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Research Article

Effect of Sand Roasting on Physicochemical, Thermal, Functional, Antinutritional, and Sensory Properties of *Sattu*, a Nourishing form of Chickpea

Iqra Qureshi,[1] **Khalid Bashir**,[1] **Shumaila Jan**,[2] **Ayon Tarafdar**,[3] **Mehvish Habib**,[1] **and Kulsum Jan**[1]

[1]*Department of Food Technology, Jamia Hamdard, New Delhi 110062, India*
[2]*Department of Food Science and Technology, NIFTEM, Haryana, Kundli 131028, India*
[3]*Livestock Production and Management Section, ICAR-Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh, Bareilly 243122, India*

Correspondence should be addressed to Kulsum Jan; kulsumnissar@gmail.com

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Sattu is a traditional Indian food product made of chickpea with tremendous nutritional benefits. However, the processing of *sattu* has not been thoroughly explored which is an impediment to industrial applications involving the development of *sattu*-based products. These products carry immense benefits for consumers and for widespread popularity; it is essential that the roasting of *sattu* for further processing be investigated for improving the properties of *sattu* while reducing its antinutritional factors. In this study, the impact of sand roasting on the physicochemical, sensory, antinutritional, thermal, functional, and antioxidant properties on *sattu* was investigated. Chickpea grains were roasted in sand for different time periods (3–17 min) and temperature combinations (171–228°C). Results revealed that samples treated at 180°C for 15 min had maximum sensory score (3.99) followed by the samples treated at 200°C for 10 min and at 228°C for 10 min. Overall *sattu* roasted at 180°C for 15 min was found suitable for further application.

1. Introduction

Chickpea (*Cicer arietinum* L.) known as *garbanzo bean* is an old-world pulse, and in terms of production, it is considered as the third most important pulse crop after dry beans and field peas [1]. The chickpea comes in two varieties: desi and kabuli. The desi (microsperma) had anthocyanin coloration on stalks, pink blooms, and thick seed coat while the kabuli (macrosperma) lacks anthocyanin coloration on stems, having white blooms, and white or beige-colored seed. Chickpeas are in high demand due to their nutritious content. In the semiarid tropics, chickpea forms a key part of the diets of those who cannot afford animal proteins or choose to be vegetarian. When compared to other pulses, chickpeas have a high carbohydrate and protein content, accounting for approximately 80% of the total dry seed mass [2].

Powdering and roasting of chickpeas, commonly known as *sattu*, is massively famous in several Indian states. *Sattu* is an age-old Indian cure for beating the heat and is taken in variety of forms from basic drinks to paranthas, laddoos, and litti chokhas [3]. Use of sand as a heating medium for simmering food grains is an ancient method, and it is adopted globally for roasting of several food grains. In this method, sand is heated in an open pan over a heating medium (gas stove coal, oil burner, wood, etc.); after that, food grains are added once the pan reaches the desired temperature varying from 150°C to 350°C in the process of roasting [4]. In order to promote overall acceptability, the roasting process transforms micro- and macronutrients into more palatable forms and enhances flavour, color, texture, etc., [5]. Food grains exposed to high temperatures for a short time lose water more quickly, have less water activity,

are crispier, have different antioxidant and functional characteristics, have a longer shelf life, and are more popular with consumers [6]. The development of various roasting techniques and equipment, such as fluidized bed roasters, spouted bed roasters, rotary type roasters, microwave roasters, infrared roasters, superheated steam roasters, and air jet roasters, has been prompted by the rise in demand for roasted food grains and dependent fortified foods as well as consumer concerns about hygiene. Most of these roasting techniques are laborious to use, produce slow and uneven production, and use significant energy [7]. The development of such a technique will help decrease manual labour, save money, boost productivity, improve roast product uniformity, have a wider range of applications (working with a wide range of material to be roasted), and help to distribute heat evenly throughout the heating chamber and to all the food grains. In this research, the preparation of chickpea *sattu* by optimization of time and temperature using software tool (research surface methodology) has not been commenced until now. The present research envisages that the effect of sand roasting on the antioxidant, functional, physicochemical, thermal, and antinutritional properties of chickpea *sattu*.

2. Materials and Methods

2.1. Materials. The raw material (hulled chickpea grain samples) was procured from IARI (variety: Pusa-372) at New Delhi, India. The foreign particles in hulled chickpea grains were manually removed, and chemicals used for the current study were of analytical grade.

2.2. Preparation of Sattu. At room temperature, chickpea grains were soaked in water for 50 minutes (2 : 1 water : grain). Chickpea grains were drained of water and air-dried for 20 minutes at room temperature. Chickpea grains were then cooked on an open pan with sand. Process optimization for sand roasting of *sattu* was carried out using statistical tool termed as response surface methodology (Design Expert: Stat-Ease, version 11 2020, Stat-Ease, Minn). The defined process variables were temperature (180–200°C) and time (5–15 mins). Central composite design was used and the responses measured were antioxidant properties and sensory evaluation. A digital laser infrared thermometer (DT-8550) was used to measure the temperature of the sand, and continuous stirring was carried out to ensure heating uniformly. Roasted chickpea grains were separated from the sand using fine wire mesh. Grains were ground in mixer grinder (Phillips HL 7505-02) and the flour was sieved with a BSS 30 sieve. After that, the powdered flour was packed in airtight bags and stored for further testing.

2.3. Experimental Design for the Preparation of Sattu by Sand Roasting Method. Using Stat-Ease software, the experimental design and analysis were done using response surface methodology (Design Expert: Stat-Ease, version 11 2020, Stat-Ease, IBM, US). The goal of the research was to create a multiple regression equation that expressed quality composition characteristics to the hypothesis that antioxidant qualities and overall acceptance of the product are related to *sattu* quality. The experiments were carried out with two independent variables, i.e., temperature and time of product using a central composite design. The experimental ranges of the time and temperature variables were 180–200°C and 5 min–15 min, respectively. A design matrix consists of 13 trail runs in it. Among all the responses (runs), 180°C for 15 min (B_{15}), 200°C for (I_{10}), and 228°C for 10 min (H_{10}) were observed to be most acceptable. The obtained runs are shown in Table 1. The quadratic model is given in the following equation:

$$Y_{k=\beta_o+\sum_{i=0}^{4}\beta_i X_i+\sum_{j=0}^{4}\beta_{ii}X_i^2+\sum_{i=0}^{4}\sum_{j=0}^{4}\beta \mathrm{ij} X_i X_j}, \quad (1)$$

where Y signifies the measured response, β_0 is an intercept, β_i is regression coefficients calculated from the observed experimental value of Y, and X_i is coded levels of independent variables. The X_iX_j and X_i^2 denote the interaction and quadratic terms.

2.4. Sensory Evaluation of Sattu. Based on preliminary trials, 12 g of *sattu* samples coded as 180°C-5 mins (A_5), 180°C-15 mins (B_{15}), 220°C-5 mins (C_5), 220 °C-15 mins (D_{15}), 200°C-3 mins (E_3), 200°C-17 mins (F_{17}), 171°C-10 mins (G_{10}), 228°C-10 mins (H_{10}), and 200°C-10 mins (I_{10}) was blended with 150 ml of water to make a *sattu* beverages. Sensory analysis was carried as per the method described by Shakeb et al. [8], with slight modifications. Panel of 12 semitrained judges (six females and six males) were offered the *sattu* beverages, which were coded. The judges were given the task of grading the samples on a 9-point hedonic scale for color, taste, mouth feel, appearance, and overall acceptance: 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. All of the chosen judges were nonsmokers who had not eaten for two hours previous to the sensory evaluation. The evaluation took place between 11 AM to 12 noon (IST).

2.5. Physical Properties of Chickpea Grain

2.5.1. Surface Area. The surface areas of grains were determined by the procedure followed by Isıklı et al. [9]. It was calculated by the following formula:

$$S\left(\mathrm{mm}^2\right) = \pi\left(L \times \mathrm{W} \times \mathrm{T}\right)^{2/3}, \quad (2)$$

where L is length, T is thickness, and W is width.

2.5.2. Bulk Density. The bulk density (g/ml) of chickpea grains was measured by the procedure discussed by Karaj and Müller [10]. It was calculated by the given formula:

$$\text{Bulk density} = \frac{\text{mass of roasted grain}}{\text{bulk volume}}. \quad (3)$$

Table 1: Experimental design with two independent variables (central composite design).

Time (min)	Temperature (°C)	Sensory score	DPPH % inhibition	TPC (mg GAE/g)
5	180	5.72	14.24	9.26
15	180	8.06	12.13	8.93
5	220	4.52	11.38	8.32
15	220	2.2	8.34	6.22
3	200	2.6	12.42	8.97
17	200	2.34	11.44	8.73
10	171	4.84	13.52	9.08
10	228	7.72	7.24	5.19
10	200	8.36	12.04	8.53
10	200	8.36	12.04	8.53
10	200	8.36	12.04	8.53
10	200	8.36	12.04	8.53
10	200	8.36	12.04	8.53

2.5.3. True Density. The true density (g/ml) of chickpea grains was measured by the method elaborated by Coskuner and Karababa [11] and was calculated by the following formula:

$$\text{True density} = \frac{\text{mass of sample}}{\text{volume of displaced toulene}}. \quad (4)$$

2.5.4. Porosity. The porosity of chickpea grains was analyzed from the bulk density and true density discussed by Mohsenin [12]. It was calculated by the given equation:

$$\text{Porosity} = \frac{\text{true density} - \text{bulk density}}{\text{true density}} \times 100. \quad (5)$$

2.5.5. Coefficient of Static Friction. The coefficient of static friction of chickpea grains was analyzed on wood and glass by discussed followed by Dutta et al. [13] and was calculated by the following equation:

$$\mu = \tan^{-1}(H/L), \quad (6)$$

where "H" and "L" signifies the elevation and "L" represents the length of tilt plate in millimeters, respectively.

2.5.6. Geometric Mean Diameter and Sphericity. The geometric mean (D_g) diameter and sphericity (ϕ) of randomly chosen grains were analyzed by the following relationships [12]:

$$D_g = (\text{LWT})^{1/3},$$
$$\phi = \frac{(\text{LWT})^{1/3}}{\text{L}}, \quad (7)$$

where L represents length, W signifies width, and T is thickness.

2.5.7. Angle of Repose. Angle of repose of chickpea grains was determined by the method described by Khan and Saini [14] and was calculated by the following equation:

$$\theta = \tan^{-1}\frac{2h}{d}, \quad (8)$$

while 'ϕ' represents the angle of repose, "h" represents the height of pile (cm), and "D" is the diameter of pile (cm).

2.5.8. Color Characteristics. The color values (L, a, b) of sample were determined by a hand-held lovi-bond spectrocolorimeter (Hunter color lab, LC100).

2.6. Proximate Composition. The carbohydrate content of flour samples was evaluated using the difference method, and the proximate composition of flour samples (protein, moisture, ash, fat, and crude fibre) was examined using the AOAC standards (1990).

2.7. Antinutritional Properties

2.7.1. Phytic Acid and Tannin. The amount of antinutritional factors (phytic acid and tannins) in samples was measured by the method described by Holt [15].

2.8. Functional Properties

2.8.1. Water Absorption Capacity and Oil Absorption Capacity. The WAC and OAC were analyzed by the procedure followed by Wani et al. [16]. The following equation was used to compute the WAC and OAC.

$$\frac{\text{WAC}}{\text{OAC}} = \frac{(\text{weight of tube + sediment}) - (\text{weight of tube + 5.0})}{5}. \quad (9)$$

2.8.2. Water Absorption and Water Solubility Index. WAI and WSI of the samples were described by the technique given by Bashir and Aggarwal [17] and it was calculated by following equation:

$$\text{WAI}\left(\frac{g}{g}\right) = \frac{\text{weight of sediments}}{\text{weight of flour sample}},$$
$$\text{WSI}\left(\frac{g}{g}\right) = \frac{\text{weight of dissolved solid in supernatant}}{\text{weight of flour samples}}. \quad (10)$$

2.8.3. Foaming Properties. The activities of foams in flour were measured by the procedure described by Jogihalli et al. [18] and it was calculated by the given equations:

$$\mathrm{FC}(\%) = \frac{\text{Volume of sample after whipping} - \text{Volumeof sample before whipping}}{\text{volume of sample before whipping}},$$
$$\mathrm{FS}(\%) = \frac{\text{Foam of sample after ten minutes} - \text{Foam of sample volume before whipping}}{\text{initial volume of foam sample}}. \quad (11)$$

2.9. Thermal Property (DSC). The differential scanning calorimetry of flour samples was analyzed by the method described by Henshaw et al. (2003).

2.10. Fourier Transfer Infrared Spectroscopy (FTIR). The Fourier transfer spectroscopy of native and treated flour of the sample was determined by the procedure followed by Bashir and Aggarwal [17]. An ATR-FTIR spectrophotometer was used to get the sample's FTIR spectra at room temperature (Perkin Elmer). The bands were placed in a scale order of 400 to 4000 cm^{-1}.

2.11. Antioxidant Properties

2.11.1. Total Phenolic Content. The phenolic content of flour sample extracts was analyzed by using Folin–Ciocalteu reagent followed by Yu et al. [19].

2.11.2. DPPH Inhibition. The % DPPH of native and treated sample was analyzed by the procedure described by Yu et al. [20] and was computed by the given formula:

$$\%\ \text{Inhibition} = \frac{\text{control absorbance} - \text{sample absorbance} \times 100}{\text{Control absorbance}}. \quad (12)$$

2.11.3. Ferric Reducing Antioxidant Potential. The ferric reducing antioxidant potential (FRAP) of native and treated flour was analyzed by the procedure described by Oyaizu [21] and reducing power was measured on a spectrophotometer at 700 nm and was obtained by the given formula:

$$\%\ \text{Reduction} = \frac{\text{absorbance of the sample} \times 100}{\text{absorbance of the control} - 1}. \quad (13)$$

2.12. Statistical Analysis. The tests were carried out in triplicates. The data are presented as means standard deviations. Duncan's multiple range test was performed to compare the results of utilizing commercial statistical software to an analysis of variance with a 5% significance level (SPSS, Inc, Chicago, IL, USA).

3. Results and Discussion

3.1. Optimization of Time and Temperature by Response Surface Methodology. The impact of time and temperature combination on antioxidant properties and overall acceptability of the product were measured using RSM, and the central composite design was used. Analysis of variance (ANOVA) was carried out to assess the data for each response, and multiple linear regressions were used to estimate the coefficients. Based on lack of fit, a nonsignificant and II-order regression equation was built for the responses (antioxidant and sensory properties) as a function of independent coded parameters. The regression constant for sensory evaluation, % DPPH inhabition, and total phenolic content by RSM was observed to be 0.94, 0.81, and 0.90, respectively.

3.1.1. Effect of Time and Temperature on Sensory Evaluation. Sensory evaluation is a scientific way of eliciting, analysing, measuring, and interpreting product responses through the senses of smell, sight, hearing, and touch. The quadratic model equation for sensory score is given in the following equation:

$$\text{Sensory score} = 4.18 + 0.041^{*}\mathrm{A} - 0.25^{*}\mathrm{B} - 1.35^{*}\mathrm{A}^{2} - 0.39^{*}\mathrm{B}^{2} - 0.71^{*}\mathrm{A}^{*}\mathrm{B}. \quad (14)$$

It is evident from Figure 1 that the acceptability of the product was affected considerably ($p \leq 0.05$) by time and temperature combination. On the basis of sensory evaluation, as there is an increase in the overall acceptability of the product quadratically with an increased time and temperature combination upon roasting. It is observed that there is an increase in the overall acceptability of the product initially with an increased time and temperature combination of sand roasting whereas further decrease in the product acceptability was observed which may be due to the increased time and temperature of the product, causing burning effects in the quality of product during processing.

3.1.2. Effect of Time and Temperature on % DPPH Inhibition. The % DPPH inhibition of product was found in the range from 17.74 to 7.24%. The quadratic model for % DPPH inhibition is

$$\%\ \text{inhibition} = +12.04 - 0.82^{*}\mathrm{A} - 1.94^{*}\mathrm{B} + 0.037^{*}\mathrm{A}^{2} + 0.74^{*}\mathrm{B}^{2} - 0.23^{*}\mathrm{A}^{*}\mathrm{B}. \quad (15)$$

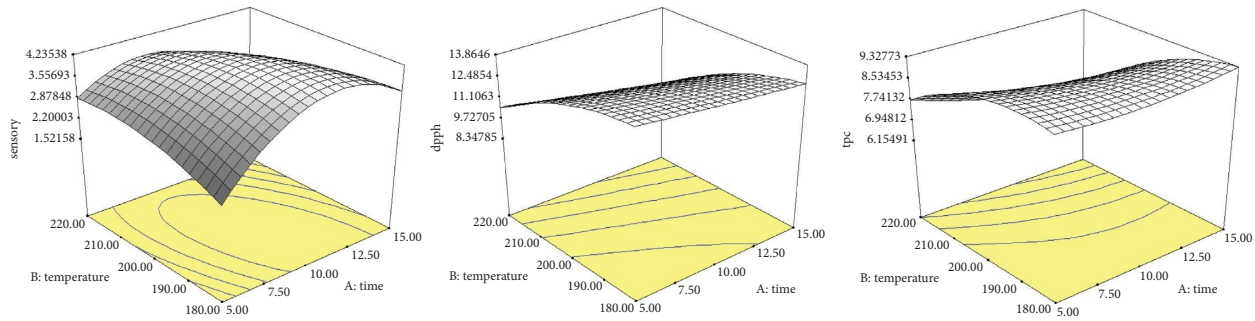

Figure 1: Effect of temperature and time on sensory score, % DPPH inhibition, and total phenolic content (from (a–c)) of *sattu*.

The response surface plots depicted in Figure 1 shows the impact of variable process on % DPPH inhibition wherein a reduction in % DPPH with increased time and temperature of the sand roasted flour was observed. The % DPPH inhibition considerably ($p < 0.05$) decreased and the lower value 7.24% was noticed for roasted samples at 228°C for 10 m (H_{10}). A higher % DPPH inhibition was noticed for control sample 17.74% Intermediate time and temperature shows a highest activity of DPPH with respect to other combination and is supported by Zakrzewski et al. [22] for roasting of buckwheat.

3.1.3. Effect of Time and Temperature on Total Phenolic Content. The TPC of the product was observed in the range from 11.58 to 5.19 mgGAE/g. The quadratic model for total phenolic content is

$$\text{TPC} = +8.53 + 0.35^{*}\text{A} - 1.14^{*}\text{B} - 0.21^{*}\text{A}^{2} - 0.65^{*}\text{B}^{2} - 0.44^{*}\text{A}^{*}\text{B}. \quad (16)$$

It is evident from Figure 1 that the TPC of the sand roasted flour is reduced by the increasing time and temperature of sand roasting. The RSM plots depicted in Figure 1 showed the impact of process variables on the content of phenols. The value of roasted samples at 228°C is 5.19% of total phenolics exhibit a continuous decline by increasing the time of roasting process. Similar findings were observed for roasted oats wherein a decrease in TPC was seen by Gujral et al. [23]. Heat-induced extractable phenolics are responsible for the rise in TPC at low roasting temperatures (180°C). Similar results were supported by Gallegos-Infante et al. [24] for roasted barley.

3.2. Sensory Properties of Optimized Samples. Table 2 shows the sensory analysis of selected sand roasted *sattu* samples and is observed with increasing time and temperature combinations; sand roasting had a significant ($p \leq 0.05$) impact on flavour, mouth feel, appearance, aftertaste, and overall acceptability. The sensory evaluation of sand roasted samples at 171°C for 10 min, 180°C for 5 min, 200°C for 3 min, and 220°C for 5 min was observed to be under cooked. Similarly, it was revealed that the samples sand roasted at 220°C for 15 min and 200°C for 17 min were overcooked (burnt) during processing. All the under cooked and burnt samples were poor in organoleptic properties and hence were discarded, and no further analysis was performed for them. The sensory evaluation carried out for sattu samples roasted at 180°C for 15 min (B15) showed high acceptability followed by the samples roasted at 200°C for 10 min (I10) and 228°C for 10 min (H10). All of the investigated parameters received a good score from semitrained panelists (score >6), indicating that the roasted samples will be well received. The semitrained panelists gave the highest sensory scores and overall acceptance (9.06) to *sattu* roasted at 180°C for 15 minutes (B_{15}).

3.3. Physical Properties

3.3.1. Surface Area, Geometric Mean Diameter, Sphericity, Bulk Density, True Density, Porosity, Coefficient of Friction, and Angle of Repose. In Table 3, sand roasting with increased time and temperature combination results in a significant ($p \leq 0.05$) increased in surface area from 188.68 to 255.47 (mm^2). The increase in surface area is also supported by Raigar et al. [25] for roasted soyabean flour. Higher surface area helps to faster moisture removal and increased grain volume [18].

The dimension of food grains determines sphericity. Time and temperature combination had a significant ($p \leq 0.05$) impact on geometric mean diameter of chickpea grain during sand roasting. Geometric mean diameter of all sand roasted samples varying from 6.84 to 10.38 mm which was higher than control sample (8.94 mm). The difference in grain length played a significant role in this discrepancy [26].

The increased geometric mean diameter in sand roasting time and temperature combination were also supported by Mirdula et al. [27] for soyabean. The increase in geometrical mean diameter contributes in increasing sphericity of grain. The sand roasting with increase in time and temperature combination exhibits a continuous increase in the sphericity of grain samples (73.09–74.84) than control sample (72.76). The expansion of roasted grain widths and thickness, rather than its length, caused the increase in sphericity [26]. Similar findings were also supported by Isıklı et al. [9] for roasted Zerun wheat.

The densities of powders have an impact on their transportation, packaging, and marketing. As a result, this property can be used to calculate the volume and weight of material needed to fill a beaker [28]. The bulk density

Table 2: Sensory scores of *sattu* beverage.

Temperature (°C)	Time (min)	Taste	Mouth feel	After taste	Appearance	Overall acceptability
180	15	8.66 ± 0.38^{a}	7.90 ± 0.18^{a}	8.00 ± 0.21^{a}	7.96 ± 0.11^{c}	9.06 ± 0.16^{c}
200	10	7.20 ± 0.37^{ab}	6.26 ± 0.13^{b}	7.56 ± 0.20^{b}	7.78 ± 0.23^{b}	8.66 ± 0.16^{a}
228	10	6.22 ± 0.65^{b}	6.04 ± 0.21^{b}	7.16 ± 0.48^{c}	7.72 ± 0.31^{a}	8.42 ± 0.15^{b}

The results are presented as mean ± SD, $n = 3$. Values in a column with distinct superscripts differ significantly ($p \leq 0.05$).

Table 3: Physical properties of control and roasted grain.

Parameters	Control sample	Roasted sample		
	C_0	B_{15}	I_{10}	H_{10}
Surface area (mm^2)	188.68 ± 1.18^{d}	216.61 ± 0.98^{c}	234.77 ± 0.59^{b}	255.47 ± 0.56^{a}
Geometric mean (mm)	6.84 ± 0.32^{c}	8.94 ± 0.60^{b}	9.47 ± 0.13^{b}	10.38 ± 0.35^{a}
Sphericity (%)	72.76 ± 0.55^{b}	73.09 ± 0.58^{b}	73.61 ± 0.45^{ab}	74.84 ± 1.00^{a}
Bulk density (kg/m^3)	765.83 ± 0.58^{a}	487.21 ± 0.58^{b}	427 ± 1.98^{c}	302.88 ± 1.14^{d}
True density (kg/m^3)	1253.00 ± 0.58^{a}	1205.10 ± 0.60^{b}	1173.29 ± 0.56^{c}	998.36 ± 0.51^{d}
Porosity (%)	38.51 ± 0.62^{d}	58.86 ± 0.60^{c}	63.58 ± 0.98^{b}	69.34 ± 0.61^{a}
Angle of repose (°)	22.33 ± 0.86^{c}	23.14 ± 0.80^{bc}	24.06 ± 0.59^{ab}	24.98 ± 0.49^{a}
Coefficient of friction on glass	0.42 ± 0.01^{a}	0.39 ± 0.01^{b}	0.34 ± 0.01^{c}	0.29 ± 0.05^{d}
Coefficient of friction on plywood	0.52 ± 0.01^{a}	0.47 ± 0.05^{b}	0.45 ± 0.01^{c}	0.40 ± 0.01^{d}

The results are presented as mean ± SD, $n = 3$. Values in a row with distinct superscripts differ significantly ($p \leq 0.05$).

significantly ($p \leq 0.05$) declined by changes in sand roasting time and temperature combination. Roasting of chickpea treated at 228°C for 10 min (H_{10}) exhibited the lowest bulk density (302.88 kg/m^3), whereas control sample (765.83 kg/m^3) had the highest bulk density (Table 3). The true density of grains also significantly ($p \leq 0.05$) decreases upon sand roasting from 1205.10 to 998.36 (kg/m^3) as compared to control samples (1253 kg/m^3). The creation of void spaces in the cellular matrix, which allows the starchy endosperm to expand, could explain the significant decrease in densities [26]. Furthermore, breaking down complicated molecules into their constituent parts may result in a less bulky structure and lower densities [27]. The decrease in true density and bulk density is also supported by Mariotti et al. [29] for puffing of brown rice. The gaps in the solid particles of a substance are measured by porosity. Void spaces can be added with different variety of fluids such as gas and water [14]. Porosity significantly increased from 38.51 to 69.34%. The control sample had less porosity value of 38.51% while the roasted samples had 58.86% roasted at 180°C $B_{10,}$ 63.58% 200°C roasted at I_{10}, and 69.34% roasted at 228°C H_{10}, respectively. Similar trend of results was also observed by Sharma and Gujral [4] for sand roasting of barley.

The angle of repose for roasted grains was significantly ($p \leq 0.05$) more than control sample (22.33°). The increased temperature and time in roasting results in increased in the angle of repose from 22.33°–24.98°. On plywood and glass, the coefficient of friction of control and roasted grain was measured. During the sand roasting process, the coefficient of friction decreases as time and temperature combinations increase as a result, the coefficient of friction for glass and plywood surfaces is constantly decreasing (Table 3). The results revealed that the rough surface, such as plywood (0.52), has a greater coefficient of friction than a smooth surface, such as glass (0.42). The drop in coefficient of friction and rise in angle of repose were caused due to the reduction in the content of moisture and an increase in grain size, which reduces grain surface friction and enhances grain to grain interaction. The increasing and decreasing in the angle of repose and coefficient of friction was also supported by Isıklı et al. [9] for roasted wheat.

3.3.2. Color Properties. Table 4 and Figure 2 represent the color characteristics of chickpea flour. Color is a significant quality indicator that is linked to food acceptability, marketability and wholesomeness [30]. The value of L* for sand roasted sample significantly ($p \leq 0.05$) decreases from 83.46 to 79.50 as compared to controlled sample (87.52). Drop in L* value may be due to lower moisture content, as well as development of glazed look after grinding the grains [31].

From the results, it was observed that the controlled chickpea flour had lowest a* value 1.72 in comparison to the roasted chickpea flour had highest a* value 5.60 roasted at 228°C (H_{10}). Similarly, b∗ value also follows same condition as shown in Table 4. The synthesis of brown pigments in the mallard reaction and caramelization may be responsible for the increasing "a" and b* values. Similar results for L*, a*, and b* were supported by Wani et al. [16] for pan roasted arrowhead.

3.3.3. Proximate Composition. The nutritional composition of sand roasting can be assessed by analysing the proximate composition of chickpea flour. Table 5 demonstrates a considerable drop in moisture content as the time and temperature of sand roasting flour is increased. In the current study, it was revealed that the moisture content of control sample (7.93%) was more than the samples roasted at 180°C, 200°C, and 228°C had 6.03%, 4.16%, and 3.47%, respectively. However, studies have showed the lowest

Table 4: Color characteristics of sand roasted *sattu*.

Parameters	*Control flour*	*Roasted flour*		
	C_o	B_{15}	I_{10}	H_{10}
L*	87.52 ± 0.85^a	83.46 ± 0.39^b	81.66 ± 0.09^c	79.50 ± 0.41^d
a*	1.72 ± 0.49^c	3.62 ± 0.36^b	3.90 ± 0.10^b	5.60 ± 0.19^a
b*	23.38 ± 0.85^c	24.65 ± 0.07^b	25.44 ± 0.46^b	26.75 ± 0.24^a

The results are presented as mean ± SD, $n = 3$. Values in a row with distinct superscripts differ significantly ($p \leq 0.05$).

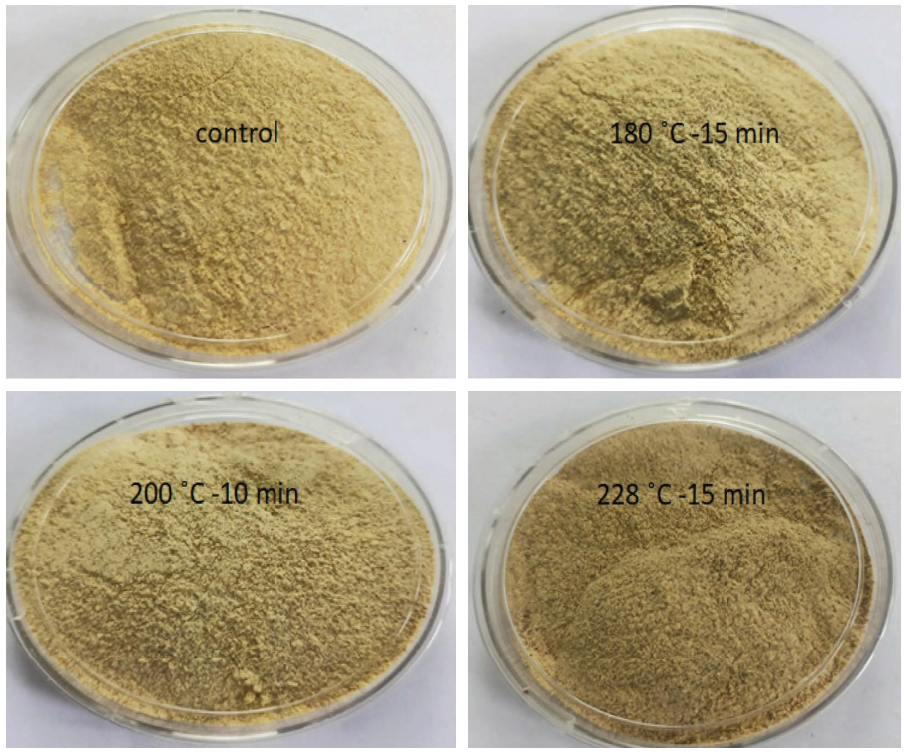

Figure 2: *Sattu* samples roasted at different temperature-time combinations.

Table 5: Proximate composition of sand roasted *sattu*.

Parameters	*Control flour*	*Roasted flour*		
	C_o	B_{15}	I_{10}	H_{10}
Moisture content (%)	7.93 ± 0.42^a	6.03 ± 0.88^b	4.16 ± 0.82^c	3.47 ± 0.30^c
Ash content (%)	3.66 ± 0.57^a	3.56 ± 0.72^a	3.20 ± 0.85^a	2.81 ± 1.00^a
Fat content (%)	5.93 ± 0.66^a	5.16 ± 0.87^a	5.06 ± 0.96^a	4.45 ± 0.76^a
Crude fibre (%)	2.98 ± 0.21^c	3.15 ± 0.19^c	3.47 ± 0.11^b	3.93 ± 0.04^a
Total carbohydrate (%)	59.53 ± 0.56^b	60.94 ± 0.72^b	61.15 ± 1.02^b	63.24 ± 1.20^a
Protein (%)	26.65 ± 0.10^a	26.39 ± 0.53^{ab}	26.13 ± 0.27^{ab}	26.04 ± 0.01^d

The results are presented as mean ± SD, $n = 3$. Values in a row with distinct superscripts differ significantly ($p \leq 0.05$).

moisture content in food product is favorable feature as it reduces the microbial activity and also improves product quality and shelf durability. It was observed that there is a decrease in the content of ash with an increased time and temperature of sand roasting, controlled flour had 3.66% ash content which was decreased to 2.81% during roasting at 228°C for 10 mins (H_{10}). Raigar et al. [25] demonstrated that the increase in carbohydrate content may be offset by a decrease in the content of ash in the roasting process. The control flour has fat content (5.93%) which was more than the roasted samples as presented in Table 5; the roasted samples had 5.16% at 180°C for 15 mins (B_{15}), 5.06% roasted at 200°C for 10 mins (I_{10}), and 4.45% roasted at 228°C for 10 mins (H_{10}). During open dry heat treatment, volatile oils are lost, which may account for the drop in fat content during roasting, could cause a significant reduction in fat content [32]. Similar trend of findings was also supported by Pandey and Awesthi [33] for fenugreek seed. The crude fibre content of a food sample is the amount of indigestible carbohydrates present [34]. It was noticed that the crude

fibre content of the roasted sample (3.93%) when roasted at 228°C was higher than that of the controlled sample (2.98%). The concentration of components after roasting, which is induced by moisture loss, results in an increase in fibre content in roasted flour [35]. The total carbohydrate content of chickpea flour was also measured, and it was observed that as the temperature of sand roasting rises, the carbohydrate content rises significantly ($p \leq 0.05$) from 59.53% to 63.24%. The gelatinization of starch could be responsible for the increase in total carbohydrate content during wheat sand roasting, resulting in an increase in overall carbohydrate content [36]. Similar trend of results was supported by Wani et al. [37] in chest nut. In the current study, it was revealed that the control samples had the maximum protein content value of 26.65%, which was reduced insignificantly ($p \leq 0.05$) by raising the sand temperature.

3.4. Functional Properties. Functional properties including WAC, OAC, WAI, and WSI respectively are shown in Table 6. WAC significantly ($p \leq 0.05$) increases from 2.78–4.12 g/g upon sand roasting. Lowest water absorption capacity 0.87 g/g was revealed for control flour while maximum water absorption capacity 4.12 g/g was found for roasted sample at 228°C for 10 mins (H_{10}). Gelatinization facilitates the increasing capacity of water absorption that may be caused by damage to starch molecules during roasting [37]. Due to the porosity nature of seeds, water penetrates the seeds and is kept inside through capillary action, resulting in an increase in water absorption capacity [4]. Similar findings are also reported by Jogihalli et al. [18]. OAC of roasted sample significantly increased from 2.55–3.14 g/g with an increasing sand temperature, while the lowest OAC was observed in controlled sample (1.32 g/g). Roasting causes protein dissociation and increases polar and nonpolar binding sites, resulting in an increase in OAC. It is affected by the solubilization and dissociation of proteins into subunits, as well as the increase or decrease in polar and nonpolar binding sites [38]. Similar trend of increase was found for the oil absorption capacity of roasted sweet chest nut [37].

WAI increases significantly ($p \leq 0.05$) during sand roasting with different time and temperature combination. The water absorption index of unroasted sample was observed to be 2.05 g/g while the roasted samples had 2.97 g/g roasted at 180°C (B_{15}), 3.06 g/g roasted at 200°C (I_{10}), and 3.57 g/g roasted at 228°C (H_{10}), respectively. However, water solubility index showed nonsignificant decrease by roasting. The accessibility of hydrophilic groups and the propensity of macromolecules to form gel after roasting may increase in water absorption index. The development of insoluble substance during roasting could explain the decrease in water solubility index [39]. The degree of starch conversion is also determined using the water-soluble index. It also shows how much soluble polysaccharides have been freed from starch granules after roasting. The increase and decrease in WAI and WSI was also supported by Hatamian et al. [40] and Jogihalli et al. [18] for roasted chia seed flour and sand roasted chickpea flour, respectively.

Sand roasting of chickpea grains reduces the foaming capacity significantly from 28.78 to 9.10% as shown in Table 6. Stability of foam was highest (21.48%) in control sample while the roasted sample (0.15%). The foaming capacity and stability may be affected by a variety of parameters, includes protein type, temperature, and manufacturing process. Proteins are often responsible for foaming properties, and their solubility is reduced as a result of heating, which could explain why roasted samples have a lesser foaming ability [41]. The foam stability was severely reduced to 0%, implying that heat caused protein denaturation, which results in the loss of foams [42]. Similar trend of results were supported by Wani et al. [16] for arrow head flour.

3.5. Antinutritional Properties of Sand Roasted Sattu. Among various antinutritional factors is presented in Table 7. Sand roasting of chickpea flour shows highest decrease in the content of tannins (4.07 mg/g) at 228°C as compared to the controlled sample having tannins content of 6.65 mg/g. The heat labile and water-soluble properties of tannins may be responsible for the decline [43]. The decline in tannins content was also supported by Khattab and Arntfield [44] for roasting of legumes. Phytate is an essential component of legumes that has the ability to chelate divalent cationic minerals such as calcium, magnesium, and zinc. These chelates render the element nutritionally inaccessible, resulting in dietary insufficiency and also prevent the action of enzymes. It was revealed that the phytic acid of *sattu* significantly ($p \leq 0.05$) reduced from 86.78 mg/100 g to 84.02 mg/100 g with an increasing temperature of sand roasting. Similar findings were observed of reduced phytic acid levels supported by Adegunwa et al. [45] for thermal processing of beniseed flour. The lowering of phytic acid content is aided by the formation of insoluble complexes between phytate-protein and phytate-protein-mineral complexes. Process of roasting can be an efficient technique to minimise phytic acid while also enhancing nutritional bioavailability in particular cereal grains [46]. The poorer water extractability of phytates due to heating procedures may account for the reduced phytic acid in sand roasted flour [47].

3.6. Antioxidant Properties. The TPC of native and treated sample is shown in Table 8. The mallard products are formed during roasting which contributes to antioxidant activity. Control sample had 11.58 (mgGAE/g), while the TPC of flour samples roasted at 180°C for 15 mins (B_{15}) increases slightly 8.94 (mgGAE/g). In case of roasted samples at 200 and 228°C, TPC value decreased steadily by increased time and temperature of sand roasting. Heat-induced extractable phenolics are responsible for the rise in TPC at lower roasting temperatures [18]. Similar trend of results are also supported by Wani et al. [16] for arrowhead. However, thermal degradation and oxidation of phenolic substances occurs at higher temperature and longer roasting time [48]. This process also involves polymerization and the formation of insoluble molecular weight molecules like melanoidins

Table 6: Functional properties of sand roasted *sattu*

Parameters	Control flour	Roasted flour		
	C_o	B_{15}	I_{10}	H_{10}
WAC (g/g)	0.87 ± 0.03^{c}	2.78 ± 0.23^{b}	3.38 ± 0.90^{ab}	4.12 ± 0.08^{a}
OAC (g/g)	1.32 ± 0.36^{b}	2.55 ± 0.53^{a}	2.80 ± 0.07^{a}	3.14 ± 0.04^{a}
WAI (g/g)	2.05 ± 0.57^{b}	2.97 ± 0.18^{a}	3.06 ± 0.14^{a}	3.57 ± 029^{a}
WSI (%)	0.43 ± 0.10^{a}	0.27 ± 0.01^{b}	0.24 ± 0.03^{b}	0.20 ± 0.03^{b}
Foaming capacity (%)	28.78 ± 0.44^{a}	15.80 ± 0.61^{b}	12.60 ± 0.17^{c}	9.40 ± 0.44^{d}
Foam stability % after 10 min	21.48 ± 0.42^{a}	2.06 ± 0.11^{b}	2.16 ± 0.03^{b}	0.15 ± 0.01^{c}
Foam stability % after 30 min	17.92 ± 0.81^{a}	0.52 ± 0.30^{b}	0.50 ± 0.07^{b}	0.00 ± 0.00^{b}
Foam stability % after 60 min	12.08 ± 0.22^{a}	0.25 ± 0.03^{b}	0.19 ± 0.01^{bc}	0.00 ± 0.00^{c}
Foam stability % after 90 min	8.28 ± 0.14^{a}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}

The results are presented as mean ± SD, $n = 3$.

Table 7: Antinutritional factors of sand roasted *sattu*.

Parameters	Control flour		Roasted flour	
	C_o	B_{15}	I_{10}	H_{10}
Tannins (mg/g)	6.65 ± 0.31^{a}	6.10 ± 0.17^{b}	5.80 ± 0.21^{b}	4.07 ± 0.17^{c}
Phytic acid (mg/100 g)	86.78 ± 0.47^{a}	85.26 ± 0.26^{b}	85.02 ± 0.04^{b}	84.76 ± 42^{b}

The results are presented as mean ± SD, $n = 3$. Values in a row with distinct superscripts differ significantly ($p \leq 0.05$).

Table 8: Antioxidant properties of sand roasted *sattu*.

Parameters	*Control flour*		*Roasted flour*	
	C_o	B_{15}	I_{10}	H_{10}
TPC (mg GAE/g)	11.58 ± 0.56^{a}	8.93 ± 0.37^{a}	8.53 ± 0.33^{b}	5.19 ± 0.32^{c}
DPPH (% inhibition)	17.74 ± 0.82^{a}	12.13 ± 0.75^{b}	12.04 ± 41^{c}	7.24 ± 0.65^{d}
Reducing power (% reduction) at 120 μL	24.42 ± 0.40^{c}	24.51 ± 0.45^{c}	25.23 ± 0.06^{b}	27.67 ± 0.33^{a}
Reducing power (% reduction) at 170 μL	25.33 ± 0.14^{d}	30.20 ± 0.10^{c}	32.39 ± 0.14^{b}	38.03 ± 0.58^{a}
Reducing power (% reduction) at 220 μL	28.89 ± 0.66^{d}	36.15 ± 0.71^{c}	39.19 ± 0.63^{b}	44.42 ± 0.47^{a}

The results are presented as mean ± SD, $n = 3$. Values in a row with distinct superscripts differ significantly ($p \leq 0.05$).

and polycyclic aromatic hydrocarbons have negative impact on TPC. The % DPPH of chickpea roasted flour significantly ($p \leq 0.05$) reduced to 7.24%, while the controlled chickpea flour (17.74%). The drop-in antioxidant activity is owing to a fall in phenolic content, which is not balanced by mallard reaction products [49]. The compound of mallard includes (5-hydroxymethyl1-2-furaldehyde) are also generated during process of roasting and also contributes to antioxidant characteristics, according to research [4]. It was observed that the control and roasted flour had reducing power are in the range of 24.42%–27.0.33%, 25.33%–38.03%, and 28.89–44.42% for samples roasted at 180°C, 220°C, and 228°C, respectively. Melanoidins generated during roasting may cause a reduction in the roasted samples' potency. Products which are formed during mallard reaction in the reducing power which are formed during sand roasting, was improved [50]. The increasing % of reducing power was also supported by Baba et al. [51] for roasted barley flour.

3.7. Thermal Property. Thermal property of samples is presented in Table 9. T_o (onset temperature) significantly ($p \leq 0.05$) decreases from 64.51 to 55.49°C between control and roasted flour. Also, the T_c (conclusion temperature) and (T_p) peak temperature decreases (70.86–64.55°C, 67.99–58.54°C) as we increase the temperature of sand. Gelatinization range of roasted chickpea flour increases from 5.48°C to 9.05°C, respectively. Lower transition temperatures are caused by the formation of tiny polysaccharides (sugars), degradation of crystalline formation that are relatively weak, and reduction in amylopectin concentration, all of which contribute to a lower range of gelatinization temperatures. Sand roasting results in decreased in enthalpy (ΔH) ranges from 6.11 to 2.86 (J/g). The drop in enthalpy (H) is related to the loss in the content of amylopectin during roasting. Similar trend of results were also supported by Sharma and Gujral [4] for roasted barley.

3.8. Fourier Transfer Infrared Spectroscopy (FTIR). From 400 to 4000 cm^{-1}, FTIR spectra of native and treated chickpea *sattu* were examined. The spectral patterns of control and roasted *sattu* shows similarity, indicating that no additional components were formed (Figure 3). On the basis of data collected, the total spectrum can be classified into eight regions: 3600–3200, 2900–2800, 2400–2100, 1700–1400, 1400–1200, 1200–1000, 1000–800, and 800–600 cm^{-1}. Due to the oxidation reaction of flour, the dale observed at 3600–3200 cm^{-1} in all treated samples showed a reduction in degree of unsaturation. The peak area 3176.46 and

Table 9: Impact of sand roasting of flour on DSC.

Roasting temp (°C)	Starch gelatinization				Gelatinization range
	T_0°C	T_P°C	T_C°C	ΔH (J/g)	T_C-T_0
C_o	64.51 ± 0.53^a	67.99 ± 14.64^a	70.86 ± 0.65^a	6.11 ± 0.18^a	5.48 ± 0.00^d
B_{15}	64.06 ± 0.14^a	66.41 ± 1.16^a	69.60 ± 1.52^a	4.58 ± 0.90^b	5.53 ± 0.00^c
I_{10}	59.46 ± 0.50^b	60.71 ± 0.86^b	65.08 ± 0.04^b	4.27 ± 0.21^b	5.61 ± 0.00^b
H_{10}	55.49 ± 0.43^c	58.54 ± 0.54^c	64.55 ± 0.44^b	2.86 ± 0.34^c	9.05 ± 0.00^a

The results are presented as mean ± SD, $n = 3$. Values in a column with distinct superscripts differ significantly ($p \leq 0.05$).

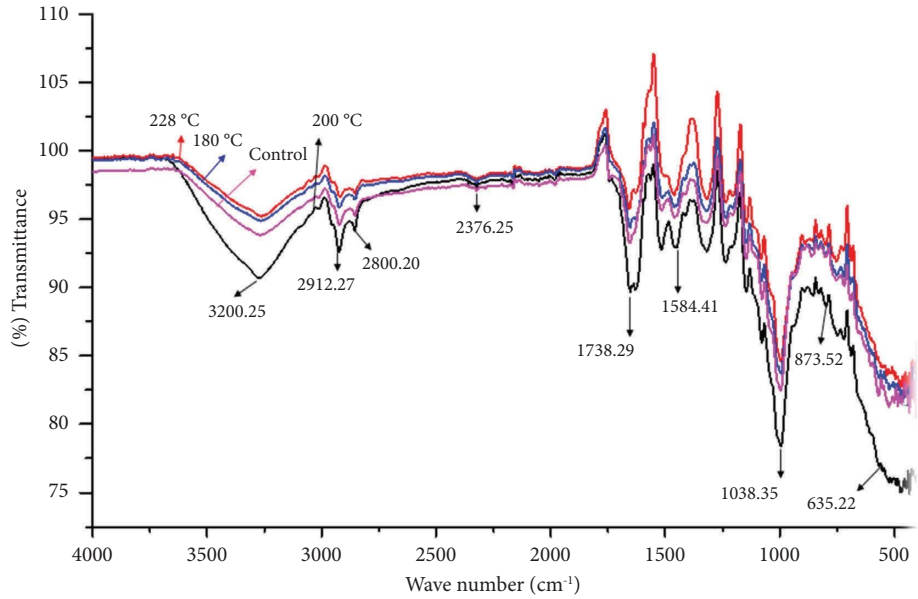

Figure 3: FTIR spectrum of sand roasting *sattu*.

2912.27 cm^{-1} observed in this study defines the stretching vibration of the C-Hcis-olefinic group. The lipid, olefinic, and alkene makeup of flour and grains are altered during the roasting process [18]. A dale may be seen in the 2900–2800 cm^{-1} region, while split peaks can be seen in the 2400–2100 cm^{-1} region, indicating changes in aliphatic groups and structures of amines. Time and temperature conditions, on the other hand, can affect absorption units, dale depth, and peak sharpness. Joghilli et al. [18] found that roasting had a significant effect on anhydrides, amides, amino acids, lactones, aldehydes, and esters groups in coffee. Changes in these compounds on absorption bands 1700–1400 cm^{-1} and 1400–1200 cm^{-1} occurr in the current investigation as well.

Increasing the degree of roasting of almond nuts from light to medium improved the percent transmittance at 1000–1200 cm^{-1} due to ester compounds [52]. Changes associated with N-O pyridine, esters, ethers, t-butyl groups, and lactones can be seen in the designated range 1400–1200 cm^{-1}. When roasted flour of chickpea was compare to control flour, the spectral region of FTIR 1200–1000 cm^{-1} shows different valleys and peaks with variable absorbance, indicating the C-C and C-O stretching modes, as well as C-O-H bending modes, are the most important absorption bands related to structural changes in starch. Techniques of cooking includes parboiling, in which food is exposed to higher temperatures, transform starch molecule to their retrograde and ruptured forms, disrupting chemical connections while also lowering vibrational activity [48]. In the presence of dicarbonyl chemicals or lipid peroxidation products, oxidative decarboxylation of parent amino acids results in the production of conjugated amines, the number of biogenic amines increases during roasting (formed because of high temperature). Wani et al. [16] found that the production of alkene groups and melanoidins increased absorbance in roasted wheat samples throughout a broad range of 1000–650 cm^{-1}. Treaments have been defined of this investigation; higher peak intensity was seen in the 1000–800 cm^{-1} area, which is normally attributed to R-NH2 of primary amines. Oracz and Nebesny [53], observed the impact of temperature and duration upon roasting on amines. In comparison to native flour, roasted samples showed peaks in the spectrum band 800–600 cm^{-1}, which is related with the C-Hmeta-disub benzene aromatic bond. The alteration and synthesis of aromatic chemicals as a result of the roasting process is one of the sources of the observed variance. In addition, the strength of IR absorption in samples varied depending on time and temperature treatments. Wani et al. [16] also documented variations in this region, with a rise in single bond OH groups, changes in amylopectin starch component, and sample gelatinization in microwave roasted samples, implying a rise in single bond

OH groups, changes in amylopectin starch component, and sample gelatinization.

4. Conclusion

The physical, functional, thermal, and spectral characteristics of chickpea grains were significantly affected by roasting. After roasting of grains, the color changes from light yellow to light brown. It was observed that significant increment was observed in the water absorption capacity of roasted samples; however, water solubility index and properties of foam shows significant decrease in roasting. High activity of DPPH was observed at intermediate time-temperature combination. The roasted samples were observed to be free from the antinutritional factors thereby improving gastrointestinal functions and metabolic performance. As roasting enhances the organoleptic characteristics without compromising the nutritional value, it may extend the shelf stability of the product. As a result, the current study identified significant parameters that could aid in the design and improvement of chickpea grain handling and processing equipment.

Data Availability

The data used to support the study are available from the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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