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Effect of banana peel powder on bioactive constituents and microstructural quality of chapatti: unleavened Indian flat bread

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Abstract Effect of banana peel powder (BPP) on the bioactive constituents and micro structural quality of chapatti was evaluated. Chapatti dough prepared from 5, 10, 15 and 20 % BPP was examined for dough stickiness, dough strength, dough kneading and rollability. With increased level of BPP, there was an increase in subjective score in kneading and rollability of chapatti. Dough stickiness was increased while increased dough strength was observed with increased level of BPP. Chapatti incorporated with BPP showed total phenolic content and flavonoid content significantly higher than the control. Chapatti incorporated with 20 % BPP showed DPPH radical scavenging activity up to 68.3 %. The tear force of chapatti prepared from dough added with 5, 10, 15 and 20 % BPP was 414, 404, 393, 356.2 g which was lower than that of control (449 g). The microstructure of chapatti prepared from dough added with 15 % BPP was uniform with solubilised starch granules while in the control starch granules were overlapping on one another to form aggregation. The X-ray diffraction pattern for chapatti incorporated with 15 % BPP showed V-type pattern. Chapatti's prepared from BPP had softer chapatti and better pliability.

Keywords Banana peel powder · Chapatti · Microstructure · Phenolics · Flavonoids

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Introduction

As per the FAO statistics, India is the leading producer of banana in the world and accounts for nearly 30 % of the total world production of banana. Though banana peel is a fruit residue, it accounts for 30–40 % of the total fruit weight and contains carbohydrates, proteins, and fiber in significant amounts [1]. The peels of variety of fruit acts as a natural source of antioxidants, rich in compounds with free radical scavenging activity [2, 3]. The banana peel is underutilized source of natural antioxidants. The peel is rich in compounds such as gallocatechin [4], dopamine, anthocyanins such as delphinidin and cyanidin, and catecholamines [5]. These compounds acts as protective scavengers against oxygen derived free radicals and reactive species that play role in ageing and various diseases. The National Cancer Standard Institute established that the banana peel extract is non-toxic to human cells and therefore can be utilised as a natural source of antioxidants [6]. Moreover, the banana peel is promising for a variety of application in health care industry due to its high fibre content.

Wheat is one of the daily staple foods in India and 90 % of the wheat produced is consumed mainly in the form of chapatti. Softness and flexibility are the most important quality parameters for chapatti. Chapatti is very susceptible to moisture loss and staling after baking [7]. Unfortunately, India is gripped with chronic diseases which are highly prevalent in urban areas [8]. Chapatti is abundant source of dietary fibre that helps in diverticular diseases and reduces constipation and rate of chronic bowl diseases and diet related cancers. Since, chapatti is consumed every meal of the day, with the addition of banana peel powder (BPP) it could be a good vehicle with improved nutritive value.

Therefore, the objective of this study was to develop functional chapatti by incorporating BPP along with its effect on phenolic, antioxidant activity, sensorial and microstructural quality.

Materials and methods

Materials

The banana was procured from the local markets of Mumbai. Branded whole wheat Aashirwad atta was procured from local stores in Mumbai.

Chemicals

Folin–Ciocalteau, 1,1-diphenyl-2-picrylhydrazyl (DPPH), gallic acid, quercetin were of analytical grade from Rankem, India. All chemicals and reagents used in the present study were of analytical grade.

Preparation of banana peel powder

The fruit was separated from the peels. The peels were dipped in 0.5 % citric acid to prevent the enzymatic blackening and were tray dried at 35 °C. Dried peels were ground to make powder and passed from 40 μmesh to obtain a fine powder.

Proximate analysis

The BPP was analysed for proximate composition. Moisture content, protein content with a nitrogen–protein conversion factor of 6.25 and ash content were determined. Fat content was determined by soxhlet method using ethanol as a solvent. Carbohydrate content was calculated from the difference of 100 − [% moisture + % ash + % protein + % fat]. The total dietary fibre contents were estimated according to enzymatic–gravimetric method [9].

Dough characteristics and preparation of chapatti

The whole wheat flour (100 g) was mixed with required amount of water judging the suitability with kneading and rollability containing 2 g of salt and varying concentrations (5, 10, 15 and 20 %) of BPP, all on flour basis. The control dough was prepared without adding the BPP. The dough was kneaded by hand for 10 min and covered with wet muslin cloth and allowed to rest for 15 min. 30 g of dough was taken and rolled into chapatti. The dough was then baked and the hot chapatti was cooled at room temperature and stored in polypropylene pouches [10]. The prepared dough samples were then analysed for dough stickiness using Chen–Hoseney dough stickiness rig test [11] with accessories such as 25-mm Perspex cylinder probe (P/25P), 50-kg load cell and SMS/Chen–Hoseney dough stickiness cell (A/DSC) in stable micro-systems texture analyzer as per the method of [12]. Dough stickiness, work of adhesion and dough strength was the parameters obtained.

Subjective dough scoring

The dough for the subjective scoring was prepared as explained in the above method "Proximate analysis". The panelists were given dough samples of 30 g each and were asked to roll out the chapatti of the fixed diameter (17 cm) and fixed thickness (1/6″). Further the panelists were instructed to give subjective scoring for the dough stickiness and rate the parameters such as dough kneading, dough rollability and puffing in the scale of 5.

Dough colour (L*, a* and b*)

The colour of the control dough and the dough containing 5, 10, 15 and 20 % BPP was measured using Hunter Lab colorimeter model DP-9000 D25A (Hunter Associates Laboratory, Reston, VA) in terms of Hunter *L* (lightness, ranging from 0 to 100 indicating black to white), *a* (+a, redness and −a, greenness) and *b* (+b, yellowness and −b, blueness).

Textural characteristics of chapatti

The shear force of chapatti was evaluated by The Stable Micro Systems TA-XT2i texture analyser according to the method described by Ghodke [12]. The chapatti samples containing 5, 10, 15 and 20 % BPP packed in polypropylene pouches were removed and three strips measuring 3 × 7.5 cm were cut from each of chapatti. One strip at a time was placed between the sample holder and due to the tensile grip probe the chapatti was teared. The force required to tear the chapatti strip was recorded.

Sensory evaluation of chapatti

Sensory evaluation of chapatti made by incorporation of BPP at 5, 10, 15 and 20 % concentrations was carried out using five-point hedonic scale with ten numbers of trained panelists. Sensory panelists were asked to rate and give score for different parameters such as colour/appearance, texture, taste and overall acceptability. Different types of sample were coded with specific code and then panelists were instructed to evaluate the samples for sensory attributes as mentioned above. Five trained panelists evaluated the chapatti for each parameter as: 5—like very much, 4—like very moderately, 3—neither like nor dislike, 2—dislike moderately, 1—dislike very much.

Extraction of polyphenols in banana peel powder and chapatti powder

A 10 g of dried chapati sample was homogenised with 50 ml of ethanol, stirred for 30 min and centrifuged at 5000 rpm for 20 min. The supernatant was filtered and used for estimation of total phenolic, flavonoids and antioxidant activity. The resulting supernatants were pooled and used for the estimation of polyphenol contents and composition and antioxidant properties [13].

Bioactive constituents determination

Total phenolic content

The total phenolic content is based on a chemical reduction of the reagent which is a mixture of tungsten and molybdenum oxides and is determined by Folin–Ciocalteau (FC) colorimetry [14]. An aliquot sample was mixed with 0.5 ml of Folin–Ciocalteau reagent and 7.5 ml deionosed water. The mixture was incubated for 10 min at room temperature for 10 min and then 1.5 ml of 20 % (w/v) sodium carbonate was added. The absorbance was read at 765 nm after 2 h. The total polyphenols content was calculated from standard calibration curve obtained from gallic acid.

Total flavonoid content

The total flavonoid content was determined by colorimetric assay as per the procedure of Sultan et al. [15]. 1 ml of aliquot sample was diluted with 5 ml of distilled water to which 0.3 ml of sodium nitrite (5 % $NaNO_2$, w/v) was added and allowed to stand for 5 min. Later 0.6 ml of aluminium trichloride (10 % $AlCl_3$) was added and incubated for 5 min, followed by the addition of 2 ml of sodium hydroxide (1 M NaOH) and volume was made up to the 10 ml with distilled water. The TFC was expressed in mg of quercetin equivalents per (QE) gram of extract.

Antioxidant activity

The 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) is a stable radical can undergo reduction by antioxidant. It is widespread used in free radical scavenging activity assessment because of its ease and convenience [16]. 5 ml of a solution of DPPH at a concentration of 0.025 g l^{-1} was added to 1 ml of extract. The mixture was shaken and kept in dark for 30 min. The absorbance of the solution was measured at 515 nm against a blank of ethanol without DPPH. The absorbance of DPPH diluted in ethanol was considered as a control.

The antioxidant capacity to scavenge DPPH radical was calculated by the equation

$$\%\,\text{Inhibition} = \frac{C - S}{C}$$

C net absorbance of control, S net absorbance of sample.

Scanning electron microscopy

The dried pieces of chapatti were used to study the microstructure. A Joel Scanning Electron Microscope Model JSM-6380 LA was used. Chapatti pieces were mounted on sample holders with the help of double-sided scotch tape and sputter coated with platinum (2 min, 200 Pa). The preparations were transferred to the microscope where it was observed at 15 kV and a vacuum of 12.99×10^{-3} Pa. Scanning electron micrographs with appropriate magnifications were selected for presentation of results [17].

X-ray diffraction

The X-ray diffraction analysis was performed on a Philips diffractometer (Philips Electronic Instruments, Mahwah, NJ) using 30 kV and 18 mA with Cu Kα radiation. The step scan mode was used with a step size of 0.05° 2θ and a dwell time of 0.02 s at each step [18].

Statistical analysis and graphical representation

The experimental data were treated statistically by Duncan's new multiple range test to determine the significance of results. Standard deviations (SDs) were calculated and graphs plotted using Excel 2007.

Results and discussion

Proximate composition of banana peel powder

The proximate composition of BPP is described in Table 1. The BPP contained significant quantities of ash content (11.10 %) and protein (7.58 %) similar to some of the staple food such as legumes, implying that the banana peel may also be a source of important nutrients [19]. The principle component of BPP was carbohydrate (77.4 %).

Effect of level of BPP on chapatti dough characteristics

From Table 2, it is observed that the control sample showed the dough stickiness of 32.83 g while the chapatti prepared from dough added with 5 % BPP showed dough stickiness of 40.73 g higher than that of control sample. Further, with the increase in concentration of BPP to 20 %

Table 1 Proximate composition of banana peel powder (per 100 g dry weight basis)

Parameters (g/100 g)	Composition
Moisture	1.77 ± 0.16
Protein	7.58 ± 0.9
Cellulose	7.066 ± 0.83
Ash content	11.10 ± 3.21
Fat content	2.09 ± 0.03
Total carbohydrates	77.4 ± 4.13
Total dietary fibre	53.8 ± 1.56

Values are mean ± standard deviations ($n = 3$)

resulted in the increase in dough stickiness. This could be due to increased water absorption capacity. This could be due to higher water absorption and hence the dough was stickier. According to the finding of Ghodke [12], the dough surface when in better contact with the surface of a probe, it results in higher surface adhesion and hence the increased stickiness. Similarly, the dough strength for the control sample was found to be 0.44 where as with the addition of BPP the dough strength was increased from 0.5 to 0.9 at 5 and 20 % BPP concentration. In this cohesiveness increased with the increase in BPP concentration as there was increase in water absorption (Ghodke [12]) due to present of soluble fibres in the banana peel.

Effect of level of BPP on subjective dough scoring

The effect of level of BPP on subjective dough scoring is presented in Table 3. The presented data inferences that the water absorption capacity increased as the concentration of BPP increased in the dough. This may be attributed due to the presence of soluble fibres in BPP. Fruit by-products are considered to be superior sources of soluble fibers [20]. The total soluble dietary fibre in the BPP was found to be 18.91 % [6] higher than that found in the apple pomaces (15.66 %) and papaya peels (13.76 %) and 14.66 % in watermelon rinds [20]. Further it was found that as the concentration of BPP increased the dough tend to be softer with each 5 % increase in the level of BPP as compared to control dough. The rating for the kneading and rolling the control dough was 4 out of 5 while for the dough added with BPP, the rating increased to 4.5 up to 15 % level of BPP. With the score of 5, it was found that the dough kneading and rollability for dough added with 20 % BPP was much as at ease as compared to others.

Effect of level of BPP on chapatti dough colour (L*, a*, b*)

The control sample showed the *L** value of 41.43 which indicates the whiteness of the product (Table 4). The decrease in *L** value indicates a decrease in whiteness as the maximum value for lightness is 100. The dough added with BPP at 5 % dosage has an *L** value of 35.50 indicating the decrease in the whiteness as compared to control. The presence of phenolic compounds and different xanthophylls might have contributed to the yellowish–brownish colour of dough added with BPP [21]. From Table 4 it can be inferred that as the percent dosage of banana peel increased, *L** value further decreased indicating the decrease in the whiteness. In the same way, an increase in the Hunter *b** value indicates an increase in yellowness.

Effect of incorporation of BPP on textural characteristics of chapatti

Control chapatti showed 449 g tear force and 5.96 mm extensibility (data shown in Table 5). Tear force and extensibility decreased with increase concentration of BPP. Addition of BPP at 5 and 10 % in the chapatti resulted in softer chapatti. Further increasing the concentration of BPP showed a decrease in the tear force (393, 356 g) and extensibility (356, 4.23 mm). This decrease in the tear force value of chapatti could be due to the increased water absorption because of added BPP which retained the moisture in the

Table 2 Effect of level of banana peel powder on chapatti dough characteristics

Sample	Dosage (g/100 g)	Dough stickiness	Work of adhesion	Dough strength
Control	0	32.86 ± 1.69^{a}	0.91 ± 0.125^{b}	0.44 ± 0.09^{a}
Banana peel powder	5	40.73 ± 0.77^{ab}	1.013 ± 0.08^{bc}	0.55 ± 0.08^{b}
	10	41.54 ± 1.30^{c}	1.04 ± 0.03^{cd}	0.5 ± 0.04^{bc}
	15	46.32 ± 1.6^{cd}	1.42 ± 0.13^{d}	0.64 ± 0.035^{d}
	20	58.30 ± 0.78^{d}	2.14 ± 0.59^{a}	0.9 ± 0.24^{e}

Values are mean ± standard deviations ($n = 3$). Means in the same column with different alphabetical letters are significantly different with control ($P < 0.05$) as analyzed by analysis of variance (least significant difference)

Table 3 Effect of level of banana peel powder on subjective chapatti dough characteristics

Parameters	Control	5 (g/100 g) BPP	10 (g/100 g) BPP	15 (g/100 g) BPP	20 (g/100 g) BPP
Water absorption capcity	73.33	83.33	86.66	96	105.33
Dough stickiness	Sticky, soft	Less sticky than control, soft	Soft	Softer than 10 %	Very soft
Dough kneading	4	4.5	4.5	4.5	5
Dough rollability	4	4.5	4.5	4.5	5
Puffing	3	3	2.5	2.5	2.5

Table 4 Effect of level of banana peel powder on chapatti dough colour values

Sample	Dosage (g/100 g)	*L* value*	*a* value*	*b* value
Control	0	41.43 ± 0.26^{d}	3.74 ± 0.19^{a}	12.56 ± 0.19^{a}
Banana peel powder	5	35.50 ± 0.16^{a}	3.11 ± 0.047^{c}	9.653 ± 0.049^{c}
	10	33.15 ± 0.14^{ab}	3.26 ± 0.075^{d}	8.58 ± 0.09^{b}
	15	30.45 ± 0.101^{c}	3.21 ± 0.11^{bd}	7.67 ± 0.107^{d}
	20	29.57 ± 0.144^{e}	3.43 ± 0.12^{e}	7.45 ± 0.03^{e}

Values are mean ± standard deviations ($n = 3$). Means in the same column with different alphabetical letters are significantly different with control ($P < 0.05$) as analyzed by analysis of variance (least significant difference)

Table 5 Effect of level of banana peel powder on tear force (g) and extensibility (mm) values of chapatti

Sample	Dosage (g/100 g)	Tear force (G)*	Extensibility (Mm)*
Control	0	449 ± 17.55^{a}	5.96 ± 1.22^{c}
Banana peel powder	5	414 ± 161.23^{ab}	5.18 ± 1.97^{a}
	10	409 ± 1.34^{c}	4.37 ± 1.64^{ab}
	15	393 ± 61.36^{d}	4.15 ± 0.71^{d}
	20	356.52 ± 33.83^{e}	4.23 ± 1.05^{d}

Values are mean ± standard deviations ($n = 3$). Means in the same column with different alphabetical letters are significantly different with control ($P < 0.05$) as analyzed by analysis of variance (least significant difference)

chapatti. This increase water absorption may be due to the presence of soluble fibres in the banana peel [6].

Effect of level of BPP on sensory characteristics of chapatti

The effect of level of BPP on sensory characteristics of chapatti is shown in Table 6. From the statistical data, a significant difference was found in the colour/appearance of chapatti prepared from the dough added with BPP. The sensory score for the colour was found to be 4.8 for the control sample while on addition of 5–20 % BPP, the sensory score decreased from 3.7 to 1.7 for first hour. The chapatis prepared from dough added with BPP were brownish in colour. This could be due to the presence of the phenolic compounds, cartenoids and different xanthophylls which are associated with colour characteristics of fruit [22].

For the taste, there was no significant difference in the sensory score for the control and chapatti added with BPP up to 10 % was observed. However, a significant difference was noted for the chapatti sample added with 15 % BPP. The sensory score was decreased from 4.15 to 3 on addition of BPP. This significant difference could be due to the astringent and bitter taste of peel. This tactile taste of sensation of astringency as well as persistent taste of bitterness is primarily elicited by flavonoids phenols [23]. Moreover, from Fig. 1 it could be noted that the total flavonoid in the control sample was found to be 2.3 mg equivalent of gallic acid g^{-1} of extract which increased to 21.5 mg g^{-1} of extract on addition of 15 % BPP.

The sensory score for the overall acceptability for the control sample was 4.25 which decreased to 3.85 for the chapatti sample added with 15 % BPP. Though, the score values are different but from the statical hypothesis test no significant difference was found in overall acceptability for

Table 6 Effect of level of banana peel powder on sensory characteristics of chapatti

Dosage BPP (g/100 g)	Colour/appearance	Texture	Taste	Overall acceptability
For 1st hour				
Control	4.8 ± 0.421[d]	4.2 ± 0.632[b]	4.15 ± 0.66[c]	4.25 ± 0.63[c]
5	3.7 ± 0.79[c]	4 ± 0.816[ab]	4.15 ± 0.88[c]	4.15 ± 0.66[c]
10	3.2 ± 0.823[c]	3.95 ± 0.95[ab]	4.15 ± 0.883[c]	3.85 ± 0.57[c]
15	2.5 ± 0.7[b]	3.55 ± 0.95[ab]	3 ± 0.81[b]	2.8 ± 0.82[b]
20	1.7 ± 0.78[a]	3.21 ± 1.20[a]	2.23 ± 0.91[a]	2.1 ± 0.831[a]
For 2nd hour				
Control	4.6 ± 0.45[d]	4.5 ± 0.33[b]	4.23 ± 0.77[c]	4.69 ± 0.39[c]
5	4.17 ± 0.25[d]	4.2 ± 0.24[ab]	4.09 ± 0.48[bc]	4.48 ± 0.29[c]
10	3.67 ± 0.29[c]	3.8 ± 0.7[ab]	3.9 ± 0.63[bc]	3.99 ± 0.72[c]
15	2.98 ± 0.7[b]	3.5 ± 1.01[a]	3.34 ± 0.92[b]	3.3 ± 0.88[b]
20	1.96 ± 0.8[a]	3.4 ± 1.39[a]	2.59 ± 1.11[a]	2.55 ± 1.11[a]
For 6th hour				
Control	4.47 ± 0.419[d]	3.27 ± 0.598[a]	3.7 ± 0.63[b]	2.85 ± 0.57[a]
5	4.04 ± 0.414[a]	3.71 ± 0.49[a]	3.2 ± 0.53[ab]	3.35 ± 0.57[a]
10	3 ± 0.33[b]	3.66 ± 0.62[a]	2.93 ± 1.18[ab]	2.95 ± 0.89[a]
15	2.76 ± 0.422[ab]	3.19 ± 0.89[a]	2.72 ± 1.03[a]	2.7 ± 1.159[a]
20	2.55 ± 0.644[a]	3.2 ± 1.035[a]	2.69 ± 1.03[a]	2.9 ± 0.87[a]

Values are mean ± standard deviations. Means in the same column with different alphabetical letters are significantly different with control ($P < 0.05$) as analyzed by analysis of variance (least significant difference)

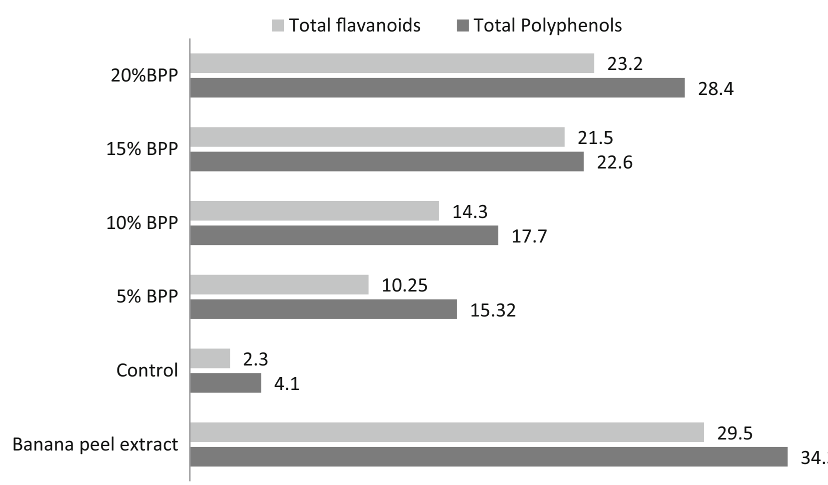


Fig. 1 Total phenolic content and flavonoid content in the banana peel extract and chapati incorporated with banana peel powder

the chapatti prepared from the dough added with BPP until 10 %.

Effect of level of BPP on bioactive constituents

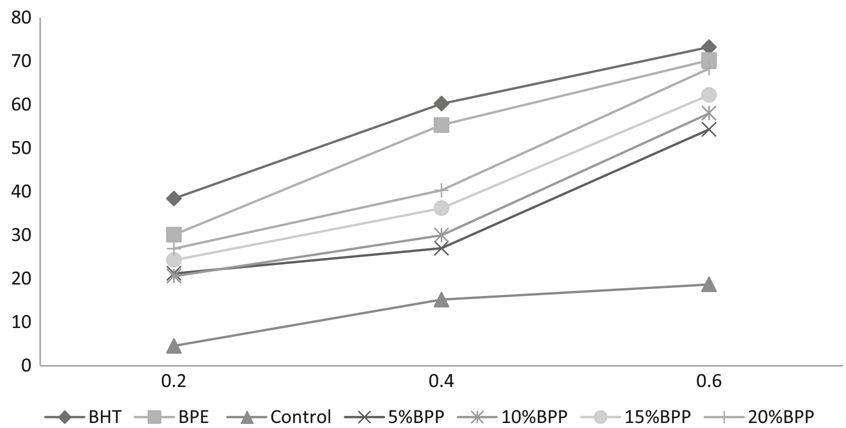
Effect of level of BPP on total phenolic content of chapatti

The total phenolic content in the banana peel extract, control chapatti and the chapatti incorporated with BPP is depicted in Fig. 1. The value obtained for the total phenols is expressed as mg of gallic acid g^{-1} of the extract. The total polyphenols in the ethanolic banana peel extract was found to be 34.5 mg g^{-1} of extract which can be converted into 1.097 gallic acid equivalent 100 g^{-1} of dry weight. Similar result has been reported in literature i.e. the banana peel flour have total phenolic content as 1.1 gallic acid equivalent 100 g^{-1} of dry weight when the extraction was carried out with ethanol [15]. The soluble total polyphenols of control chapatti prepared from whole wheat flour was found to be 4.1 mg g^{-1} of extract. As the concentration of BPP in chapatti increased from 5 to 20 %, the total phenolic content also increased from 15.32 to 28.4 mg g^{-1} of extract. Phenolics are important plant constituents as they can scavenge free radicals because of the presence of hydroxyl groups [24]. Hence, the antioxidant activity is directly related to the phenolic content of the plants [25].

Effect of level of BPP on total flavonoid content of chapatti

The total flavonoid content in the banana peel extract, control chapatti and chapatti prepared from dough added with BPP is shown in Fig. 2. The total flavonoid content in the ethanolic banana peel extract is expressed in terms of quercetin equivalent. The value obtained for the total flavonoids is expressed as mg of quercetin g^{-1} of the extract. The total flavonoid content in the ethanolic banana peel extract was found to be 29.5 mg g^{-1} of extract which is converted to 0.944 g of quercetin 100 g^{-1} dry weight. The total flavonoid content was higher in comparison to previous report which presented 0.62 g, 100 g^{-1} dry weight [15]. The total flavonoid content in the control sample was 23.3 mg g^{-1} and was found to increase from 10.25 to 23.2 mg g^{-1} of extract when

Fig. 2 DPPH radical scavenging effect of the chapatis made by incorporation of banana peel powder



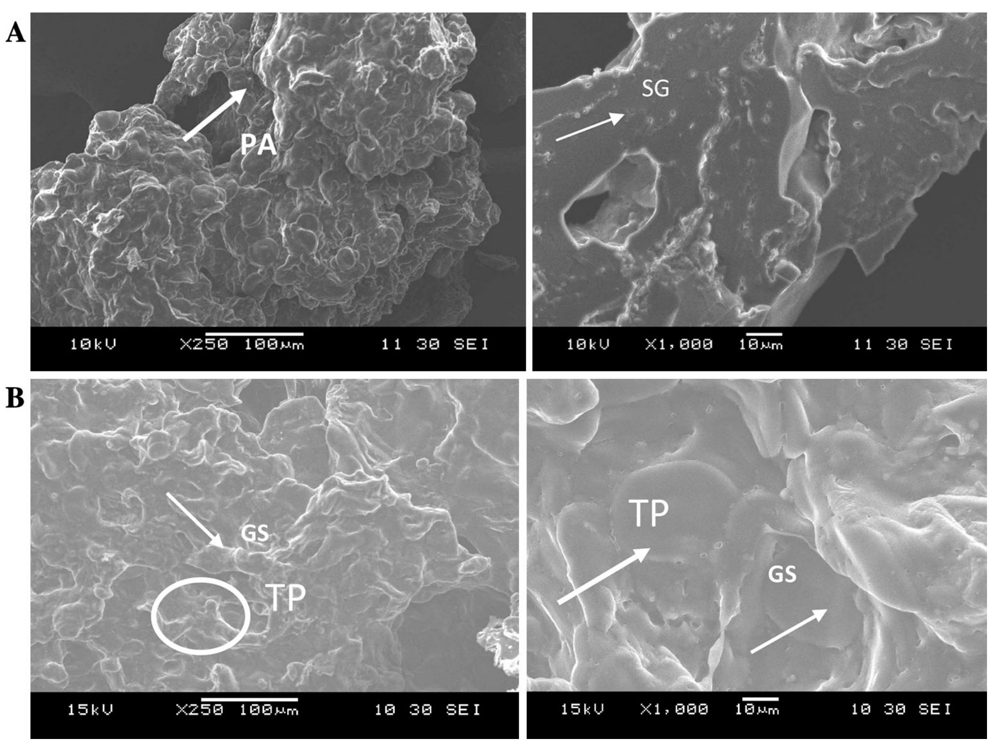


Fig. 3 The microstructures of control chapati and chapati prepared from dough added with banana peel powder. **a** Control sample, **b** chapati sample prepared from dough added with 15 % banana peel powder *PA* protein aggregates, *SG* starch granules, *TP* thinned protein matrix, *GS* gelatinised starch molecule

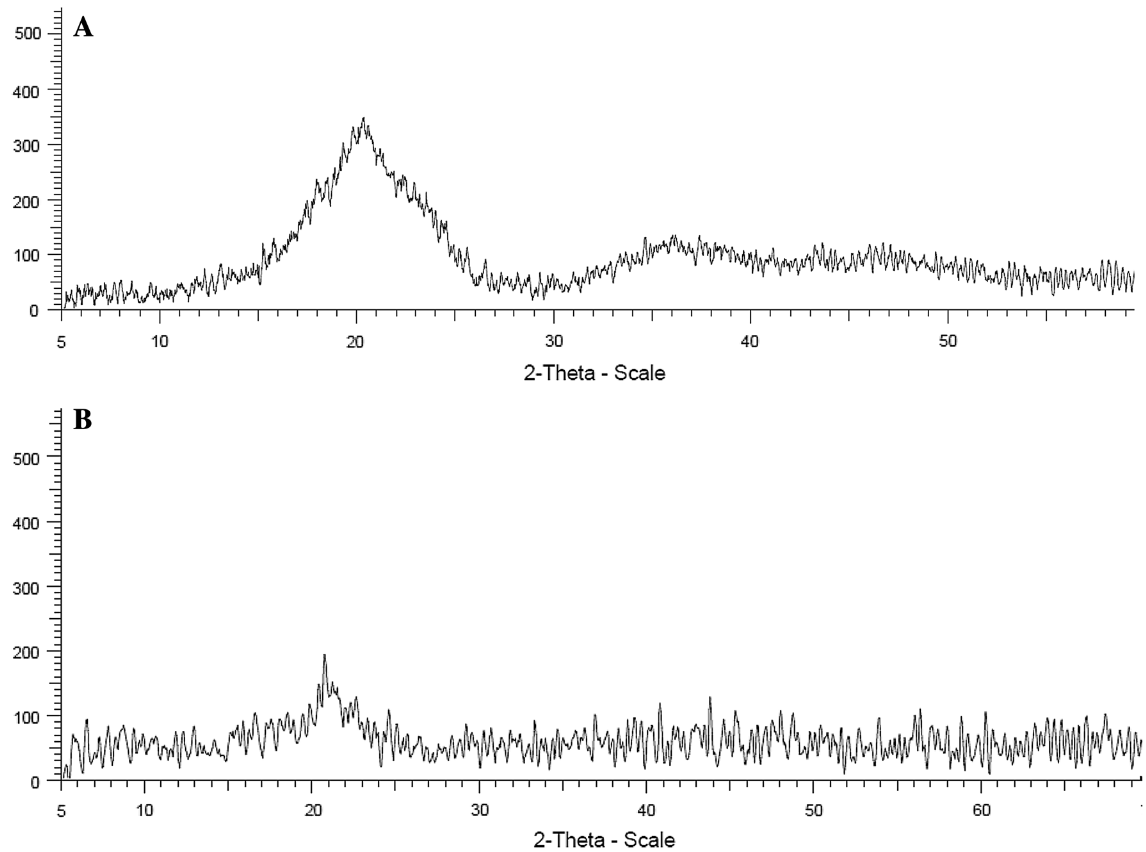


Fig. 4 **a** X-ray diffraction pattern of control chapati. **b** X-ray diffraction pattern of chapati incorporated with 15 % banana peel powder

the concentration of BPP increased from 5 to 20 %. The presence of phenolic hydroxyl groups on the flavonoids enables them to effectively scavenge the free radicals and thus, show a stronger antioxidant activity. Based on in vitro and animal research there is growing evidence that flavonoids can improve glucose homeostasis and enhance insulin secretion and sensitivity. The total flavonoid study followed the similar trend to that of the total phenolic i.e. the total flavonoid content increased with the increase in concentration of BPP in chapatti.

The total phenolic content and the total flavonoid content values obtained for the control suggested that the wheat flour contain antioxidants. The ferulic and p-coumaric acids are the main phenolic acids present in the wheat [26, 27]. The presence of polyphenol compounds in the banana peel have in turn added up to the increased levels of the total polyphenols and flavonoids in the chapatti thus enhancing its antioxidant content.

Effect of level of BPP on antioxidant activity of banana peel extracts and chapatti

The antioxidant activity of control chapatti, banana peel extract, BHT and the chapatti prepared from dough added with BPP (added at varying concentrations was 5, 10, 15 and 20 % was analyzed at concentrations of 0.2, 0.4 and 0.6 mg ml^{-1}. From the reduction in the optical absorbance at 515 nm the free radical scavenging activity was determined. The banana peel extract with a concentration of 0.6 mg l^{-1} quenched 70 % of DPPH radicals, indicating only a slightly lower activity than that of the synthetic antioxidant BHT. The antioxidant activity increased with the increase in the banana peel concentration in the chapattis, in trend which was similar to the study of total phenolic and flavonoid contents of chapattis. Thus, the antioxidant activity of banana peel extract and the chapattis would be attributed to the total phenolic and flavonoid content. The scavenging activity of the chapatti (chapatti incorporated with 20 % BPP) extract reached a value of 68 % at a concentration of 0.6 mg l^{-1}.

Effect of level of BPP on microstructure of chapatti by scanning electron microscopy

Figure 3a, b depicts the microstructures of control chapatti and chapatti prepared from dough added with 15 % BPP respectively. The microstructures of control chapatti were quite different from the chapattis prepared from dough incorporated with BPP. In case of control chapatti, the starch granules were overlapping on one another to form aggregation. Uniformity was absent in control chapatti (Fig. 3a). The micrographs of the chapatti prepared from dough added with BPP showed slight distortion in outline and shape of granules and thinning of protein matrix (Fig. 3b). The microstructure of chapatti prepared from dough added with BPP at ×1000 showed highly solubilised starch granules. There was uniformity in the structure. Unlike, in control chapatti, the protein aggregation was absent in the chapatti prepared from dough incorporated with BPP [17].

Effect of level of BPP on microstructure of chapatti by X-ray diffraction

X-ray diffraction patterns of control sample and the chapatti prepared from dough added with 15 % BPP are illustrated in Fig. 4a, b. From the figure, it can be seen that the control chapatti had higher intensity crystallinity peak and decreased in case of chapatti prepared from dough added with 15 % BPP. This could be due to the increase in water absorption with the addition of BPP in dough which ultimately resulted in stickiness and formed a gelatinised structure of starch as shown in SEM images [28]. The chapatti prepared from dough added with 15 % BPP showed V-type pattern or diffraction peak at $2\theta = 20.1°$ which indicated a typical diffuse pattern of an amorphous system. In the study carried out by Imberty et al. [29], the ^{13}C NMR result indicated that the preferred state for the amorphous granules is a V-type conformation.

Conclusions

Chapatti prepared from dough added with BPP yielded soft texture chapatti. Scanning electron microscopy revealed the changes in starch properties. The free radical scavenging activity of chapatti prepared from the dough incorporated with BPP was higher than that of control sample. The phytochemical content and the antioxidant activity increased with the increased concentration of BPP in chapatti. Thus, the result indicates that the chapatti prepared from dough incorporated with BPP would be a vehicle to impart health benefits as they show antioxidant activity.

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