Influence of bamboo shoot powder fortification on physico-chemical, textural and organoleptic characteristics of biscuits

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Abstract Bamboo shoot has attracted significant research and a commercial interest due to its many health-promoting bioactive compounds as well as its effectiveness in decreasing blood pressure, cholesterol and increasing appetite. As availability of fresh shoot is limited due to its seasonality there is need of incorporation of nutrients of shoot to any common food product which is easily available throughout year. Shoots of *Bambusa balcooa* variety were taken and edible parts were separated. Slices of shoot were boiled, dried, powdered, sieved, analysed for nutritional status and used for biscuit making. Bamboo shoot powder (BSP) was added in 0 % (control), 5, 10, and 15 % level in dry ingredients by replacing wheat flour and other ingredients were kept constant. Dough prepared are firstly analysed for basic characteristics. Then biscuits were prepared and analyzed for moisture, water activity, protein, fiber, fat, ash, phenolics, antioxidant activity, dimension, hardness, color and sensory acceptability. Variations were observed for fiber, antioxidant activity and phenolics from 1.08 to 1.97 %, 3.50 to 17.85 % and 0.45 to 4.19 mg/100 g respectively. Results showed that up to 10 % fortification level the biscuits were acceptable with improved functional and nutraceutical properties compared to the control.

Keywords Bamboo shoot · Biscuits · Fiber · Texture · Fortification

Introduction

Bamboo, one of the biggest kinds of grass, is utilized by human races all over the world for its ethnic uses since ages. But the edibility of tender shoots was discovered during rainy seasons as a replacement of vegetables only in East Asian countries. In India, use of bamboo shoots is still limited to North-East region and some other hilly parts in south. Analysis of bamboo shoots to understand its nutritional values is already highlighted by many researchers (Bhargava et al. 1996; Bhatt et al. 2005; Chen et al. 1999; Kumbhare and Bhargava 2007; Nirmala et al. 2007, 2008; Satya et al. 2010; Choudhury et al. 2012). The conclusions were withdrawn that bamboo shoots are highly nutritious and therapeutically rich. It contains high amount of dietary fiber, vitamins, minerals, protein, antioxidants, polyphenols, and low amount of fat. It also contains phytosterols which are known to reduce the level of cholesterol in the body. Other health benefits include improving appetite and digestion, loss of weight, positive effects on cardiovascular diseases and cancer, etc. Bamboo shoots are also quite rich in 17 amino acids. The eight amino acids which are not synthesized in the body and regarded as essential amino acids are all found in bamboo shoots, which is a very rare case. Moreover, it contains 17 types of enzymes and more than ten types of minerals i.e. Fe, Mg, Zn, Mn, Cu, Ni, Cr, Co, etc. Due to such high profile of nutrition, bamboo shoot is considered as an ideal healthy vegetable. But, bamboo shoots also contain lethal concentration of the anti-nutrient (cyanogen) that can be minimized by boiling it with NaCl solution (Pandey and Ojha 2011; Rana et al. 2012). In the Northeastern states of India, bamboo shoots are largely sold in the unprocessed form. They are harvested from homestead in clumps and brought to the local market for sale. The shelf life of bamboo shoot is limited and they have to be sold

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immediately after harvest. They are sold in various processed shapes and available in fresh, dried, fermented, pickled and canned versions (Bashir 2010). Fermented bamboo shoots are the part of diet of both rural and urban people and are extensively used as a main ingredient in different food items like meat, fish preparations, preparing pickles etc. (Badwaik et al. 2014).

Food fortification is a mean of overcoming micronutrient deficiency of some foods. It is also used to enrich some kind of foods by incorporation of nutritionally rich entities. Foods to be fortified are chosen in a way that it is commonly and regularly used by the target consumers. But during fortification, it should also strictly be kept in mind that the sensorial characteristics of the food are not hampered much, or it may not be acceptable to the consumers (Akhtar et al. 2008).

Biscuits are one of the most popular snacks all over the world. It is kind of bakery product which can be consumed by all age groups. It is ready-to-eat in nature, have a longer shelf life and good nutritional quality and can be prepared in different types of tastes (Gandhi et al. 2001). Many researchers have already fortified with fiber rich components, such as wheat bran, oat bran, rice bran, barley bran, apple, lemon and mango peel powder, corn and fenugreek flour, coconut meal, legumes, mushroom etc. (Ajila et al. 2008; Eissa et al. 2007; Hussein et al. 2011; Nassar et al. 2008; Srivastava et al. 2010; Sudha et al. 2007; Vitali et al. 2009) in biscuits. Such attempts not only increase the food value of the biscuits, but also give a diversification in bakery products. In this study, biscuits are enriched with dried bamboo shoot powder, so that nutritional benefits of bamboo shoots can be utilized for a longer duration in a most readily available form. The objective of this study is to analyze the physico-chemical properties and sensory values of the biscuits and basic dough characteristics at different level of fortification.

Materials and methods

Collection of raw materials Edible shoots of *Bambusa balcooa* (Local name: Bhaluka) sample was collected from Tezpur, Assam, India. The samples were transported to the department of Food Engineering and Technology, Tezpur University within 24 h of collection. In laboratory, the shoots were defoliated and washed. The unwanted parts are removed, and the soft edible portions are used for preliminary studies. The shoots were stored at 4 °C till further processing. Commercially available wheat flour, fat, sugar, skim milk powder, common salt and baking soda (sodium bicarbonate) were procured from the local market. All the chemicals and solvents were of analytical grade.

Preparation of bamboo shoot powder (BSP) The shoots were cut into smaller pieces and blanched for 30 min by changing

the water after every 10 min. Then it was dried in tray dryer (IKON Instruments, Delhi, India) at 70 °C (Satya et al. 2010) until it reached equilibrium moisture content of about 5 %. Dried pieces of shoots were ground to get powder, passed through sieve of 100 mesh size and stored in polyethylene pouches with proper sealing. The powder was tested for vitamin C, phenolics, antioxidant activities, crude fiber, protein, fat and ash contents.

Preparation of biscuits A total of four types of biscuits were prepared, each of a batch of 100 g flour. While one sample was kept as control having only 100 g flour, in the other three samples, 5, 10 and 15 % of the flour was replaced by the prepared bamboo shoot powder respectively. The other ingredients used for each batch were as follows: 25 g fat, 50 g sugar, 6 g skim milk powder, 2 g salt, 1 g sodium bicarbonate and water as per their water absorption capacity (WAC). Sugar was ground to powder consistency and creamed along with fat with a Philips hand mixer till a smooth paste was obtained. Skim milk powder was mixed with water in 1:5 proportions and added in the paste slowly while whipping was continued. Salt and sodium bicarbonate were added in paste little by little, and whipping was continued till foaming occurs. Sieved flour and bamboo shoot powder were added in above mix with predetermined quantity and soft dough was prepared. Dough was rolled to a thickness of 0.3 cm and cut with circular mould having diameter of 4.0 cm. Cut parts were kept in a greased pan and backed in oven for 20 min at 160 °C. The time temperature combination for baking was decided on the basis of preliminary experiments and overall baking quality of biscuits. After baking the biscuits were cooled at room temperature and packed in airtight containers for further analysis.

Water absorption capacity of flour Ten gram of flour from each batches were taken in beaker (one having pure wheat flour alone and another three batches of flour were replaced by 5, 10 and 15 % with BSP. Water was added drop by drop in a beaker for each batch, with constant stirring till the dough was prepared. Amount of water added was noted and WAC for each samples were calculated by the following equation (Siddaraju et al. 2008).

$$\text{WAC}(\%) = [\text{Amount of water used}(\text{g}) / \text{Weight of dry flour}(\text{g})] \times 100$$

Gluten content of flour Fifty gram of flour was taken and dough was prepared for each batch by adding sufficient quantity of water. Prepared dough was allowed to stand in the water for an hour. Then each was washed in the running water to squeeze off the starch (and fiber part in case of fortified dough). Washing was done until squeezed water runs clear. After washing, excessive water was squeezed and dried in hot air oven at 100 °C for 1 h. Weight of dried gluten was taken

and gluten content was calculated by the following equation (AACC 2000; Pedersen and Jørgensen 2007).

$$\text{Gluten content(\%)} = [\text{Weight of dry gluten(g)}/\text{Weight of flour(g)}] \times 100$$

Texture properties of dough Extensibility of flour-water dough and gluten for four different combinations were measured by Kieffer Dough and Gluten Extensibility Rig (A/KIE) with the help of Texture Analyzer (TA-HDPlus, Stable Microsystems, UK) (Aamodt et al. 2005). Dough was prepared by addition of water according to WAC and gluten was prepared. From this batch 15 g of sample was clamp in the form press for 40 min. This cut the samples into strips, allowed the dough/gluten to relax and prevented the loss of moisture. Prepared strips were used for measurement of extensibility. The test had a tension mode with following settings. Pre-test speed of 2 mm/s, test speed of 3 mm/s, post test speed of 10 mm/s, distance of 75 mm, trigger force of 10 g and the probe is attached to a 5 kg load cell. Distance traveled in negative direction during extension was noted, it gave the value of extensibility (mm) and maximum force required during extension was resistance to extension (N). Hardness and adhesiveness of dough were determined by 75 mm diameter platen (P/75). The test had a compression mode with following settings. Pre-test speed of 2 mm/s, test speed of 1 mm/s, post test speed of 5 mm/s, distance of 5 mm, trigger force of 10 g and the probe is attached to a 25 kg load cell.

Proximate analysis Powder and biscuits were analyzed for moisture, ash, protein and fat, according to the standard AOAC (1990) methods. Fat, fiber and protein in the samples were determined using Socs plus (SCS6), Fibro plus (FES06) and Kel plus apparatus (Pelican Equipment, Chennai, India) respectively. The nitrogen content was converted to protein by multiplying with a factor of 6.25.

Preparation of methanolic extract One gram of sample was extracted with 10 ml of 80 % methanol and centrifuged at 10,000 g at room temperature. Residue was re-extracted with five times the volume of 80 % methanol and centrifuged. Supernatant was collected and used for the analysis of total phenolics and antioxidant activity.

Estimation of total phenolic The total phenolics in the sample were estimated using Folin-ciocalteu reagent (FCR) procedure as described by (AOAC 1990). Supernatant was evaporated to dryness and residue was dissolved in 5 ml distilled water. From this mixture 0.2–2 ml of aliquots were taken in different test tubes and volume of 3 ml was made using distilled water. FCR of 0.5 ml and after 3 min 2 ml of 20 % sodium carbonate was added to each test tube. The mixture was heated on a

water bath at 100 °C for 1 min and then cooled. Absorbance was measured at 650 nm in spectrophotometer (Spectronic 20D+, Thermo Scientific, USA). The results are expressed as mg phenol/ 100 g of sample as catechol equivalent.

Estimation of total antioxidant activity Free radical scavenging activity was used to measure the total antioxidant activity by using 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay method. DPPH is a commercial oxidising radical used to be reduced by anti-oxidants. The disappearance of the DPPH radical absorption at a particular wavelength is monitored by the reduction in optical density. To 20 µL methanolic extract of bamboo shoot, 1.5 ml of DPPH solution (0.025 g DPPH in 1000 ml of methanol) was added. The tubes were vortexed (Vortex Shaker, Labotech) for proper mixture and allowed to react for 45 min in a dark environment at room temperature. The control was prepared without the addition of any sample for baseline correction. Absorption was measured at 517 nm in a spectrophotometer (Spectronic 20D+, Thermo Scientific, USA). The Free radical scavenging activity was expressed as inhibition percentage and calculated by using the following equation.

%Free radical scavenger activity

$$= [(\text{Control absorbance} - \text{Sample absorbance})/\text{Control absorbance}] \times 100$$

Dimensional characteristics of biscuits Diameter (W) of biscuits was measured by laying six biscuits edge-to-edge with the help of a scale. The same set of biscuits was rotated 90° and the diameter was remeasured. Thickness (T) of biscuits was measured by stacking six biscuits on top of one another and taking the average of six biscuits. The spread ratio was calculated by dividing diameter (W) by thickness (T). Average values of these biscuits were reported in centimeter (Ajila et al. 2008; Srivastava et al. 2010; Sudha et al. 2007).

Hardness of biscuits Hardness of biscuit was measured by cutting using Knife Blade (HDP/BS) with the help of Texture Analyzer (TA-HDPlus, Stable Microsystems, UK). The test had a compression test mode, with a pre-test speed of 1 mm/s, test speed of 1 mm/s, post test speed of 5 mm/s, distance of 3 mm, trigger force of 8 g and the probe is attached to a 25 kg load cell. Force required to break biscuits individually was noted and the average value for hardness (g) was calculated.

Color measurement of biscuits Color is the most important parameter for acceptability of the product. The color of biscuits were measured in terms of 'L', 'a' and 'b' values using a Hunter Color Measuring System (Ultrascan VIS, Hunter Lab. Inc., USA).

Table 1 Chemical analysis data of BSP (dry weight basis)

Component	Content
Fiber (g/100 g)	34.41±1.27
Protein (g/100 g)	34.51±1.62
Fat (g/100 g)	4.41±0.19
Ash (g/100 g)	9.41±0.34
Antioxidant activity (%)	72.36±1.19
Total phenolics (mg/100 g)	96.6±0.21

All data are the mean ± SD of three replicates

Sensory analysis of biscuits Organoleptic qualities of biscuits incorporated with BSP were conducted to determine the acceptability of the product with the help of a 10-member consumer panel, using a 9-point hedonic scale, following standard procedure (Ranganna 1986). The aspects considered for analysis were surface color, surface appearance, texture, taste, flavor and overall quality. The average scores of all the 10 panelists were computed for different characteristics.

Statistical analysis All analyses were performed in triplicate and data were reported as mean ± SD. The data was assessed by single factor analysis of variance (ANOVA) (Snedecor and Cochran 1987) and by Duncan's multiple range test with probability ≤ 0.05 .

Results and discussion

Analysis of bamboo shoot powder The proximate composition of dried bamboo shoots of *Bambusa balcooa* is shown in Table 1. Results showed that bamboo shoots of *Bambusa balcooa* was rich in mineral, fiber and protein, having good amount of vitamin C, antioxidant activities, phenolics and very low in fat, which makes it an ideal food. Fiber and protein content of shoot powder were found to be 34.41 and 34.51 g/100 g respectively which made it attractive to fortify in different food items which would enhance the nutritional quality of the product.

Water absorption capacity WAC for all the four types of dough samples, one control and rest fortified, were calculated as shown in Table 2. Results showed that with the increased level of fortification, WAC also increased. Similar observations were found in case of fortification of fiber rich sources like mango peel powder (Ajila et al. 2008), oat flour (Peymanpour et al. 2012), bran of wheat, rice, oat and barley (Sudha et al. 2007), orange peel (Nassar et al. 2008) in flour. Some authors reported that, differences in water absorption is mainly caused by the greater number of hydroxyl group which exist in the fiber structure and allow more water interaction through hydrogen bonding (Chaplin 2003; Dikeman and Fahey 2006; Rosell et al. 2001). But above result is contradicted with study of Saeed et al. (2009), who predicted that water absorption decreased with increased in addition of rice bran. As rice bran was partially replacing the gluten-containing wheat flour, it restricted the water fiber interaction and the dough became more hydrophobic. As a result, the dough absorbed less water.

Gluten content Results of gluten content for all four type of flour are given in Table 2. It was seen that gluten content was decreased with the increase in the level of fortification. This may be due to the replacement of wheat flour with bamboo shoot powder has led to the dilution of gluten in fortified sample. Similar results were reported by Saeed et al. (2009). Peymanpour et al. (2012) state that decrease in the gluten content of the dough and the increase of bran proportion (ending up with weaker formation of gluten matrix) could not maintain the dough extensibility. The specific volume of bread always decreased as consequence of fiber addition. This effect is attributed to the interaction between fiber and gluten, which led to a decrease in the gas retention capacity (Gomez et al. 2003).

Texture properties of dough Extensibility of flour-water dough was found to decrease with increased in level of BSP fortification, although extensibility of gluten were less affected. Values of extensibility of dough were changed from 49.70 mm for control to 20.26 mm for

Table 2 Analysis of dough

% BSP	WAC (%)	Gluten (%)	DE (mm)	DRE (N)	GE (mm)	GRE (N)	Hardness (N)	Adhesiveness (Ns)
0 % (Control)	51.25±0.53 ^a	9.52±0.28 ^a	49.70±1.34 ^a	0.17±0.01 ^a	45.25±0.98 ^a	1.01±0.11 ^a	33.25±1.35 ^a	47.93±1.48 ^a
5 %	54.14±0.67 ^b	8.70±0.13 ^b	31.93±1.28 ^b	0.14±0.01 ^a	40.23±1.95 ^b	0.55±0.08 ^b	48.14±1.33 ^b	32.82±1.36 ^b
10 %	56.37±0.82 ^c	8.36±0.17 ^b	25.87±1.45 ^c	0.33±0.02 ^b	38.60±1.13 ^b	0.63±0.09 ^b	63.92±1.13 ^c	25.14±1.27 ^c
15 %	59.15±0.38 ^d	7.80±0.21 ^c	20.27±1.30 ^d	0.43±0.02 ^c	32.83±1.54 ^c	0.37±0.03 ^c	81.15±1.23 ^d	16.01±1.44 ^d

Values are the mean ± SD of three replicates. Mean followed by different letters in the same column differs significantly ($P \leq 0.05$)

WAC water absorption capacity, DE dough extensibility, DRE dough resistance to extension, GE gluten extensibility, GRE gluten resistance to extension

Table 3 Chemical analysis data of the biscuit samples

% BSP	Moisture (%)	Water activity	Fiber (%)	Protein (%)	Fat (%)	Ash (%)	Phenolic (mg/100 g)	Antioxidant activity (%)
0 % (control)	3.96±0.12a	0.29±0.02a	1.08±0.23a	07.37±0.08a	14.16±0.28a	0.70±0.04a	0.45±0.32a	3.50±0.12a
5 %	4.05±0.17a	0.32±0.07b	1.63±0.14b	09.83±0.14b	15.01±0.16b	0.85±0.07a	1.26±0.27b	8.57±0.24b
10 %	5.10±0.11b	0.39±0.05b	1.85±0.09b	11.06±0.11c	15.18±0.11b	1.24±0.10b	2.98±0.10c	14.31±0.65c
15 %	5.35±0.08b	0.41±0.03c	1.97±0.27b	12.69±0.18d	15.29±0.09b	1.43±0.08b	4.19±0.19d	17.85±0.49d

All data are the mean ± SD of three replicates. Mean followed by different letters in the same column differs significantly ($P \leq 0.05$)

15 % level of fortification and for gluten values were changes from 45.25 to 32.83 mm. Resistance to extension for dough and gluten were largely affected by BSP addition. Values were increased with level of fortification for dough but reverse trend was found in case of gluten (Table 2). This may be due to interaction of BSP with wheat flour, which makes the dough harder and reduces its extensibility by replacing gluten. Hardness of dough was more for BSP based flour-water dough as compared to control. Increment in values was observed from 33.25 to 81.15 N, this is because of more fiber in BSP which make the dough harder. Analogous results were reported by Sudha et al. (2007) and Srivastava et al. (2010). Adhesiveness of dough decreased with incorporation of BSP. As fiber absorbed more water, adhesion properties of dough gets reduced.

Physico-chemical characteristics of biscuits

Moisture, water activity, fiber, protein, fat and ash content of biscuits The moisture content increased from 3.96 in control to 5.36 % in 15 % level of fortification and water activity varied from 0.29 in control biscuits to 0.41 in 15 % BSP fortified biscuits (Table 3). The gradual increase in moisture and water activity level may be due to more water retaining capacity of the fibers as well as more amount of water required to prepare the biscuit dough having more amount of fiber (Ajila et al. 2008). The fiber, protein, fat and ash content of biscuits were increased from 1.08 to 1.97 %, 7.37 to 12.69 %, 14.16 to 15.29 % and 0.70 to 1.43 % respectively, with increased level of fortification. Similar trend was found for

moisture and fiber by Srivastava et al. (2010) and for fiber by Ajila et al. (2008); Hussein et al. (2011); Nassar et al. (2008) and Sudha et al. (2007).

Total phenolic and antioxidant activity The total phenolics content of BSP is very high (96.6 mg/100 g as catechol equivalent), ultimately its fortification in biscuits, increases the phenolics content from 0.45 for control to 4.19 mg/g for 15 % BSP fortified biscuit (Table 3). Although there is loss of polyphenol content during processing, there was an increase in polyphenol content in biscuits by the incorporation of powder (Ajila et al. 2008). With increase in the level of BSP incorporation, the DPPH radical scavenging activity increased. DPPH radical scavenging activity for the biscuits incorporated with 5, 10 and 15 % levels of BSP was 8.57, 14.31 and 17.85 % respectively; while for control the value was 3.50 %. The increase in the free radical scavenging may be due to increase in the proportion of polyphenols and vitamin C through the incorporation of BSP in biscuits.

Dimensional characteristics of biscuits Influence of BSP on physical characteristics of biscuits prepared using 5, 10, 15 % of powder was evaluated. Physical characteristics of biscuits such as diameter, thickness and spread ratio are presented in Table 4. It was seen that percent expansion decreases with the increased level of fortification. The average diameter of biscuits decreased from 4.68 to 4.50 cm where as thickness was decreased from 0.39 to 0.31 cm and ultimately spread ratio was decreased from 14.18 to 11.56 cm from control to 15 % fortified biscuit. It may be due to the fact that gluten is decreased with increased level of replacement of wheat flour.

Table 4 Effect of BSP on physical characteristics of biscuits

	% BSP	Diameter (cm) (D)	Thickness (cm) (T)	Spread ratio (D/T)	Hardness (N)
	0 % (Control)	4.68±0.08 ^a	0.39±0.04 ^a	14.18±1.28 ^a	54.20±1.35 ^a
	5 %	4.58±0.04 ^{ab}	0.37±0.04 ^{ac}	13.77±1.15 ^{ac}	56.16±1.27 ^a
	10 %	4.52±0.08 ^b	0.33±0.03 ^{bc}	12.35±1.94 ^{bc}	91.94±1.31 ^b
	15 %	4.50±0.07 ^b	0.31±0.04 ^b	11.56±1.18 ^b	95.17±1.24 ^b

All data are the mean ± SD of five replicates. Mean followed by different letters in the same column differs significantly ($P \leq 0.05$)

Table 5 *L*, *a*, *b* values of different biscuit samples

% BSP	<i>L</i> - value	<i>a</i> - value	<i>b</i> - value
0 % (Control)	54.10±4.91 ^a	10.00±0.08 ^a	20.26±0.54 ^a
5 %	43.12±2.38 ^b	10.97±0.63 ^b	17.45±0.76 ^b
10 %	42.41±3.35 ^{bc}	11.01±0.42 ^b	17.07±1.22 ^b
15 %	36.31±1.08 ^c	11.45±0.53 ^b	14.41±0.83 ^c

All data are the mean ± SD of three replicates. Mean followed by different letters in the same column differs significantly ($P \leq 0.05$)

Similar results were reported with orange peel powder biscuit (Nassar et al. 2008), mango peel powder biscuit (Ajila et al. 2008), corn-fenugreek flour biscuit (Hussein et al. 2011) and biscuit fortified with bran of different cereals (Sudha et al. 2007), but reverse result was found for coconut meal biscuit (Srivastava et al. 2010) because of high amount of fat in coconut meal.

Hardness Hardness, which is expressed as breaking strength of biscuits, increased with incorporation of Bamboo shoot powder. Biscuits prepared from flour containing 15 % powder had a breaking strength of 95.17 N compared to 54.20 N of the control biscuits (Table 4). Similar trend was found by Ajila et al. (2008) and they concluded that increased in hardness of biscuits is due to relatively higher water content in mango peel powder incorporated dough. Also hardness was found high for biscuits prepared with cereals bran (Sudha et al. 2007) but low for coconut meal biscuit (Srivastava et al. 2010).

Color characteristics The change in color of the biscuits were measured using change in *L*, *a*, *b* values and results are shown in Table 5. '*L*' value decreased with the increase in the levels of BSP fortification; therefore the control biscuit had the highest brightness compared to the BSP enriched biscuits. Same trend was seen for '*b*' value, which indicates yellowness, upon addition of the powder. The change in '*a*' value, which indicates the redness, gradually increased with increase in BSP level. These all changes take place mainly because of brown color of BSP and caramelization of sugar substances during baking. The similar trend for '*L*' and '*a*'

values has been reported for biscuits fortified with mango peel powder (Ajila et al. 2008) and corn-fenugreek flour (Hussein et al. 2011). Sudha et al. (2007) showed that the biscuits became darker with increasing level of cereal bran except for barley bran incorporation where the percent whiteness was reduced marginally.

Sensory analysis of biscuits Sensory analysis results for all four types of prepared biscuits are given in Table 6. Overall appearance of biscuits was acceptable upto 10 % fortification. Color of biscuits had low scores with increase in the level of bamboo shoot powder. It increased the darkness and reduced the surface smoothness. Above 10 % incorporation of bamboo shoot powder, biscuits had dark color and very hard texture compared to the control. Increase in darkness also reflected in *L* values (Table 5) and hardness value as measured using a Texture Analyzer (Table 4). For the same reason, biscuits incorporated above 10 % level were not acceptable to the panel up to mark. The flavor and mouthfeel of the biscuits were gradually less acceptable with increased level of fortification. It may be because of slight bitterness that is present in the raw bamboo shoots due to high polyphenol content. Considering the color, appearance, texture, flavor, mouthfeel and the overall acceptability, biscuits of acceptable overall quality can be prepared using upto 10 % BSP formulations.

Conclusions

Bamboo shoot powder is a good source of phytochemicals such as phenolics and fibers, as well as high levels of protein, vitamin C, and antioxidant activity. Biscuits enriched with BSP showed higher phenolics, fibers, and protein contents than the control. It may be concluded from the present study that BSP could be incorporated up to a 10 % level in the formulation of biscuits without affecting their overall quality. At 10 % BSP level incorporation, the biscuits had a crude fiber content of 1.85 %, protein content of 11.06 %, phenolics of 2.98 mg/100 g and antioxidant activity of 14.31 % DPPH

Table 6 Sensory analysis of the biscuit samples

% BSP	Appearance	Color	Texture	Flavor	Mouthfeel	Overall acceptability
0 %	7.50±0.82 ^a	7.65±0.75 ^a	7.35±0.47 ^a	7.40±0.46 ^a	7.55±0.96 ^a	7.60±0.66 ^a
5 %	7.25±0.72 ^a	7.15±0.75 ^a	7.22±0.75 ^a	6.85±0.94 ^{ab}	6.85±1.00 ^{ab}	7.05±0.96 ^a
10 %	7.00±0.97 ^{ab}	6.65±1.25 ^{ab}	6.85±0.88 ^{ab}	6.675±0.85 ^b	6.62±0.81 ^{ab}	6.80±0.89 ^{ab}
15 %	6.30±1.16 ^b	5.80±1.23 ^b	6.30±1.16 ^{bc}	6.05±1.26 ^b	6.05±1.28 ^b	5.87±1.16 ^b

All data are the mean ± SD of ten replicates. Mean followed by different letters in the same column differs significantly ($P \leq 0.05$)

radical scavenging activity. Thus, bamboo shoot, a generally less utilized seasonal vegetable, could be utilized for the preparation of biscuits and other food products with improved functional and nutraceutical properties.

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