Effect of germination and roasting on the proximate composition, total phenolics, and functional properties of black chickpea (Cicer arietinum)

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Abstract
Germinated and microwave roasted black chickpea were evaluated for physical, proximate, pasting, functional, and antioxidant properties. A significant variation was observed in quality of grain upon germination and roasting. The effect of germination and roasting on functional groups was analyzed using Fourier-transform infrared spectroscopy. The results showed that germination improved the physical and pasting properties, whereas roasting enhanced the functional properties. The lightness of germinated grains significantly improved as compared with dark colored roasted sample. The germinated sample was found rich in protein, whereas carbohydrates and fiber content increased in roasted sample. Water and oil absorption content were reduced by 7.14% and 5.13% in germination as compared with control. However, roasting significantly improved the water absorption capacity and oil absorption capacity by 69.51% and 6.41% as compared with control.

KEYWORDS
black chickpea, functional properties, germination, microwave roasting, pasting properties

1 | INTRODUCTION

Black chickpea (BC; Cicer arietinum) is one of the essential legumes grown all over India. The production of BC in India at present is 2.926 million metric tons with a yield of 651 kg/ha (Directorate of Pulses Development, 2017). As a good nutritional source of carbohydrates, protein, essential amino acids, polyphenols, and dietary fiber, BC has huge potential for consumer market as baked goods, snacks, soups, and ready-to-eat foods (Bravo, Siddhuraju, & Saur-Calixto, 1999; Kon & Burtea, 1979; Singh, Kaur, Sandhu, & Guraya, 2004). The snacks prepared from BC are very feasible in Indian subcontinent due to wide availability, sweet taste, and low cost. Other legumes are still underutilized due to their undesirable beany flavors (Walker & Kochhar, 2007) and the presence of anti-nutritional compounds such as trypsin inhibitors (Salunkhe, 1982). Germination and roasting are the two commonly and extensively used methods for the preparation of snacks and ready-to-eat foods. These processes are also known to reduce trypsin inhibitors and antinutrition compounds (Malomo, Alamu, & Oluwajoba, 2014; Daun & Malcolmson, 2003; Gupta & Wagle, 1980; Wang, Hatcher, Toews, & Gawalko, 2009; Vijayakumari, Sidduraju, Pugalenthi, & Janardhanan, 1998). Moreover, germination and roasting simplified the complex compounds to improve the nutritional value and reduce the unacceptable flavor.

Germination is a slow natural biochemical phenomenon that occurs at low temperature and changes the metabolic activities and digestibility of carbohydrate (Dueñas et al., 2016; Wu, Yang, Touré, Jin, & Xu, 2013). It enhances the protein content, antioxidants, and bioavailability of nutrients (Singh, Sharma, & Singh, 2017). On the other hand, roasting is a high temperature controlled time process known to improve the digestibility, shelf life, and antioxidant
properties (Dueñas et al., 2016). Exposure at high temperature leads upon roasting to development of characteristic flavor, taste, and crispy texture in grains that allure the consumers (Jogihalli, Singh, Kumar, & Sharanagat, 2017). In addition, germination and roasting improve the functional properties of grain/legumes, which affects their processing applications, quality, acceptance, and formulation of the potential ready-to-eat snack foods (Ma et al., 2011). Germination and roasting also affect the pasting properties that decide the textural characteristics of cooked legumes, whereas the thermal properties help in designing the process parameters.

In India, germination and roasting are two most commonly used cooking method for preparation of chickpea snacks. Germination and roasting have been extensively studied, but no comparative study has been reported on BC that can provide better insight about potential of these two methods. Hence, the present study was aimed to compare the effect of germination and microwave roasting in terms of physic-functional and antioxidant properties of BC and explore the potential of both methods.

2 | MATERIALS AND METHODS

2.1 | Material

BC grains were collected from Reliance Fresh food outlet, Narela, Delhi, India. The grains were manually cleaned to remove broken and unwanted foreign materials. The initial moisture content of BC grain (11.7 g/100 g) was determined by using hot air oven method (Association of Official Analytical Chemists, 1984).

2.2 | Method of analysis

Chickpea grains were soaked in water (water: grain ratio, 2:1) for 10 hr at room temperature. Soaked grains were kept in jute bag for 12 hr to facilitate germination. Germinated grains were dried in hot air oven for 24 hr (45°C). For roasting, cleaned grains were placed microwave (Samsung CE104VD-B microwave of 230 V-50 Hz AC, 2450 MHz) at 600 W for 10 min. On the other hand, germination soaking temperature and time were considered based on the most common method used by people, whereas microwave roasting power and time were selected based on the previous study of Jogihalli, Singh, and Sharanagat (2017). Roasted and dried germinated grains were ground to flour using mixer grinder. The flour was sieved (BIS212 sieve), and the grounded flour samples were packed tightly in aluminum packets till further analysis.

Physical properties (surface area [S] and sphericity [q]) of control, roasted, and germinated samples were determined by measuring the three major dimensions, that is, length (L), width (W), and thickness (T) as described by Sharanagat and Goswami (2014). The proximate composition, that is, moisture, protein, fat, fiber, and ash of the control, roasted, and germinated BC flour was analyzed using the standard method of American Association of Cereal Chemists (2000). Total carbohydrate (%) was calculated by subtracting the sum of other components (moisture, protein, fat, fiber, and ash) from 100. The color of powdered samples was determined by CIE color scales using hand hold Chroma meter (Konica Minolta, CR-400, Japan) as described by Jogihalli, Singh, Kumar, and Sharanagat (2017).

Pasting and Fourier-transform infrared spectroscopy (FTIR) analysis of control, germinated, and roasted chickpea flours were performed using a rheometer (MCR 302, Anton Paar, Austria) and FTIR spectrophotometer (ALPHA Bruker), respectively, as described by Sharanagat, Kumar et al. (2019). In brief, pasting properties were determined using 24-mm starch probe (ST24-2D/2V/2V-30, Antonpar). BC flour (2 g) was mixed with water (16.66 g) and was equilibrated for 1 min (50°C). The blend was heated from 50°C to 95°C (6°C per minute rate) followed by incubation at 95°C (5 min), cooling to 50°C (6°C per minute rate). Further incubation was performed at 50°C for 2 min. For FTIR analysis, flour samples were directly put over the attenuated total reflection (ATR) plate, and spectra were observed for each sample in the infrared range from 4,000 to 400 cm⁻¹ at a 4 cm⁻¹ (24 scans).

The functional properties including bulk density (BD), water absorption capacity (WAC), and oil absorption capacity (OAC) of germinated and roasted BC flour were determined using modified method of Elkhalfa and Bernhardt (2010).

The total phenolic content (TPC) was determined by the Folin–Ciocalteu method. A 200 mg of flour sample was mixed with 4 ml acidified methanol (methanol : HCl: water, 80:1:9) and kept in a shaking incubator at 40°C for 2 hr. The sample was centrifuged at 10,000 rpm, and the supernatant was separately stored from the rest of the sample. Afterwards, the clear extracts were collected in test tubes, wrapped with aluminum foil, and stored at 4°C for further analysis.

In a 0.2 ml of sample extract, 2.5 ml freshly diluted (10-fold) Folin–Ciocalteu reagent was added and allowed to stand for 5 min. Then, 2 ml of 7.5 g/100 ml sodium carbonate solution was added. The mixture was then allowed to stand for 30 min at room temperature, and the absorbance was measured at 760 nm against reagent blank using UV/VIS spectrophotometer (Shimadzu, UV-2600, Japan). The total phenols of samples were estimated by using a calibration curve of Gallic acid, and the results were expressed as milligram of Gallic acid equivalent per gram dry weight. For the calibration curve, standard series of known concentration of Gallic acid (0, 10, 20, 30, 40, 50, and 60 mg/L) in methanol was prepared and thereafter treated in same way as the sample.

2.3 | Statistical analysis

All the experiments were carried out in triplicates, and analysis of variance was performed. The significance of difference was defined at p < .05. The mean was compared by Duncan’s multiple range tests. The analysis was performed by using an SPSS package (SPSS 17.0, SPSS Inc., Chicago, IL). The principle component analysis was performed using graphing and analysis software Origin (OriginPro, 2017, OriginLab, USA).
RESULTS AND DISCUSSION

3.1 | Physical properties

The effect of germination on surface area and sphericity of BC is presented in Table 1. The surface area of control BC was found to be 244.31 mm² and changed significantly (p < .05) after roasting and germination. Germination led to an increase, whereas roasting reduced the surface area by 42.84% and 15.21%, respectively. The sphericity of BC was significantly (p < .05) increased with the roasting of chickpea, whereas nonsignificant variation was observed in germination. The highest sphericity 0.87 was observed for the roasted BC. The increase in surface area upon germination is due to the increase in moisture content during hydration, which leads to swelling of BC grain. The results were also supported by the germination of moong (Sharanagat, Kumar et al., 2019). On the other hand, reduction in surface area in microwave roasting is justified by removal of water from BC matrix. Moreover, the breakdown of complex structure during roasting shrinks the structure of BC grains. The results are in line with the reported value for surface area of microwave roasted sorghum by Sharanagat, Suhag et al. (2019). However, Jogihalli et al. (2017) and Kumar, Haq, and Prasad (2016) have reported significant increase in surface area of sand roasted chickpea and extra thin flaked rice, respectively. This might be due to the puffing of food grain with the increase in roasting power and time.

3.2 | Proximate analysis

The effect of germination and roasting on nutritional significance of BC can be assessed by the help of proximate analysis. The proximate composition varied significantly (p < .05) with roasting and germination of BC (Table 2). The germination significantly increased the protein and ash content, but nonsignificant effect was observed on the fat, fiber, and carbohydrate content. On the other hand, roasting significantly reduced the protein, ash, and carbohydrate content. The protein content of BC was found to increase by 7.43% upon germination but reduced by 14.8% with roasting process. The highest carbohydrate content (67.3%) was observed for the roasted BC and lowest (64.0%) for germinated BC, but these differences were found to be nonsignificant. Also, the fiber content of BC varied significantly upon roasting, whereas nonsignificant effect was observed with germination, in comparison with control BC.

Germination led to the production of amino acids and enhanced the crude protein content, which increased the amount of overall protein (Tarasevičienė, Danilcenko, Jarienė, Paulauskienė, & Gajewski, 2009; Uwaegbute, Iroegbu, & Eke, 2000). Contrarily, roasting resulted in a reduction of protein content and might be due to the denaturation of protein and loss of nitrogenous volatile compounds at high temperature (Wani, Hamid, Hamdani, Gani, & Ashwar, 2017). The increase in carbohydrate content of BC upon roasting was found to be in accordance with the results reported by Oboh, Ademiluyi, and Akindahunsi (2010) for the roasting of yellow and white maize. They reported that the carbohydrate content is calculated by the method/formula of difference, and hence, the increase in carbohydrate content upon roasting might be due to the decrease taking place in fat, protein, ash, and moisture contents during the roasting process. The significant variation in fiber content upon roasting is related to process temperature and heating mechanism (Liao, Zhao, Xu, Gong, & Jiao, 2019). The findings were supported by Liao et al. (2019) for roasting of cashew nut kernels. They reported an increase in fiber content associated with high temperature of roasting. Ren, Wei, Zhang, and Chen (2008) concluded that the increase in temperature above 170°C led to an increase in fiber content of oat upon roasting. The result of germination and roasting on proximate composition is also in agreement with the reported value of germinated cowpea (Uwaegbute et al., 2000), germinated sorghum flour (Singh et al., 2017), germinated Chenopodium flour (Jan, Saxena, & Singh, 2018), microwave roasted chestnut (Wani et al., 2017), and thermal roasted lentil, chickpea, and pea flours (Ma et al., 2011).

3.3 | Color analysis

Color is an important parameter which mainly attracts the consumer. Color parameters significantly (p < .05) varied with roasting process, whereas germination had nonsignificant effect on color of BC (Table 1). The “L*” value increased (95.02–97.16) with germination and reduced (95.02–68.68) with roasting, and the highest value of “L*” (97.16) was observed for germinated BC. The trend of increase in “a*” value was associated with roasting and germination (raw < germinated < roasted), whereas “b*” value increased with roasting process only and exhibited a reduction trend with germination (raw > germinated < roasted). The total color difference reduced by 17.88% upon
germination and increased by 17.88% upon roasting, in comparison with the control sample. The change in color of roasted BC might be due to the caramelization and browning reaction (Moss & Otten, 1989; Wani et al., 2017). Additionally, the enzymatic and non-enzymatic browning at high temperature roasting led to the formation of brown pigment, which further reduced the lightness. On the other hand, reduction in color properties in germinated samples might be due to change in carbohydrates and protein hydrolysate (Tian et al., 2010). The results of present study were also supported by Tian et al. (2010) for germinated oat seed, Wani et al. (2017) for chestnut, and Sharanagat, Suhag et al. (2019) for sorghum.

3.4 Pasting properties

The effects of germination and roasting on pasting properties, that is, peak viscosity, holding viscosity, breakdown viscosity, final viscosity, setback from through, setback from peak, and pasting temperature of black gram flour are presented in Table 3. The peak viscosity, which is related to the swelling of starch, decreased from 1,020 to 615.70 cP after germination; almost 40% reduction was observed. Compared with germination, roasting drastically reduced the peak viscosity, and 90.95% reduction was observed. The reduction after germination might be due to the enhanced destruction starch upon activation of enzymes during germination (Charoenthaikij et al., 2009; Cornejo & Rosell, 2015). On the other hand, the reduction in peak viscosity after roasting might be due to the change in gelatinization and retrogradation temperature of starch granules causing their rupture, even at low water absorption, which reduced the degree of polymerization during gelatinization (Kumar et al., 2018; Liu, Ying, Xue, & Shi, 2012). The pasting temperature of roasted BC flour was found to reduce from 71.53 to 49.51, indicating lower resistance towards swelling. The trough viscosity decreased from 762.3 to 461 cP and 762.3 to 33.94 cP after germination and roasting, respectively. This can be correlated with the breakdown of starch granules at higher cooking temperature (Andrabi, Wani, Gani, Hamdani, & Masoodi, 2016). The breakdown viscosity, which is related to the fragility of starch granules, also decreased drastically for roasted sample by 93.50% as compared with raw, indicating that roasted BC flour was more resistant to shear thinning during cooking (Wani et al., 2017). Final viscosity is ability to form viscous paste during cooling of cooked paste and was found to be reduced by 35.79% and 94.66% respectively for germinated and roasted BC as compared with raw BC. The setback viscosity, which is related to the retrogradation of starch, also reduced drastically for roasted sample, indicating higher resistance of roasted starch to rearrangement and reorientation (Clifford, Chika, Jude, & Tochi, 2014). The trend of pasting properties of germinated BC flour is in agreement with the reported values of Jan et al. (2018) for germinated Chenopodium, Sharanagat, Kumar et al. (2019) for germinated moong, and Cornejo and Rosell (2015) for germinated rice flour, whereas the pasting values for roasted BC flour are supported by Wani et al. (2017) for microwave roasted chestnut and Sharanagat, Suhag et al. (2019) for microwave roasted sorghum flour.

3.5 FTIR analysis

The effect of germination and roasting on major functional groups of BC flour was observed in terms of change in absorbance unit and types of peaks of FTIR spectrum as given in Figure 1. It was observed that spectrum pattern for germinated and roasted sample was almost same with main variation observed in absorbance units. The broad region 3,500–3,000 cm⁻¹ that appeared was due to O–H stretching vibration from starches and starch–proteins interaction and also from various compound like alcohol, phenols, and carboxylic acid. The absorbance in this region increased after roasting of BC and might be due to the dissociation of complex compounds into subunits, which may increase the number of O–H groups, hence changes the absorbance unit. The occurrence of a peak at 2,915 cm⁻¹ only in roasted sample confirmed the development of more C–H bonds, possibly

### TABLE 2 Effect of germination and roasting on proximate composition of black chickpea

| Sample       | Protein (mg/100 mg dry mass) | Fat (mg/100 mg dry mass) | Fiber content (mg/100 mg dry mass) | Ash content (mg/100 mg dry mass) | Carbohydrate content (mg/100 mg dry mass) |
|--------------|-----------------------------|--------------------------|-----------------------------------|---------------------------------|------------------------------------------|
| Raw          | 14.8 ± 0.62                 | 5.2 ± 1.69               | 10.3 ± 0.90                       | 3.4 ± 0.65                      | 64.8 ± 3.12                              |
| Germinated   | 15.9 ± 0.49                 | 4.6 ± 0.29               | 10.3 ± 1.57                       | 4.1 ± 0.80                      | 64.0 ± 2.87                              |
| Roasted      | 13.0 ± 0.25                 | 5.0 ± 0.57               | 10.8 ± 1.15                       | 2.4 ± 0.16                      | 67.3 ± 0.39                              |

Note. Means ± standard deviation of triplets. Columns with different superscript letters are significantly (p < .05) different.

### TABLE 3 Pasting properties of raw, germinated, and roasted black chickpea

| Sample | Peak viscosity (cP) | Pasting temperature (°C) | Trough viscosity (cP) | Breakdown viscosity (cP) | Final viscosity (cP) | Setback Viscosity (cP) |
|--------|---------------------|--------------------------|----------------------|-------------------------|----------------------|------------------------|
| Raw    | 1,020.00            | 71.53                    | 762.30               | 257.40                  | 1,623.00             | 861.10                 |
| Germinated | 615.70            | 71.90                    | 461.00               | 154.80                  | 1,042.00             | 581.20                 |
| Roasted | 50.66              | 49.51                    | 33.94                | 16.72                   | 86.54                | 52.60                  |
from unsaturated C-bonds. Prominent peaks appeared with higher absorbance at 1,743 cm\(^{-1}\) in roasted sample due to the presence of esters, 1,640 cm\(^{-1}\) due to amide I, and 1,537 cm\(^{-1}\) due to amide II and confirmed the development of desirable flavor and rich aroma (Silverstein, Webster, & Kiemle, 2005; Wani et al., 2017). More peaks appeared in the region 1,000–650, 1,430–1,630, and 1,700–1,200 cm\(^{-1}\), which revealed the presence of alkenes, acetyl, and carboxylic group, respectively. The effect of germination on functional groups is comparable with the reported FTIR analysis of Sharanagat, Kumar et al. (2019) for moong beans. On the other hand, effect of microwave roasting is in agreement with Wani et al. (2017) for microwave roasted chestnut and Jogihalli, Singh, Kumar, and Sharanagat (2017) for roasted chickpeas.

### 3.6 Functional properties

Functional properties like BD, WAC, and OAC play important role in the preparation of baked, fried, cooked snacks as well as flour based drinks and functional foods. The functional properties of BC flour were significantly (\(p < .05\)) affected by germination and roasting processes (Table 4). The BD which is heaviness of the BC flour and their dispensability significantly (\(p < .05\)) decreased after germination (0.52 g/cm\(^3\)) and roasting (0.57 g/cm\(^3\)). The low BD value is always beneficial in the preparation of complementary food (Balogun & Olatidoye, 2010). The decrease in BD after germination might be due to the modification of carbohydrates during germination (Singh et al., 2017), whereas the decrease in BD after roasting was due to the formation of porous structure that increased the porosity along with simultaneous reduction in moisture content due to high temperature. The results of BD are comparable with the reported value of germinated chickpea (Desalegn, 2015), germinated chickpea (Köksel, Sivri, Scanlon, & Bushuk, 1998), germinated sorghum flour (Singh et al., 2017), and germinated rice flour (Chinma, Anuonye, Simon, Ohiare, & Danbaba, 2015).

The WAC of BC flour significantly decreased from 0.82 to 0.76 g/g after germination but increased to 1.39 g/g upon roasting, whereas OAC of BC flour significantly increased with roasting (0.82 g/g) and decrement occurred with germination (0.74 g/g), in comparison with raw sample (0.78 g/g). The higher hydrophilic groups present in protein and carbohydrates are responsible for higher WAC of BC flour. However, the reduction WAC and OAC after germination of BC flour might be due to the enzymatic degradation of starch and fiber that reduce the hydrophilic points. On the other hand, roasting denatured the protein. The dissociation of proteins in simple units exposed the binding sites for water that increased the WAC (Wani et al., 2017). It may also be stated that the reduction observed in fat, protein, and increase in carbohydrate content upon roasting of BC may contribute in an increase in WAC of BC. The possible reason of increase in OAC of roasted sample is dissociation of protein to increase the nonpolar sites that facilitated binding of hydrocarbon chain (Ghavidel & Prakash, 2006). The results of WAC and OAC are supported by Singh et al. (2017) for germinated sorghum flour, Sharanagat, Kumar et al. (2019) for moong, Desalegn (2015) for chickpea, Wani et al. (2017) for microwave roasted chestnut flour, Sharanagat, Suhag et al. (2019) for microwave roasted sorghum flour, and Jogihalli, Singh, and Sharanagat (2017) for roasted chickpeas.

### 3.7 Total phenolic content

TPC are main bioactive compounds that promotes the health benefits. TPC was found to increase significantly after microwave roasting (Table 4). On the other hand, the effect of germination on TPC was positive but nonsignificant. Maximum TPC was observed for roasted sample (11.42 mg GAE/g), 16.41% higher than raw sample. TPC for germinated sample was increased by 2.24% only. The increase in TPC
after germination might be attributed to the enzymatic degradation of kernel structures of BC that helped in extraction of phenolic compounds (Tian et al., 2010). Moreover, roasting led to thermal degradation of cellular constituents due to which bound phenolic released and contributed as an increase in TPC (Jogihalli, Singh, & Sharanagat, 2017). Also, thermal alteration in the chemical structure of molecules associated with phenolic compound enhanced the TPC. The results of present study are comparable with the reported TPC for germinated moong (Sharanagat, Kumar et al., 2019), germination of oat seeds (Tian et al., 2010), roasted Chickpea (Jogihalli, Singh, & Sharanagat, 2017), microwave roasted chestnut (Wani et al., 2017), and roasted sorghum (Sharanagat, Suhag et al., 2019).

3.8 Principle component analysis

Principle component analysis was performed to conclusively visualize the effect of roasting and germination on all the properties of BC. A biplot, which is a combination of score and loading plot, is shown in Figure 2, representing 100% (PC1: 86.46% and PC2: 13.58%) variations. Biplot graphically shows both samples and variables information from data matrix and simultaneously provides the effect of roasting and germination on properties of BC. It can be observed that many properties are highly grouped around germination as well as roasted sample. The properties forming cluster either at germination or roasting are positively correlated with themselves but negatively correlated with properties of other cluster. Roasting process enhanced important properties like WAC, OAC, TPC, and fiber content, whereas germination improved the pasting properties, physical, and lightness of BC sample. Observing the given plot, it can be concluded that in order to gain benefits from BC as functional or complimentary food, roasting process will be a good option. On the other hand, germinated flour have better potential in the development of bakery, confectionary, fried, or texturally important foods.

4 CONCLUSION

It may be concluded that roasting and germination both improve the quality of BC. Roasting led to increase in WAC (0.82–1.39 g/g), OAC (0.78–0.82 g/g), TPC (by 16.41% fold over raw sample), and fiber content (10.3 to 10.8 mg/100 mg dry mass), whereas germination enhanced the pasting and physical properties. Approximately 40% reduction occurred in peak viscosity and trough viscosity upon germination. Germination also favored lightness of BC sample with an increase in “L” value from 95.02 to 97.16. The results show that the roasted BC flour can be used for the development of functional drink or complimentary foods, whereas the germinated BC flour will aid in the development of bakery, confectionary, fried, or texturally important foods.

DATA AVAILABILITY STATEMENT

None.

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