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Optimization of Process Variables and Formulation Parameters for Maize Flour-Based Flatbread Utilizing Response Surface Methodology

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Flat breads, commonly known as '*chapati*' or '*roti*' are the most consumed bread in India especially in north India. In rural north India, especially in Punjab '*Sarsoka sag and Makki di roti*' is the signature dish during winter season. Maize flour based flatbreads are generally prepared by hand; this process is laborious, time consuming and requires expertise. The present investigation was planned to standardize the process parameters and formulations for mechanized preparation of maize flour based flatbread using response surface methodology. The central composite rotatable design (CCRD) was used with independent variables i.e. resting time of dough (0–20 min), blending ratio of supplement flour (20–40%) and temperature of water (18–36°C). The results of the study revealed that the process parameters had a significant effect ($p<0.05$) on moisture content, browning index, peroxide value, free fatty acid, cutting force, colour change and overall acceptability of flatbread. The models obtained had a high coefficient of determination ($R^2 \geq 0.99$) and were quite significant. The optimum process conditions obtained by numerical optimization technique for maize flour based flatbread blended with gram flour were; dough resting time 12.45 min, blending ratio 38.90% and temperature of water 31.47°C; likewise maize flour based flatbread blended with wheat flour were obtained as dough resting time 20 min, blending ratio 20% and temperature of water 29.68°C. The present investigation showed that addition of wheat and gram flour in flour mix helped in preparation of quality flatbread and meets the nutritional requirements of developed product.

Keywords: Flatbread, Gram flour, Maize flour, Response surface methodology, Wheat flour

Introduction

Maize is an eloquent source of food for a large segment of the world's population and serves as a mechanism for vitamin and mineral insufficiency intervention. There are diverse industrial procedures which bring ample changes in maize products to satisfy desire and usage of the consumer. Reduced product stability, mainly due to fat content, results in the need for persistent processing of maize at the household or at small-scale industry level.[1–3] The maize flour is baked into roti or chapati. Chapatti is a staple baked food in many households, offering a nutritious and wholesome combination, especially when made with maize.[4] Excellent dough with good elastic properties can be made from maize flour of dehulled grains. Maize is also processed into semolina (sooji) and it also serves as the replacement of wheat semolina in various food preparations. The grain may be dried up, ground to flour and cooked into porridge. It can also be consumed in roasted form or in boiled form on the cob itself.

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Maize flour is often used in pharmaceutical and food preparations throughout the world. Since ancient times, maize has been regarded as a remedy for various health issues, including emaciation, eating disorders, and haemorrhoids.[5] It is utilised either in its pure form or in combinations with other grain flours including groundnut and soybean.[5] Functional properties play a big role in its industrial and food applications. The intrinsic physicochemical qualities of flour that show the structural and textural behaviour of food products include water absorption, oil absorption, gelation, foaming, and emulsifying capacities. The research into the functional qualities of flours provides enhanced information for their usage in medicinal and food product formulations. Any alteration in these qualities during processing, transportation, or storage may have a major impact on the nutritional and dietary value of the food materials. To improve the functional characterization of food materials, the elements that affect their functional qualities during storage and processing should be improved.

Flat breads are the world's oldest and most well-known bread kinds. Flat breads are consumed by almost 1.8 billion people in India, Central America, Scandinavia, South Europe, South Africa, the Middle East, and areas of China.[6] The majority of people on the Indian subcontinent eat unleavened flat bread, also known as chapati.[7,8] It is created by combining flour and water to form dough, which is then relaxed and sheeted to a consistent thickness of roughly 2 mm before being baked for a short period. It is frequently eaten as fresh.[9] Maize flour commonly known as '*Atta*' in Indian subcontinent is a product obtained by grinding. Generally whole maize flour is used to make '*chapati*', an Indian flatbread. Whole grain flours are prepared by a variety of techniques and with different particle sizes. About one third of maize production is consumed in the form of flat breads, which are mostly consumed in India's northern states.[10] In Punjab, maize chapati with 'SarsonkaSaag' is a famous and frequently consumed dish.[11] Maize flat breads are generally prepared with hands. This process is highly time consuming and requires a lot of practical expertise because of the lesser gluten content and binding characteristics. The use of mixed flours to make flatbreads is one such unique approach.[12–15] Thus to increase the gluten content and the binding capacity, maize flatbreads are blended with gram flour and wheat flour. There is no study till date done on supplementation of maize flour. There has been no research done on maize flour supplementation with wheat and gram flour for the development of flatbread till date. Furthermore, there is a scarcity of knowledge on the development of maize flatbread using mechanized system. Therefore the combination of maize flour with gram and wheat flour would provide a better overall nutrition value of the flatbread and improves binding capacity in the developed product. The current study was carried out with these facts in mind in order to optimise the process parameters i.e. resting time of dough, temperature of water and blending ratio of gram and wheat flour for preparation of maize flour based flatbread.

Materials and Methods

Procurement of Basic Ingredients and Flour Preparation

Punjab Agriculture University Farm in Ludhiana, India, provided the whole maize kernels (cv. PMH–1). A burr mill was used to grind the cleaned and graded entire maize kernels into flour. With the use of a rotary sieve shaker, ground maize flour was sieved into fine flour (355 μm) and very fine flour (180 μm) and blended with wheat and gram flour in various proportions.

Preparation of Flatbread

Dough was prepared using a dough maker with varying water temperatures for different flour blends. Maize flour alone was excluded due to lack of gluten. Twenty five gram dough balls were shaped into chapatis using a roti maker. Cooked flatbreads were cooled at room temperature after baking under optimized conditions.

Experimental Design and Data Analysis

The response surface methodology (RSM) was performed using commercial statistical package Design Expert 10 DX7.0 (Trial version) to identify optimum levels of three independent variables viz., resting time of dough (0–20 min), flour blend ratio (20–40%), and temperature of water used for dough kneading (18–36°C) as shown in Table 1. The depended variables were moisture content, Browning Index, Peroxide value, free fatty acid, colour change, cutting force and overall acceptability. The experiments were designed according to factorial, 3-level-3 factor rotatable design as presented in Table 2. The adequacy of the fitted model was tested through the analysis of variance. For each response, polynomial quadratic (second order) equations were created, and statistical significance was determined using ANOVA.

Table 1 —Variables and their levels for flatbread preparation

Independent variables	Coded	Levels		
		−1	0	+1
Resting time of dough (min)	A	0	10	20
Blending ratio of flour (%)	B	20	30	40
Temperature of water used for dough kneading (°C)	C	18	27	36

Table 2 — Experimental Design for flatbread preparation

Runs	Resting time of dough (min)	Blending ratio of flour (%)	Temperature of water (°C)
1	0	20	27
2	0	30	18
3	10	30	27
4	10	20	18
5	20	20	27
6	20	30	18
7	0	30	36
8	10	20	36
9	10	40	36
10	20	40	27
11	10	30	27
12	20	30	36
13	0	40	27
14	10	40	18
15	10	30	27
16	10	30	27
17	10	30	27

Quality Evaluation of Flatbread

Different quality parameters of flatbread like moisture content, colour, browning index, free fatty acid, peroxide value and the texture profile were determined. Standard AOAC[16] method was used to determine the moisture content of maize flour sample. The Color Reader (Miniscan XE Plus) was used to determine the colour attributes of the samples. The change in colour was calculated from 'L', 'a' and 'b' readings (model: Konika Minolta 1994). Browning intensity was measured by shaking a 5g maize flatbread sample with 100 ml 70% ethanol for 2 hr, filtering and measuring optical density at 420 nm with the help of a spectrophotometer.[17] The peroxide value and free fatty acids were determined as per method described by AOCS.[18] Cutting force of flatbread was evaluated by using the texture analyzer (Model: Instron, TA-XT2). Organoleptic characteristics were determined through evaluation of overall acceptability by a semi trained panellist on a 9 point hedonic scale.[19]

Results and Discussion

Effects of Process Parameters on Quality of Flatbread

Moisture Content

Moisture content affects flatbread quality, impacting freshness and stability. For gram flour blends, the highest moisture (49.68%) was at 40% blend, 18°C water, 10 min rest; the lowest (40.24%) at 40% blend, 27°C, 20 min rest. For wheat flour blends, maximum moisture (54.08%) occurred at 40% blend, 27°C, 20 min rest; minimum (51.09%) at 20% blend, 36°C, 10 min rest (Fig. 1). The regression Eqs (1) and (2) for moisture content of maize flour based flatbread with blending of gram and wheat flour respectively showed the negative effect of resting time (A) and water temperature (C) i.e. increment in water temperature leads to decrease in moisture content of flatbread. Same finding was also reported by shah *et al.*[20] This could be due to moisture evaporating through dough during cooking.[21] At the high heating rate, bubble expansion was faster. Whereas blending of gram and wheat (B) showed the positive effect on moisture content of bread.

In maize flour-based dough, which lacks sufficient gluten-forming proteins, resting allows starches and proteins to hydrate, improving moisture retention and creating a more uniform texture. When maize is blended with gram and wheat flours, resting further boosts water absorption due to wheat gluten and gram proteins.[22] The temperature of water used during dough preparation also plays a crucial role. Warm water (30–40°C) speeds up starch gelatinization and enhances moisture absorption, though excessively hot water may degrade starches, causing uneven consistency and reduced moisture after baking.[23] For

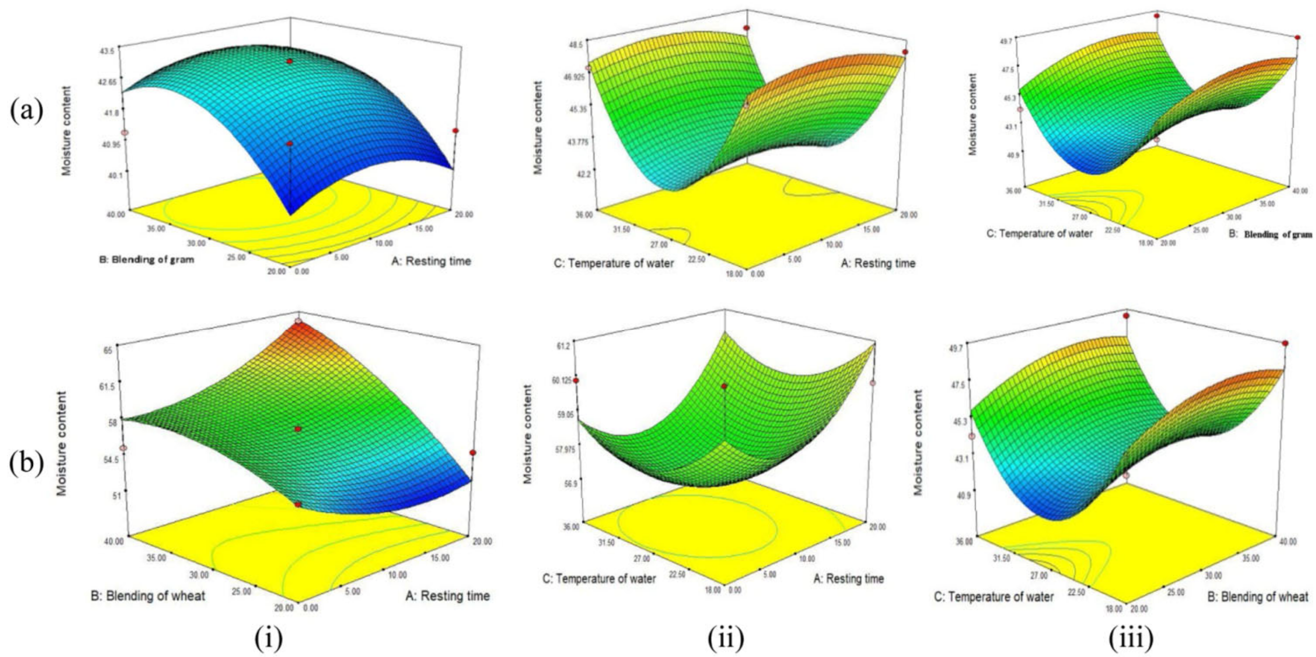

Fig. 1 — The 3D response surfaces of moisture content showing the effect of (i) blending ratio and resting time (ii) temperature and resting time (iii) temperature and blending ratio for: (a) gram flour subsitute flatbread, (b) wheat flour subsitute flatbread

dough containing maize and wheat flours, using warm water helps achieve a smooth, moist texture.[24] Research indicates that a resting period of 20 to 30 minutes is ideal for such blends, giving enough time for proper hydration without significant evaporation.[25] This rest period ensures improved dough structure and better performance during baking.

$$(Moisture\ content)_{gram} = 43.10 - 0.11A + 0.97B - 0.23C - 0.020AB - 0.048AC + 0.12BC - 0.74A^2 - 1.18B^2 + 5.15C^2 \quad \ldots (1)$$

$$(Moisture\ content)_{Wheat} = 57.07 - 0.79A + 3.81B - 0.38C + 2.33AB + 0.048AC + 0.20BC + 1.71A^2 - 1.47B^2 + 1.23C^2 \quad \ldots (2)$$

Browning Index

Measuring browning index is vital, as discoloration affects flatbread's appearance, taste, and nutrition. For gram flour blends, the highest browning index (0.089) occurred at 20% blend, 36°C water, 10 min rest; the lowest (0.029) at 30%, 18°C, 0 min rest. For wheat blends, maximum (0.096) was at 20%, 36°C, 10 min rest; minimum (0.053) at 40%, 18°C, 10 min rest (Fig. 2).

Regression Eqs (3) and (4) show the effect of process parameters on browning index of flatbread. The water temperature and resting time of dough had the positive effect, but the blend ratio had the negative effect on browning index. The browning index of maize-based flatbread blended with gram flour is influenced by several factors, including water temperature, resting time, and the proportion of gram flour. The water temperature had positive effect on browning Index of flatbread. Warmer water temperatures (30-40°C) accelerate starch gelatinization and enhance protein hydration, promoting more efficient Maillard reactions and resulting in a higher browning index.[23] Resting the dough allows for more even hydration, improving the availability of amino acids from gram flour proteins, which further supports the Maillard reaction during baking. Resting time of dough had positive effect on browning Index of flatbread. Longer resting times lead to better dough consistency and more pronounced browning, whereas shorter resting times can reduce the effectiveness of browning due to insufficient hydration.[22] The inclusion of gram flour, rich in proteins, increases the potential for browning, as the amino acids in gram flour react with sugars from maize flour, enhancing the overall color and flavor of the flatbread.[25] Optimizing these factors, such as using warm water and resting the dough for 20–30 minutes, leads to a flatbread with an optimal browning index and better sensory quality.[24,26]

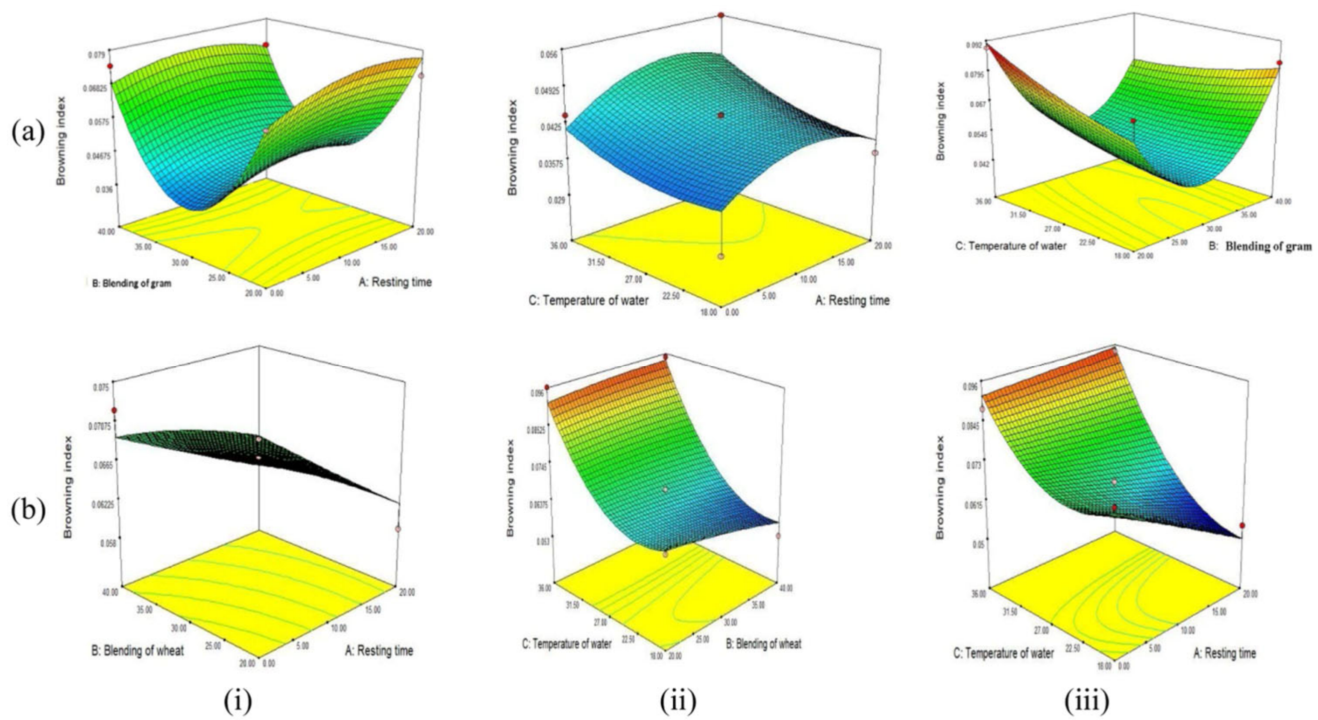

Fig. 2 ––The 3D response surfaces of browning index showing the effect of (i) blending ratio and resting time (ii) temperature and resting time (iii) temperature and blending ratio for (a) gram flour subsitute flatbread (b) wheat flour subsitute flatbread

$$(Browning\ Index)_{gram} = 0.044 + 0.023A + 0.017B + 0.033C - 0.017AB + 0.01AC - 0.082BC - 0.047A^2 + 0.032B^2 + 0.022C^2 \quad \ldots (3)$$

$$(Browning\ Index)_{Wheat} = 0.067 + 0.052A - 0.016B + 0.016C + 0.010AB + 0.070AC + 0.027BC + 0.012A^2 - 0.062B^2 + 0.011C^2 \quad \ldots (4)$$

Peroxide Value

Peroxide value indicates primary oxidation and rancidity risk in flatbreads. The highest peroxide value (7.09) for gram flour at 30% blend, 18°C water, 20 min rest; the lowest (6.22) at 40%, 27°C, 20 min rest. For wheat blends, maximum peroxide (7.09) occurred at 40%, 18°C, 10 min rest; minimum (6.12) at 20%, 27°C, 0 min rest (Fig. 3). The peroxide value (PV) of maize-based flatbread blended with gram flour is influenced by water temperature, resting time of the dough, and the proportion of gram flour. Warmer water temperatures (30–40°C) enhance dough hydration and starch gelatinization, but they also accelerate lipid oxidation, leading to a higher peroxide value due to increased enzymatic and non-enzymatic oxidation of lipids.[24] Resting time further affects oxidation, as longer resting periods expose lipids to oxygen, potentially increasing the peroxide value due to enhanced lipid breakdown by lipases and other enzymes. However, a balanced resting time (20–30 minutes) helps maintain optimal dough hydration and limits excessive oxidation, keeping the peroxide value in check.[22] The inclusion of gram flour, which contains both lipids and antioxidants, also affects the peroxide value; higher gram flour proportions can lead to greater lipid oxidation, though its antioxidant properties may reduce the oxidative stress and help maintain a lower peroxide value.[26] Optimizing these factors-moderate water temperature, appropriate resting time, and balanced gram flour content-can minimize lipid oxidation and ensure a flatbread with a favorable peroxide value, contributing to better quality and shelf-life.[23,25]

$$(\text{Peroxide value})_{\text{gram}} = 6.47 + 0.14A + 0.056B - 0.11C - 0.018AB - 0.022AC + 0.020BC - 0.046A^2 - 0.036B^2 + 0.35C^2 \quad \ldots (5)$$

$$(\text{Peroxide value})_{\text{wheat}} = 6.54 + 0.15A + 0.20B - 0.062C - 0.010AB - 0.037AC - 0.032BC - 0.057A^2 - 0.098B^2 + 0.26C2 \quad \ldots (6)$$

Free Fatty Acids

Free fatty acids influence flatbread taste and texture (Fig. 4). The highest value (1.48%) in gram flour blends occurred at 30%, 18°C water, 20 min rest; the lowest (1.053%) at 20%, 36°C, 10 min rest. For maize-wheat blends, maximum free fatty acids (1.522%) were at 30% wheat, 18°C, 20 min rest; minimum (1.048%) at 30% wheat, 36°C, 0 min rest.

The water temperature, resting time of dough, and blending of gram flour can significantly influence the

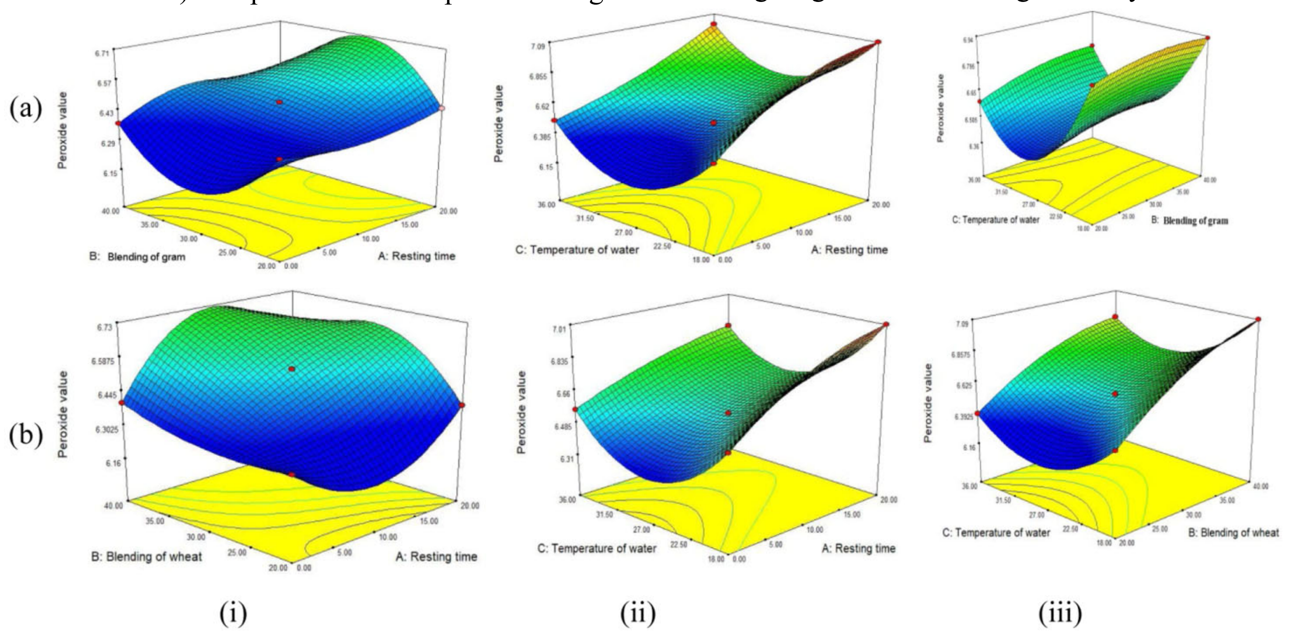

Fig. 3 — The 3D response surfaces of peroxide value showing the effect of (i) blending ratio and resting time (ii) temperature and resting time (iii) temperature and blending ratio for (a) gram flour subsitute flatbread (b) wheat flour subsitute flatbread

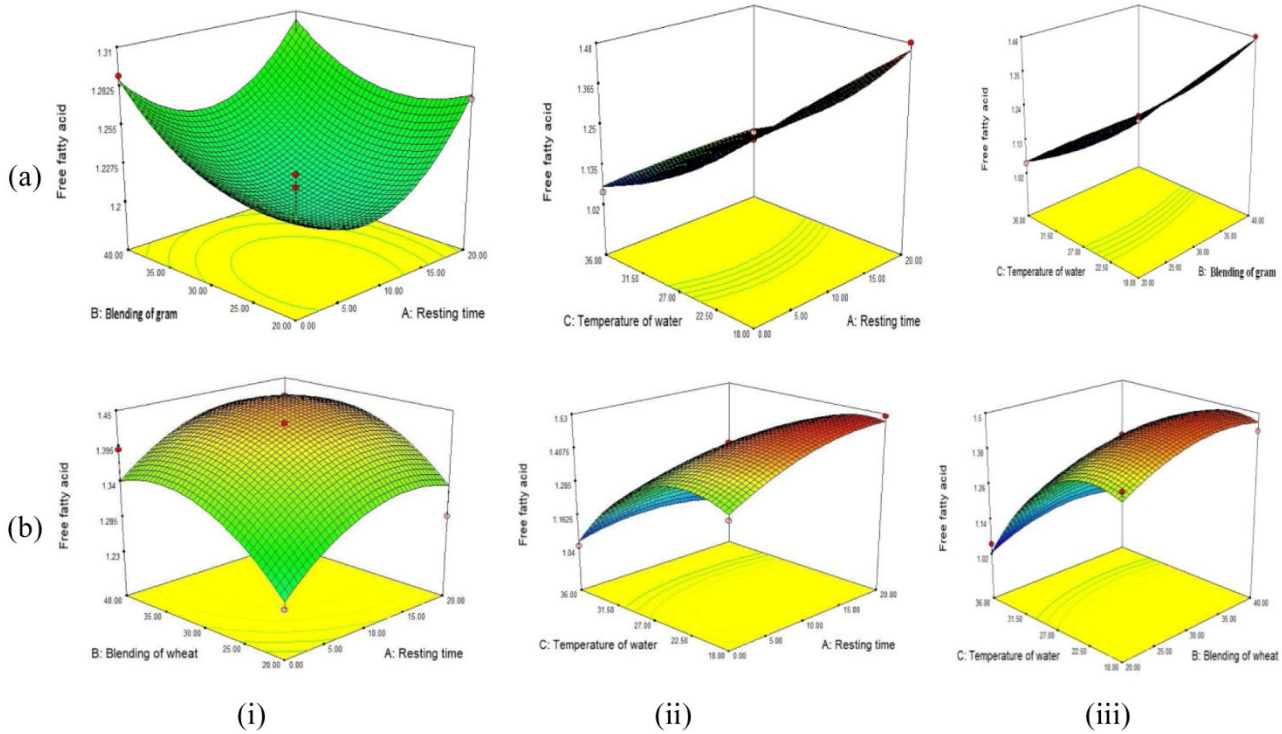

Fig. 4 ── The 3D response surfaces of FFA content showing the effect of of (i) blending ratio and resting time (ii) temperature and resting time (iii) temperature and blending ratio for (a) gram flour subsitute flatbread (b) wheat flour subsitute flatbread

free fatty acid (FFA) content in maize flatbread. Higher water temperatures during dough preparation can lead to increased enzymatic activity, potentially enhancing the breakdown of fats and resulting in higher FFA levels.[27] The resting time of the dough allows for fermentation and enzymatic activity, which may further influence the development of FFAs, as prolonged resting times can lead to greater lipid hydrolysis.[28] Additionally, the blending of gram flour with maize flour has been shown to alter the lipid composition of flatbread, potentially affecting FFA formation. Gram flour contains significant amounts of lipids, and its inclusion can either increase or decrease FFA content depending on the ratio and preparation methods.[29] Therefore, a careful balance of water temperature, dough resting time, and gram flour blending is crucial to controlling the FFA content in maize-based flatbreads.

$$(\text{Free fatty acid})_{\text{gram}} = 1.21 + 0.015A + 0.020B - 0.18C - 0.0656AB - 0.021AC - 0.029BC + 0.042A^2 + 0.023B^2 - 0.053C^2 \quad \ldots (7)$$

$$(\text{Free fatty acid})_{\text{wheat}} = 1.43 + 0.039A + 0.043B - 0.18C - 0.065AB - 0.043AC - 0.011BC - 0.046A^2 - 0.051B^2 - 0.14C^2 \quad \ldots (8)$$

Cutting Force

Cutting force indicates flatbread hardness; higher values mean tougher bread, less suitable for consumption. It was observed that the maximum cutting force (4.9078 Kg) for gram flour at 40% blend, 18°C water, 10 min rest; the minimum (3.3914 Kg) at 20%, 36°C, 10 min rest. For wheat flour, maximum cutting force (2.92 Kg) occurred at 30%, 18°C, 0 min rest; minimum (2.3001 Kg) at 40%, 27°C, 0 min rest as shown in Fig. 5.

The water temperature, resting time of dough, and blending of gram flour can significantly affect the cutting force of maize flatbread. Higher water temperatures during dough preparation can promote faster hydration of starches, resulting in a softer dough that may lead to a lower cutting force.[30] Resting time allows the dough to relax, improving its extensibility and reducing the cutting force required to slice the flatbread.[28] The blending of gram flour with maize flour alters the structural properties of the dough, as the presence of proteins and fibers in gram flour can influence the bread's firmness. A higher proportion of gram flour tends to increase the dough's viscosity and firmness, resulting in a higher cutting force.[31]

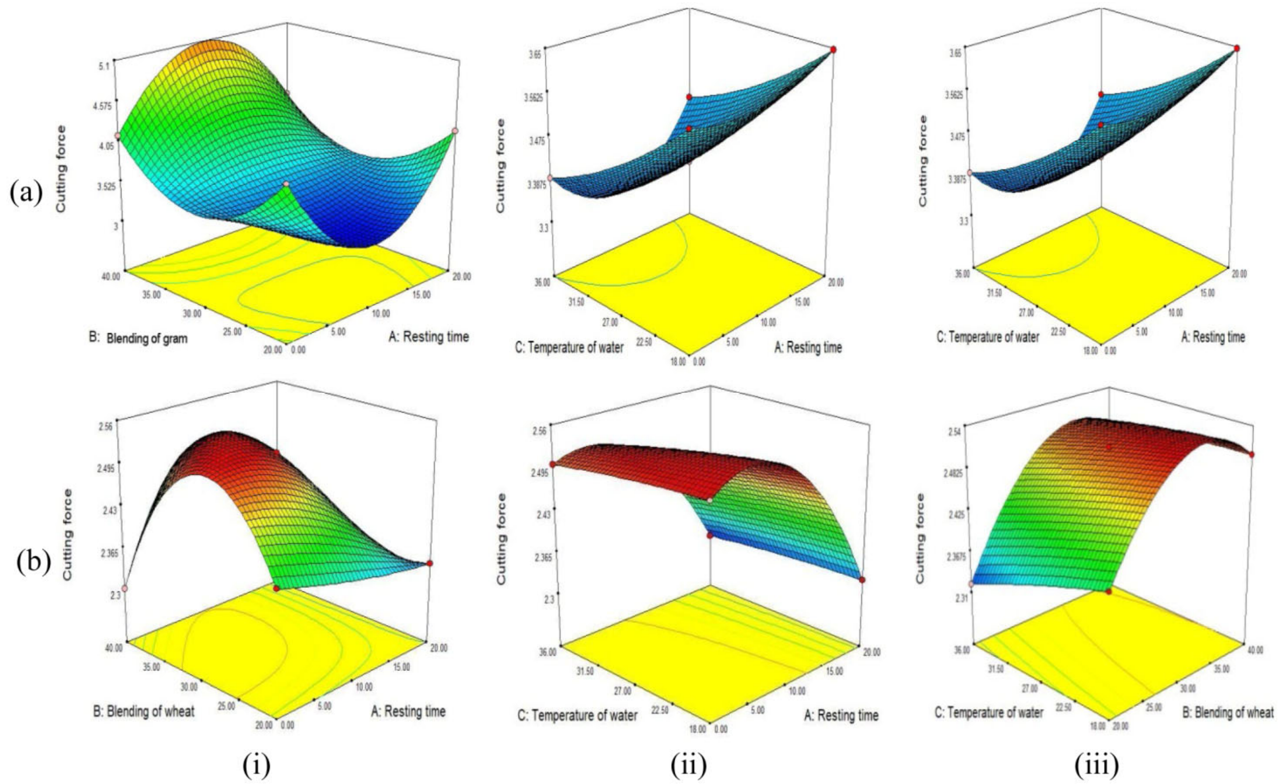

Fig. 5 — The 3D response surfaces of cutting force showing the effect of (i) blending ratio and resting time (ii) temperature and resting time (iii) temperature and blending ratio for (a) gram flour subsitute flatbread (b) wheat flour subsitute flatbread

$$(\text{Cutting force})_{\text{gram}} = 3.42 - 0.14A + 0.41B - 0.047C - 0.075AB + 0.04AC + 0.062BC + 0.014A^2 + 0.073B^2 + 0.085C^2 \quad \text{... (9)}$$

$$(\text{Cutting force})_{\text{wheat}} = 2.51 - 0.058A + 0.051B - 0.046C + 0.25AB + 0.0494AC + 0.016BC + 0.023A^2 + 0.041B^2 - 0.12C^2 \quad \text{... (10)}$$

Regression equations 9 and 10 reveal that on increasing the resting time of dough cutting force of flat bread was decreased. The porosity of dough increased as the resting time was increased. As the resting period passed, the number of smaller bubbles decreased and the median pore area of the bubbles present in the dough increased.[32] It has been also observed that resting the dough allows for better water absorption, leading to uniform hydration of the starches and proteins in maize flour. This improves the dough's workability, reduces cracking, and enhances the final flatbread's softness and structural integrity. Studies have found that longer resting times (20–30 minutes) yield smoother and more pliable dough, resulting in flatbreads with superior sensory qualities.[18] On increasing the water temperature, cutting force was decreased. It may be due to the fast rate of loss of moisture from the bread's surface during baking.[1] Warmer water enhances starch gelatinization in maize flour, improving dough cohesiveness and pliability. This is particularly important because maize flour lacks gluten, which affects dough elasticity. Using hot water can help compensate for this deficiency, leading to better dough binding and improved texture of the flatbread.[18]

Colour Change

Color change affects flatbread taste, appearance, and acceptability. The maximum color change (75.53) at 30% gram flour, 18°C water, 0 min rest; minimum (59.87) at 40%, 36°C, 10 min rest; for wheat flour, highest color change (76.67) occurred at 30%, 18°C, 20 min rest; lowest (62.33) at 30%, 36°C, 0 min rest as shown in Fig. 6.

The water temperature, resting time of dough, and blending of gram flour can significantly affect the color change of maize flatbread during baking. Higher water temperatures during dough preparation can lead to faster gelatinization of starches, which may result in a lighter color in the final product due to less Maillard reaction activity.[33] The resting time of dough allows for the even distribution of moisture, promoting uniform baking and potentially reducing color variation. Longer

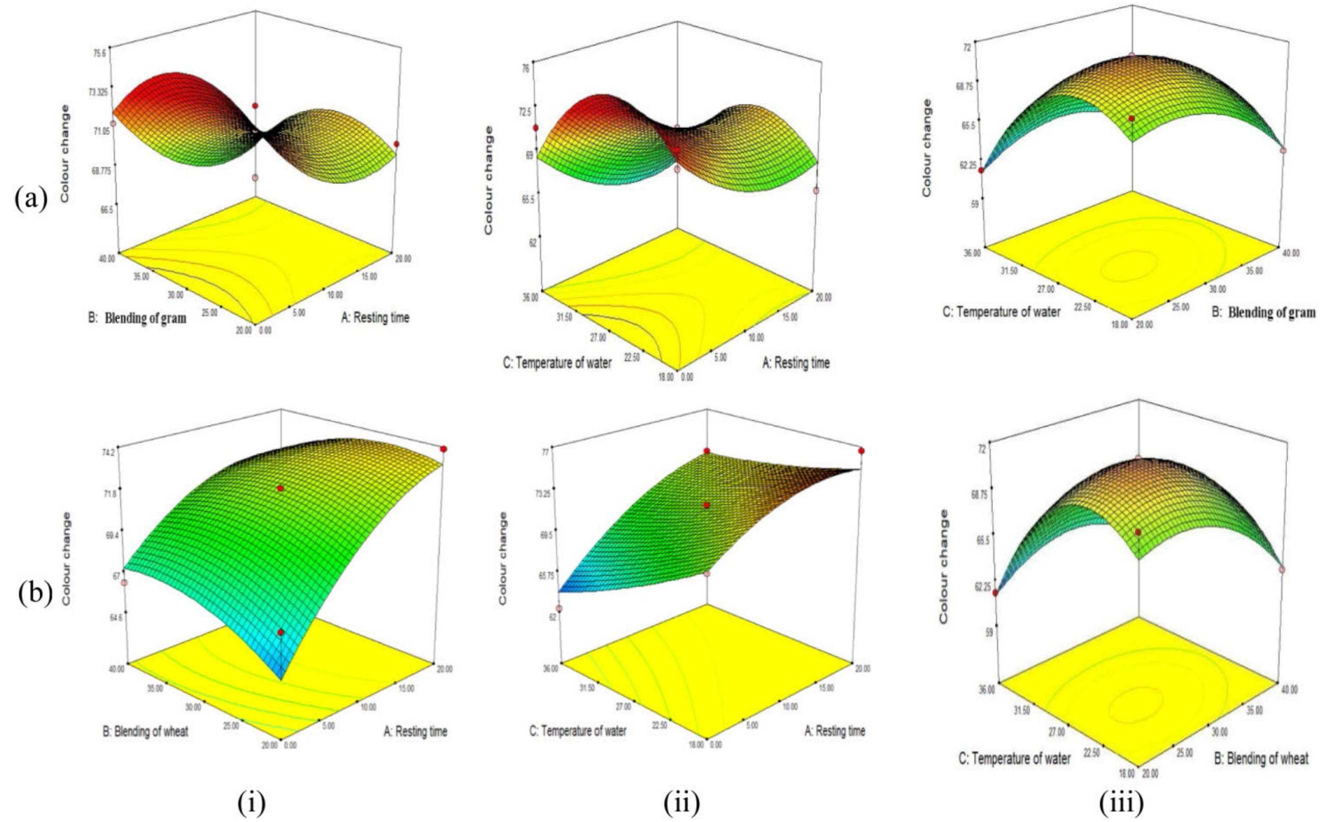

Fig. 6 — The 3D response surfaces of colour change showing the effect of (i) blending ratio and resting time (ii) temperature and resting time (iii) temperature and blending ratio for (a) gram flour subsitute flatbread (b) wheat flour subsitute flatbread

resting times may lead to slight darkening of the flatbread, as fermentation processes enhance Maillard reactions, which are responsible for browning.[29] The blending of gram flour with maize flour impacts the flatbread's color, as gram flour, being rich in proteins and pigments, may contribute a darker hue to the final product. The ratio of gram flour can influence the extent of this color change, with higher proportions leading to more pronounced browning.[34] Thus, a balance in water temperature, resting time, and gram flour blending is essential for achieving the desired color in maize flatbread.

$$(\text{Colour change})_{\text{gram}} = 70.87 + 2.35A + 1.12B + 2.16C - 0.10AB - 0.068AC + 1.31BC + 2.20A^2 - 2.49B^2 - 4.81C^2 \quad \ldots (11)$$

$$(\text{Colour change})_{\text{wheat}} = 71.88 + 3.22A - 0.22B + 2.39C - 1.05AB + 1.21AC - 1.18BC - 1.60A^2 - 1.09B^2 + 0.43C^2 \quad \ldots (12)$$

Regression Eqs (11) and (12) for gram and wheat flour blended flatbread respectively shows the resting time (A) and water temperature (C) had positive effect on colour change. The overall colour of the flatbread increased as the water temperature and resting time increased. The panellists prefer flat breads with a little darker colour.[34] The darker overall color may be due to the maillard reaction between reducing sugar and proteins. Mixing of wheat enhanced the firmness in flat bread but mixing of gram imparted dark colour.

Overall Acceptability

Overall acceptability is an important factor to invoke measure, analyze and interpret reactions to the characteristics of flatbreads as perceived by senses of sight, smell, taste, touch and hearing. It was observed that the maximum acceptability (9) was observed at 30% gram flour blending, 27°C of water temperature and 10 min resting time of dough while the minimum acceptability (8) was observed at 30% gram flour blending, 36°C of water temperature and 0 min of resting time of the dough as presented in Fig. 7.

In maize flatbread blended with wheat flour, the maximum acceptability (9) was observed at 30% flour blending, 18°C of water temperature and 20 min resting time of dough while the minimum

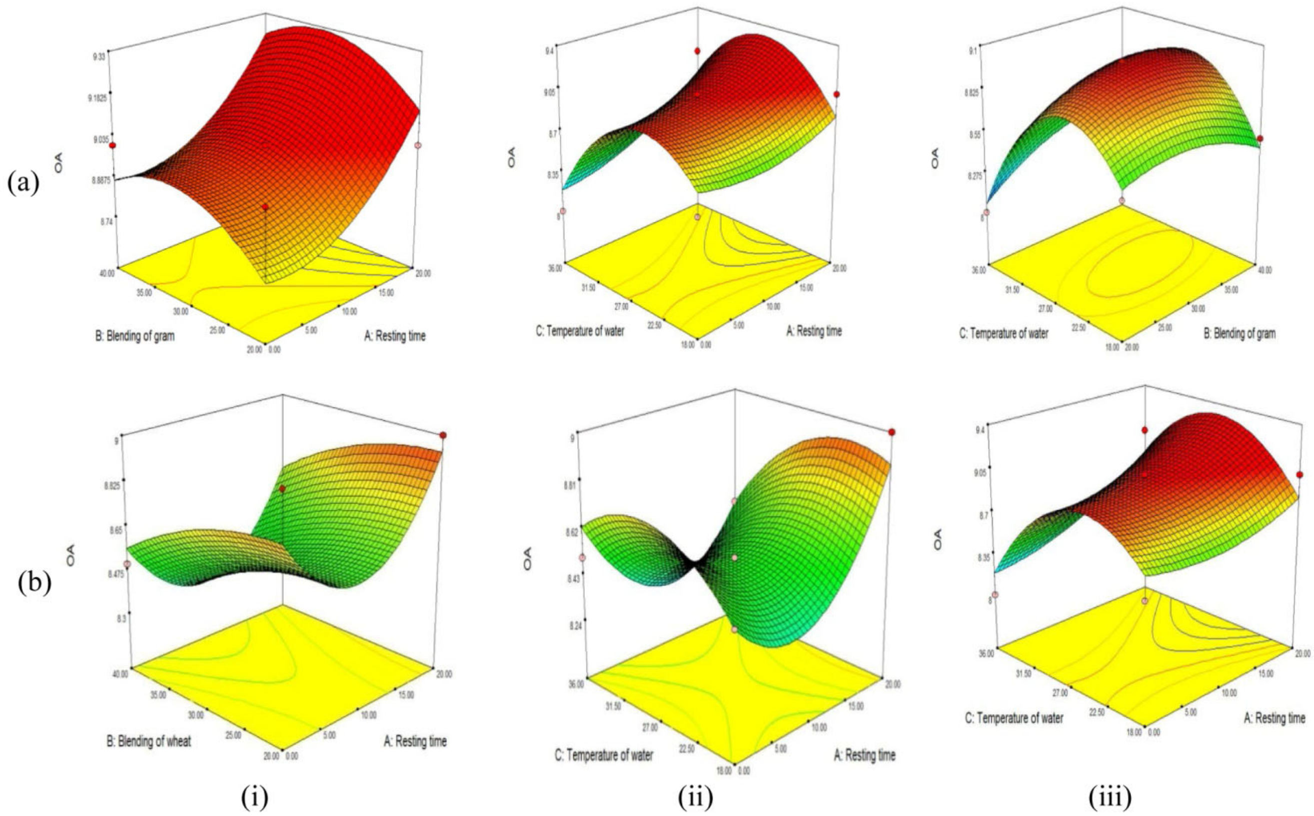

Fig. 7 — The 3D response surfaces of overall acceptability showing the effect of (i) blending ratio and resting time (ii) temperature and resting time (iii) temperature and blending ratio for (a) gram flour subsitute flatbread (b) wheat flour subsitute flatbread

acceptability (8) was observed at 20% wheat flour blending, 18°C of water temperature and 10 min of resting time of the dough (Fig. 7).

$$(\text{Overall acceptability})_{\text{gram}} = 9 + 0.19A + 0.062B + 0.13C + 012AC + 0.12BC + 0.12A^2 - 0.12B^2 - 0.50C^2 \quad \ldots (13)$$

$$(\text{Overall acceptability})_{\text{wheat}} = 8.50 + 0.063A - 0.13B + 0.062C + 0.13AC - 0.25BC + 0.31A^2 - 0.063B^2 - 0.19C^2 \quad \ldots (14)$$

Type of grain flour and water are the key ingredients that alter the texture, aroma and chewability of flat bread. Regression Eqs (13) and (14) represented the positive effect of resting time of dough (A) and water temperature (C) on overall acceptability of flatbread. On increasing the water temperature and resting time, overall acceptability increased as well because of the improved general qualities of flat bread.

The water temperature, resting time of dough, and blending of gram flour can all influence the overall acceptability of maize flatbread by affecting its texture, flavor, and appearance. Higher water temperatures can lead to softer dough that may improve the texture and make the bread more desirable.[30] The resting time of dough also contributes to its final quality by allowing for better fermentation, which can improve flavor and texture, leading to higher overall acceptability.[28] However, excessively long resting times may cause the dough to become overly soft, potentially affecting the bread's structure negatively. Blending gram flour with maize flour can enhance the nutritional profile, but it may also influence the sensory characteristics of the flatbread. While higher gram flour content can improve the protein and fiber content, it may also impart a more pronounced, slightly earthy flavor and alter the texture, which could either increase or decrease consumer preference depending on the balance of blending.[29,31]

Optmization of Process Variables for Maize Flour Based Flour Flatbreads

The process parameters were optimized using Design Expert 10 DX7.0 software, simultaneously optimization of multiple responses were carried out using numerical optimization technique. A solution

Table 3 — Optimum values of process parameters and responses for gram flour blended flatbread and wheat flour blended flatbread

Independent variables	Goal	Gram flour blended flatbread				Wheat flour blended flatbread			
		Lower limit	Upper limit	Optimization values	Actual values	Lower limit	Upper limit	Optimizatio n values	Actual values
Resting time (min)	in range	0	20	12.45	—	0	20	20	—
Blending (%)	in range	20	40	38.90	—	20	40	20	—
Temperature of water (°C)	in range	18	36	31.47	—	18	36	29.68	—
Responses									
Moisture content	Minimize	40.24	49.68	44.14	42.11	51.09	64.08	54.66	51.38
Browning Index	Minimize	0.029	0.089	0.066	0.068	0.053	0.096	0.078	0.076
Peroxide value	Minimize	6.35	7.09	6.53	6.51	6.32	6.71	6.34	6.32
Free fatty acid	Minimize	1.053	1.48	1.15	1.149	1.048	1.522	1.22	1.221
Cutting force	Minimize	3.0413	5.3211	4.70	4.63	2.3001	3.302	2.54	2.543
Colour change	Maximize	59.87	73.53	65.74	65.14	62.33	76.67	66.42	66.45
Overall acceptability	Maximize	8	9	8.88	8.50	8	9	8.94	8

having the maximum desirability, colour change and overall acceptability and minimum change in moisture content, browning index, peroxide value, free fatty acid, colour, and cutting force were selected as optipum condition for prepration of flatbread. The optimized results for maize flour based flatbread using gram flour as blended flour was; resting time, blending ratio and temperature were 12.45 min, 38.90% and 31.47°C respectively.

The perdicted values of various responses viz., moisture content, browning index, peroxide value, free fatty acid, cutting force, colour and overall acceptability were 44.14%, 0.066, 6.53%, 1.15%, 4.70 N, 65.74 and 8.88 respectively as presented in Table 3. The overall desirability was 0.858.

The optimized results for maize flour based flatbread using wheat flour as blended flour was; resting time, blending ratio and temperature were 20 min, 20% and 29.68°C respectively. The perdicted values of various responses viz., moisture content, browning index, peroxide value, free fatty acid, cutting force, colour and overall acceptability were 54.66%, 0.078, 6.34%, 1.22%, 2.54 N, 66.42 and 8.94 respectively as presented in Table 3. The overall desirability was 0.783.

Conclusions

With respect to modern lifestyles and healthy eating trends, traditional and nutritional food products are gaining popularity. *Chapatti* is a major staple baked food in most households and could bring the combination of nutrition and goodness of maize. The present study indicates that incorporating gram flour or wheat flour as substitutes in maize flour-based flatbread can enhance its nutritional value, quality, overall acceptance and reduces the preparation time of flatbread. Numerical optimization techniques have been used to determine optimal process parameters for these blends, with gram flour-based flatbread showing superior overall acceptance and quality compared to wheat flour-based flatbread. Statistical analysis confirmed the adequacy of the developed models with high R^2 values and non-significant lack-of-fit, ensuring model reliability. The mechanized preparation of maize flour based flatbread, alongside optimized formulations, can streamline the process of making flatbreads, enhance its nutritional quality reducing preparation time for making *chapatti* and improving efficiency

References

1 Barnwal P, Sharma A & Kore P, Assessment of storage stability of whole and degermed maize flour, *Int J Food Safety*, **15** (2013) 83–87.

2 Sidhu G K, Sharma S & Neha, Influence of milling speed on proximate composition of pearl millet flour during storage, *Intl J Food Ferment Tech*, **6** (2016) 49–56.

3 Sidhu G K, Singh A K & Singh M, Effect of milling speed on the quality and storage stability of maize flour, *J Appl Nat Sci*, **8** (2016) 1015–21.

4 Kaur H, Rani A & Arora R, The impact of water temperature on dough hydration and quality of chickpea-wheat-maize flour blends for flatbread preparation, *Food Chem*, **338** (2021), 127764.

5 Swati P, Rasane P, Kaur J, Kaur S, Ercisli S, Assouguem A, Ullah R, Alqahtani A & Singh J, The nutritional, phytochemical composition, and utilisation of different parts of maize: A comparative analysis, *Open Agric*, **9(1)** (2024), 20220358, https://doi.org/10.1515/opag-2022–0358.

6 Malik H, Nayik G A & Dar B N, Optimization of process for development of nutritionally enriched multigrain bread, *J Food Process Tech*, **7(01)** (2016).

7 Nazir F and Nayik G A, Impact of wheat-barley blending on rheological, textural and sensory attributes of leavened bread, *J Food Process Tech*, **7(8)** (2016).

8 Sandhu K, Singh N & Malhi N S, Some properties of corn grains and their flours I: Physicochemical, functional and

chapati-making properties of flours, *Food Chem*, **101(3)** (2007) 938–946.

9 Gujral H S & Pathak A, Effect of composite flours and additives on the texture of chapatti, *J Food Engg*, **55** (2002) 173–79.

10 Chhabra N & Kaur A, Evaluation of maize varieties and their particle size for chapatti making, *Int J Chem Stud*, **6** (2018) 3639–3642.

11 Priya K & Verma S, Organoleptic evaluation of recipes based on maize flour, *J Food Sci Res*, **1** (2010) 72–75.

12 Bhol S & Bosco S J D, Influence of malted finger millet and red kidney bean flour on quality characteristics of developed bread, *LWT-Food Sci Technol*, **55(1)** (2014) 294–300, http://dx.doi.org/10.1016/j.lwt.2013.08.012.

13 Gracia E A, Herarra J M & Torres T C, Textural, chemical and sensorial properties of maize tortillas fortified with nontoxic *Jatrophacurcas* L. flour, *J Food*, **2** (2017) 301–06.

14 Hussain M, Choudhry M A & Shad M A, Functional properties of maize flour and its blends with wheat flour: optimization of preparation conditions by response surface methodology, *Pak J Bot*, **45** (2013) 2027–2035.

15 Kathuria P, Kaur G & Kanojia V, Physico-chemical and functional properties of whole maize flour bended with wheat and gram flour, *Asian J Dairy Food Res*, **40(3)** (2021) 301–308.

16 AOAC International, Official Methods of Analysis of AOAC International, G W Latimer (Ed.), 21st ed. Gaithersburg, MD: AOAC International (2019).

17 Khan A, Hossein M & Zarifi S, Dough performance, quality and shelf life of flat bread supplemented with fractions of germinated date seed, *J Food Sci Tech*, **51** (2011) 3776–3784.

18 AOCS, *Official Methods and Recommended Practices*, 4thEdn., American Oil Chemists Society, 1990

19 Premlatha M R, Sundaram S P & Seevaratnam V, Studies on preparation of biscuits incorporated with potato flour, *World J Dairy Food Sci*, **7** (2012) 79–84.

20 Shah T R, Prasad K & Kumar P, Development and parameter optimization of maize flat bread supplemented with asparagus bean flour, *Food Sci Technol*, **38(1)** (2018) 148–156, http://dx.doi.org/10.1590/1678- 457x.36616.

21 Peluola-Adeyemi O A, Obi T E & Ugbogu D I, Effect of temperature and time on the physical properties of bread produced from wheat: cocoyam flour using response surface methodology, *J Food Technol Res*, **3** (2016) 63–71.

22 Adu P A & Nti C A, Influence of resting time on the physicochemical properties of maize-based dough in the preparation of flatbreads, *J Cereal Sci*, **98** (2022) 87–94.

23 Singh P, Rani S & Sharma A, Influence of water temperature and dough resting time on the sensory attributes and quality of flatbreads, *Food Res Int*, **132** (2020) 109086.

24 Mahajan P, Verma R P & Chawla H, Effects of water temperature and resting time on the dough rheology and quality of multigrain flatbreads, *J Food Sci Technol*, **58(10)** (2021) 3747–3756.

25 Kaur N, Kumar R, Singh A, Shobha D, Das A K, Chaudhary D, Kaur Y, Kumar P, Sharma P & Singh B, Improvement in nutritional quality of traditional unleavened flat bread using Quality Protein Maize, *Front Nutr*, **9** (2022) 963368, doi: 10.3389/fnut.2022.963368.

26 Shaheen S, Khan M I & Yaseen M, Effect of resting time and water temperature on the quality and texture of maize and chickpea-based flatbreads, *Int J Food Sci Technol*, **58(7)** (2023) 3174–3184.

27 Abdel-Aal E S M, Hucl P & Chibbar R N, The effect of water temperature on the enzymatic activity in wheat flour, *Cereal Chem*, **89(5)** (2012) 289–298.

28 Sulieman A A, Elkhalifa E A & Abdullahi H E, Influence of dough resting time on the texture of wheat-based bread, *Int J Food Sci Technol*, **51(3)** (2016) 730–735.

29 Rashid, M T, Iqbal Z, Shafiq M, Khan M A & Rehman S, Blending of gram flour with maize flour and its effects on nutritional composition and quality of flatbread, *Food Sci Nutr*, **7(4)** (2019) 1255–1263.

30 Gomez M, Ronda F, Blanco C A, Caballero P A & Apesteguía A, Effect of water temperature and resting time on the rheological properties of wheat dough, *J Food Eng*, **97(4)** (2010) 594–600.

31 Akin M A, Ozdemir M & Akin M B, Effect of gram flour blending on the textural properties of maize-based flatbreads, *J Food Sci*, **77(4)** (2012) E500–E505.

32 Jha P K, Chevallier S, Cheio J, Rawson A & Le-Bail A, Impact of resting time between mixing and shaping on the dough porosity and final cell distribution in sandwich bread, *J Food Eng*, **194** (2017), doi: 10.1016/j.jfoodeng.2016.07.016.

33 Zhang Y, Zhang H, Wang L & Qian H, Effect of water temperature on the color and texture of wheat flour dough, *Food Res Int*, **44(3)** (2011) 728–733.

34 Chaudhary P, Singh A K & Verma A, Influence of gram flour addition on the color and nutritional properties of maize-based flatbreads, *J Food Qual*, **41(1)** (2018) 87–95.