 to 106.03 N and 51.1 to 80.3 N, respectively. The variation in hardness of baked cookies is due to the variation in moisture losses of the cookies during baking at different time and compositional experimental variations.

The hardness data were fitted to full second order polynomial model to developed the hardness of cookies eqn 5 for 13 minutes baking

$$HAR_{13} = 58.58 + 1.38\,C + 14.30\,R - 3.99\,CR + 2.85\,C^2 + 11.95\,R^2 \quad (5)$$

The hardness models, F value found significant ($P \leq 0.001$) with R^2 of 91.71% and ($P \leq 0.001$), Therefore, the developed hardness model could very well be used to predict the cookies hardness values directly or using the contour plot (Fig. 10).

The lightness (L values) of the compositional variable prepared cookie samples range from 52.02 to 68.75, 50.86 to 67.25 and 50.67 to 65.95 for 12 to 14 min baking time, respectively. The a values of the compositional variable prepared cookie samples range from 12 to 14 min baking time were found between 5.24 to 10.90 for 12 min, 5.78 to 11.47 for 13 min and 7.01 to 11.44 for 14 min. The b values of prepared cookies range from 12 to 14 min baking time were found between 17.06 to 20.70, 16.21 to 20.23 and 15.83 to 20.08, respectively.

The ΔE values of the compositional variable prepared cookie samples range from 12 to 14 min baking time were found between 9.3 to 25.5, 10.7 to 26.5 and 12.3 to 26.6. The variation in the percentage of sugar and SMP content has affected the colour of the samples.

The spread ratio of the prepared cookies was in the range of 5.10 ± 0.040 to 6.25 ± 0.005. Cookies containing the non-emulsified hydrogenated fat had the least spread also found [15]. The Bulk volume of the prepared cookies was in the range of 15.44 ± 0.044 to 17.01 ± 0.224 ml. The weight of cookie per piece of prepared cookies was in the range of 10.65 ± 0.022 to 10.95 ± 0.019 gm. The moisture content for the baked cookies at 12, 13 and 14 minutes baking time ranged from 4.75 ± 0.17 % to 6.61 ± 0.10 %, 3.77 ± 0.99 % to 5.64 ± 0.14 % and 3.37 ± 0.01 % to 5.25 ± 0.15 %, respectively.

The sensory overall acceptability of the prepared cookies ranged from 7.37 ± 1.88 to 8.31 ± 0.47. The highest value was observed for the cookies prepared at experiment no 13 using corn starch (25 gm) and rice flour (175 gm), while lowest value was found for the cookies prepared from maximum corn starch (50 gm) and rice flour (175 gm) at experiment no 6.

The textural profile in some cookie samples hardness for 12 min baking time was resulted in hyperbolic nature of peak, which revealed that the presence of free moisture. In case of 13 and 14 min baking time the hardness is found to be adequate due to typical cookies texture profile. The colour of prepared cookies at 14 min baking time were found less lightness as compared to 13 min baking time due to more caramalization of sugar at this temperature. Thus, the cookies baking as 13 min were considered for further optimization. Statease (version 6.0) was used to minimize the hardness of cookies. The numerical value of optimized cookie was 52.97 N with the composition of 11.97 gm and 162.27 gm for corn starch and rice flour, respectively.

The coded values of-0.739 for corn starch and-0.723 for rice flour was used to prepare the optimized cookies. Experimental evaluation showed that optimized cookies hardness was 53.52 N as compared to 52.97 N as theoretical value.

The objective colour values (L, a, b and ΔE) were found to be 57.47, 10.25, 19.27 and 20.74, respectively. The physical properties of optimized prepared cookies were found to be 5.09 ± 0.016 cm, 0.83 ± 0.009 cm, 6.13 ± 0.047, 16.09 ± 0.039 ml, 10.85 ± 0.021 gm and 0.67 ± 0.008 gm/ml for diameter, thickness, spread ratio, bulk volume, weight of biscuit per piece and bulk density, respectively. The chemical properties of optimized prepared cookies were found to be 3.82 %, 5.16 %, 24.01 %, 65.95 % and 1.061 % for moisture, protein, fat, carbohydrate and ash, respectively.

The sensory properties of optimized prepared cookies were found to be 8.56 ± 0.73 for colour, 8.07 ± 0.69 for texture, 8.51± 0.077 for flavour, 8.13 ± 0.26 for mouthfeel, 8.49 ± 0.65 for appearance and 8.19 ± 0.23 for overall acceptability (OAA).

CONCLUSION

The baking time temperature combination of 12 to 14 minutes was found suitable for gluten free rice cookies under the condition of 170 ± 5° C upper and 185 ± 5°C as lower burner temperature to provide the similar objective colour (L, a, b and ΔE) characteristics of plain cookies. The compositional optimization of variables (rice flour and corn starch) were obtained using steepest accent method applied on data of central composite rotatable design based experimentations and thus obtained the optimized composition as 162.27 gm rice flour and 11.97 gm corn starch. The optimized cookies when subjected for sensory evaluation results in more than 8 sensory overall acceptability (OAA) score on hedonic rating represented the developed gluten free cookies as "very acceptable". The gluten free cookies and other food products will certainly improve the quality of life of celiac disease patients and help them in compliance for gluten free diet.

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