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Functional biscuits from bamboo shoots: Enrichment of nutrients, bioactive compounds and minerals in bamboo shoot paste fortified biscuits

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Abstract
Bamboo shoot is a traditional delicacy in many Asian countries and considered as a healthy food since ancient times. However, changing lifestyle and increasing globalization has caused a drastic change in the food system and traditional vegetables like bamboo shoots are being neglected though they are highly nutritious. In recent years, its importance as a health food has been highlighted and has generated a huge amount of interest amongst researchers and nutritionist alike. Its application in the food industry for food fortification is being highlighted in the present work. Functional biscuits were developed by substituting wheat flour with 20% processed bamboo shoot paste. Fortified biscuits had a significant ($P<0.05$) increase in the amount of proteins, phenols, phytosterols, vitamin C and dietary fiber content compared to the control biscuits. On the basis of high sensory score and overall acceptability of the bamboo shoot paste fortified biscuits, it is concluded that bamboo shoot supplementation in biscuits is a convenient vehicle for imparting nutrients and health-promoting phytochemicals into people's diet.

Keywords: bamboo shoot paste, biscuits, fortification, nutrition, functional foods

1. Introduction

During the last decade, production and consumption of functional or fortified foods have gained much importance as they provide health benefits beyond the basic nutritional functions [1]. Fortification is the process of adding nutrients or non-nutrient bioactive components of edible products and has been identified as one of the most cost-effective nutrition intervention that can help in tackling chronic micronutrient deficiencies also known as hidden hunger [2, 3]. Worldwide, about 88 million people are undernourished and more than 2 billion people are affected by hidden hunger due to micronutrient deficiency [4]. The shrinkage of food basket vis-a-vis decrease in agricultural biodiversity or food diversity has risen serious questions on how effectively major crops alone can contribute towards food security, poverty alleviation and malnutrition, biodiversity maintenance and ecosystem conservation. At present, the calories for more than 90% of world population is provided by about 30 crops out of which rice, wheat and maize are the main food crops that provide food to nearly 95% of the world population [5]. Consequently, emphasis is being paid upon the usage of nutrient-rich neglected and underutilized crops, which are otherwise being marginalized as they are available mostly in remote areas, need long and tedious processing methods, have less market value, traditional method of consumption being followed which is not accepted by present generation, have various anti-nutrients and sometime socially and strategically despised [6]. For food fortification, neglected and underutilized plants can be used as they offer the potential to diversify the human di*et al*ong with increasing the nutritional value as such crops are usually rich in micronutrients, vitamins and health-promoting secondary metabolites. Bamboo shoot, a neglected traditional delicacy, is gaining popularity as the young shoot is nutritious and endowed with health-promoting phytochemicals and has been used both as food and medicine in several Asian countries like China, Korea, India, Japan and Thailand since ancient times. Juvenile bamboo shoots are not only delicious but are rich in nutrients, antioxidants and bioactive compounds but low in fat and sugar [7-10]. Some value-added edible products have been developed using bamboo shoot powder [11-14]. However, no detailed analyses of nutrients and bioactive compounds have been conducted, particularly of bamboo shoot fortified food products. The present work reports for the first time the use of bamboo shoot paste for developing nutritionally and functionally improved biscuits.

2. Material and Methods

2.1 Procurement of plant material

The juvenile shoots of *Dendrocalamus hamiltonii* Nees & Arn. Ex Munro was procured from the local vegetable market of Shillong, Meghalaya (India), during the peak season from June- September, packed properly and transported to Department of Botany, Panjab University, Chandigarh (India) by air for further analysis.

2.2 Preparation of bamboo shoot sample

The shoots were hand peeled to remove outer culm sheath, washed properly, chopped into small chunks and subjected to processing (boiling (20min), soaking (24hr in plain water). Thereafter, shoots were spread over a tissue paper to remove excess water and then put inside glass bottles, sealed tightly and stored at 4^0C for further analysis.

2.3 Preparation of bamboo shoot biscuits

For biscuit preparation, bamboo shoots were made into a paste using a grinder. A total of four formulations of biscuits were prepared; control biscuit (CB), fresh shoot paste fortified biscuit (FB), 20min boiled shoot paste fortified biscuit (BB) and 24hr soaked shoot paste fortified biscuits (SB). One sample was considered as a control having only 100g wheat flour, for test samples, 20% of the wheat flour was replaced by the paste of fresh shoots, 20min boiled shoots and 24hr soaked bamboo shoots. The other ingredients used for each batch were clarified butter (30 g), sugar (40 g), milk (60 ml) and baking powder (2 g). All the ingredients for each formulation were mixed for 5-10 min to make the dough and then dough was sheeted to a uniform thickness of 3 mm using a wooden rolling pin. Thereafter, circular biscuits of 2.5 cm diameter were cut, baked for 15-20 min at 200^0C in a baking oven, cooled and then packed in airtight containers for further analyses.

2.4 Biochemical evaluation

The biochemical analysis was performed for nutrients, anti-nutrient and bioactive compounds using the established methods, total carbohydrate content (Whistler) [15], starch content (MecCreddy *et al.*) [16], amino acids (Lee & Takahashi) [17], protein content (Bradford method) [18], moisture content (AOAC) [19], ash content by dry-ashing method of (Harbers) [20], crude fat by Soxhlet method of (AOAC) [19], total phytosterol content (Srivastava) [21], total phenol by Folin-Ciocalteau method (Singleton & Rossi) [22], vitamin C (Riemschneider *et al.*) [23], vitamin E (Baker *et al.*) [24], total cyanogens by the picrate method of (Haque & Bradbury) [25], dietary fiber content (Goering & Van Soest) [26] and mineral content using Wavelength Dispersive X-ray Fluorescence Spectroscopy (WDXRF, S8 TIGER, Bruker, Germany).

2.5 Sensory evaluation

Biscuits were subjected to sensory evaluation by 20 untrained panelists, after labeling each of the biscuit formulations with a secret code. The panelists were requested to record their ratings for colour, aroma, texture, taste and overall acceptability on a 9 point Hedonic Scale using numerical values ranging from 1 to 9, where 1 represented disliked extremely and 9 represented liked extremely.

2.6 Statistical analysis

All analyses were performed in triplicate and data were reported as mean ± SD. The results were analyzed through one-way analysis of variance (ANOVA) using PASW Statistics (version 18.0.0) followed by Duncan test. In the case of sensory analysis, data (n=20) were analyzed using the Tukey test to separate the means of other parameters that examined the acceptability of the biscuits. The numerical consequence was well-defined as $P \leq 0.05$.

3. Result and Discussion

3.1 Biochemical evaluation of wheat flour and bamboo shoot

The nutrients, anti-nutrient and bioactive compounds were analyzed in wheat flour and three different forms of shoots and results are shown in Table 1. As can be seen, wheat flour was highest in protein (9g/100g), starch (76.51g/100g), fat (1.75g/100g) and NDF (53g/100g) compared to the bamboo shoots. Among the bamboo shoots, fresh shoots were rich in nutrients but contents decreased after processing. Boiling and soaking are the commonly used processing techniques for shelf life enhancement and removal of cyanogenic glycoside. The permissible limit of cyanogen content in food is 500 mg/kg [27]. Freshly harvested shoots of *D. hamiltonii* had 1008.83 mg/kg of cyanogen content. However, amount decreased by 78% after boiling and 79% after soaking. Regarding nutrients and bioactive compounds, free amino acid content was highest in the fresh shoots (4.22g/100g) and lowest in 20 min boiled shoots (2g/100g). On the other hand, protein content was found lowest in 24hr soaked shoots (0.53g/100g; $P<0.05$) but a significant ($P < 0.05$) decrease was also seen after boiling (1.21g/100g) compared to the fresh shoots (3.50g/100g). Decrease in protein and amino acid content in boiled shoots may be due the denaturation of proteins caused by prolonged boiling in water for the removal of cyanogens. Cooking diminishes the biological value of the proteins by destroying the essential amino acids. In the case of soaking, decrease in nutrient content might be due to prolonged storage (Pandey and Ojha) [28]. Carbohydrate content was highest in the fresh shoot (3.29g/100g) but decreased significantly ($P<0.05$) after processing with highest decrease in 24 hr soaked shoots. Starch content increased after boiling (38%) but a significant ($P<0.05$) decrease was seen after soaking (40%). Increase in starch content after boiling might be due to amylose retrogradation which was also reported by de Almeida *et al.* [29] and Vaidya and Sheth [30]. Ash content was also decreased after boiling (44%) and soaking (66%) of bamboo shoots [31]. Similarly, fat content decreased after boiling but a slight increase (6%) was seen after soaking. Rawat *et al.* [32] also reported decrease in the fat content in 10 min boiled shoots of three bamboo species. Freshly harvested bamboo shoots are good source of bioactive compounds and antioxidants such as phenol, phytosterol, dietary fiber, vitamin C and vitamin E [9, 10] but a significant ($P<0.05$) decrease was seen after boiling and soaking. Phenol content in fresh shoots was 0.61g/100g but decreased after boiling and soaking by 69% and 54% respectively. The highest reduction ($P<0.05$) in phytosterol (30%), vitamin C (50%), vitamin E (58%), NDF (34%) and ADF (29%) was observed in 24 hr soaked shoots. Vitamins are most sensitive among all nutrients to loss during processing. Vitamin C changes to a less active form and reduction in the shoots as a result of time, temperature and storage. Amongst the processed forms, the boiled shoots retain maximum nutrients as compared to the soaked form except amino acid and fat content which were more in soaked shoots however, cyanogen content was almost same in both the processed forms.

Table 1: Biochemical evaluation of bamboo shoots and wheat flour

Parameter (g/100g)	Wheat Flour	Bamboo shoots		
		Fresh	20 min boiled	24hr soaked
Amino acid	0.21±0.01^d	4.22±0.06^a	1.98±0.02^c	2.08±0.03^b
Proteins	9.00±0.20^a	3.50±0.01^b	1.21±0.04^c	0.53±0.02^d
Carbohydrates	0.65±0.01^d	3.29±0.01^a	2.19±0.04^b	0.96±0.01^c
Starch	76.51±1.59^a	1.11±0.01^{bc}	1.53±0.01^b	0.67±0.01^d
Moisture	8.72±0.50^d	92.28±0.18^{bc}	92.33±0.09^b	93.34±0.16^a
Ash	0.62±0.15^{ab}	0.80±0.06^a	0.45±0.04^c	0.27±0.08^d
Fat	1.75±0.12^a	1.09±0.^{18bc}	0.77±0.10^d	1.16±0.15^b
Phenol	0.39±0.01^b	0.61±0.01^a	0.19±0.01^d	0.28±0.01^c
Phytosterol	0.14±0.01^d	0.47±0.02^a	0.42±0.01^b	0.33±0.02^c
Vitamin C	0.63±0.05^d	1.87±0.01^a	1.32±0.01^b	0.94±0.03^c
Vitamin E	0.54±0.02^b	0.59±0.01^a	0.28±0.01^c	0.25±0.01^d
NDF	53.43±0.04^a	5.50±0.01^{bc}	4.69±0.01^{bc}	3.61±0.^{01cd}
ADF	0.46±0.01^d	1.65±0.01^a	1.26±0.01^b	1.17±0.01^c
Cyanogenic glycoside	0.00±0.00	1008.83±2.01	218.59±1.06	205.22±2.50

Values are expressed as mean ± SD (n = 03); Mean followed by different letters in the same row differs significantly ($P<0.05$).

3.2 Biochemical evaluation of biscuits

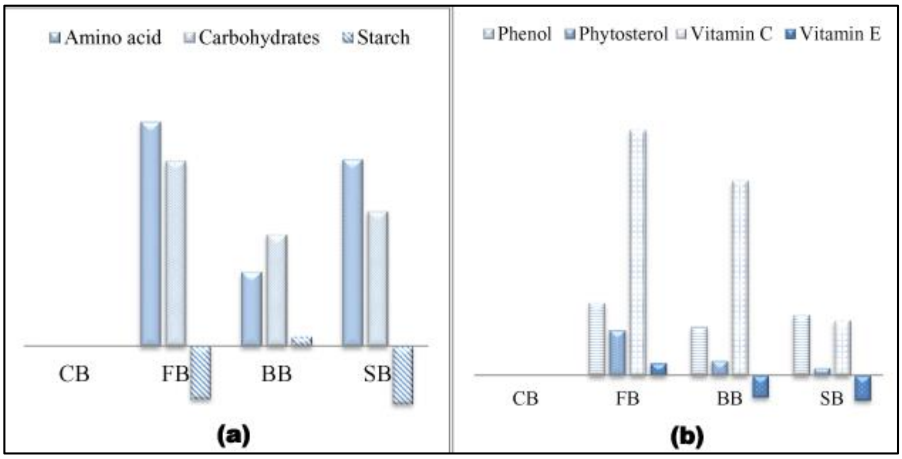
The biscuits fortified with bamboo shoot paste had significantly ($P<0.05$) higher content of free amino acids, protein and carbohydrate compared to the control biscuits (CB) (Table 2 & fig 1). The free amino acid content in fortified biscuits ranged from 0.08g/100g to 0.12g/100g. The maximum increment of around 100% in free amino acid content was observed in FB compared to CB (Fig 1a). Protein content was very high in bamboo shoot fortified biscuits [12, 13] with highest content in FB (1.68g/100g) followed by BB (1.31g/100g). A similar trend was seen in the case of fat but starch content was found highest in BB (59.47g/100g) and lowest in SB (42.46g/100g). Increase in starch content may be as a result of heat treatment which is also reported by Rehman and Shah [33]. Carbohydrate content was higher in FB (16.72g/100g) but 18% decrease was seen in BB and 12% in SB compared to the FB (Fig 1a). Moisture and ash content was lowest in CB while highest in FB.

Besides nutrients, bamboo shoots are also reported to be rich in phenols, phytosterols and vitamins [8]. Phenols, vitamin C and vitamin E promote human health by neutralizing cell damage caused by free radicals while, phytosterols are known for their cholesterol-lowering activities and reducing the incidence of cardiovascular disease, cancer and other chronic diseases [34]. Phenolic content in CB was 0.10 g/100g but increased by 60% in FB, 40% in BB and 50% in SB while, no significant difference was found in the phytosterol content of CB (0.16 g/100g), BB (0.18 g/100g) and SB (0.17 g/100g). A significant increase in phenols was also observed in cookies, nuggets and other products fortified with bamboo shoot powder [11-13]. In industrialized food, naturally occurring vitamins are lost during their processing and storage hence, need to be added to reduce nutritional deficiencies [35]. Vitamin C content of fortified biscuits was high compared to CB, with highest content in FB (3.12 g/100g). Contrarily, vitamin E content decreased in BB and SB when compared with the CB and FB (Table 2 & fig 1b). Bamboo shoot is also one of the rich sources of dietary fiber [36]. The major sources of dietary fibers for food fortification are cereals such as wheat, oat and barley though other sources such as apple, orange, mango and carrot have also been reported. Bamboo, the fastest growing plant with huge biomass can be an alternative source for providing the much needed dietary fiber for food fortification. Dietary fiber incorporated into food such as bakery and dairy products, jams, meats and soups can modify textural properties, avoid syneresis, stabilize high-fat food and emulsions and improve shelf life [37]. A significant ($P<0.05$) increase of dietary fiber components was observed in bamboo shoot fortified biscuits. FB were high in NDF (56.16g/100g), ADF (4.07g/100g), lignin (2.62g/100g), hemicelluloses (52.10g/100g) and cellulose content (1.45g/100g) while, lowest was found in CB. The increase of NDF and ADF in BB and SB was 13%, 10% and 88%, 75% respectively, compared to the CB. But there was no significant difference found ($p < 0.05$) in the cellulose content of the samples (Table 2 & fig 1c).

Table 2: Biochemical evaluation of biscuit samples

Parameter (g/100g)	Biscuits			
	CB	**FB**	**BB**	**SB**
Amino acid	0.06 ± 0.01^{d}	0.12 ± 0.01^{a}	0.08 ± 0.01^{c}	0.11 ± 0.01^{b}
Proteins	0.40 ± 0.07^{d}	1.68 ± 0.08^{a}	1.31 ± 0.04^{b}	1.15 ± 0.05^{c}
Carbohydrates	9.16 ± 0.43^{a}	16.72 ± 0.41^{a}	13.72 ± 0.48^{c}	14.66 ± 0.33^{b}
Starch	57.05 ± 0.63^{b}	43.67 ± 0.12^{c}	59.47 ± 0.43^{a}	42.46 ± 0.28^{d}
Moisture	0.14 ± 0.04^{d}	1.23 ± 0.39^{a}	0.86 ± 0.24^{b}	0.82 ± 0.19^{bc}
Ash	0.61 ± 0.02^{cd}	1.08 ± 0.13^{a}	0.78 ± 0.12^{b}	0.75 ± 0.06^{bc}
Fat	26.23 ± 0.49^{bc}	30.47 ± 1.31^{a}	27.27 ± 0.06^{b}	26.90 ± 0.89^{bc}
Phenol	0.10 ± 0.00^{d}	0.16 ± 0.01^{a}	0.14 ± 0.01^{c}	0.15 ± 0.01^{ab}
Phytosterol	0.16 ± 0.01^{cd}	0.22 ± 0.01^{a}	0.18 ± 0.01^{b}	0.17 ± 0.01^{bc}
Vitamin C	1.03 ± 0.01^{d}	3.12 ± 0.02^{a}	2.69 ± 0.13^{b}	1.50 ± 0.14^{c}
Vitamin E	0.39 ± 0.05^{ab}	0.43 ± 0.01^{a}	0.32 ± 0.01^{c}	0.31 ± 0.02^{cd}
Dietary fiber				
NDF	46.15 ± 0.23^{d}	56.16 ± 0.07^{a}	52.17 ± 0.04^{b}	50.57 ± 0.01^{bc}
ADF	1.90 ± 0.01^{d}	4.07 ± 0.01^{a}	3.58 ± 0.01^{b}	3.32 ± 0.01^{c}
Lignin	0.69 ± 0.01^{d}	2.62 ± 0.01^{a}	2.18 ± 0.01^{b}	2.09 ± 0.01^{bc}
Hemicellulose	44.26 ± 0.23^{cd}	52.10 ± 0.68^{a}	48.58 ± 0.04^{ab}	47.24 ± 0.01^{bc}
Cellulose	1.21 ± 0.01^{a}	1.45 ± 0.01^{a}	1.40 ± 0.01^{a}	1.24 ± 0.01^{a}

Values are expressed as mean ± SD (n = 03). Mean followed by different letters in the same row differs significantly ($P<0.05$).



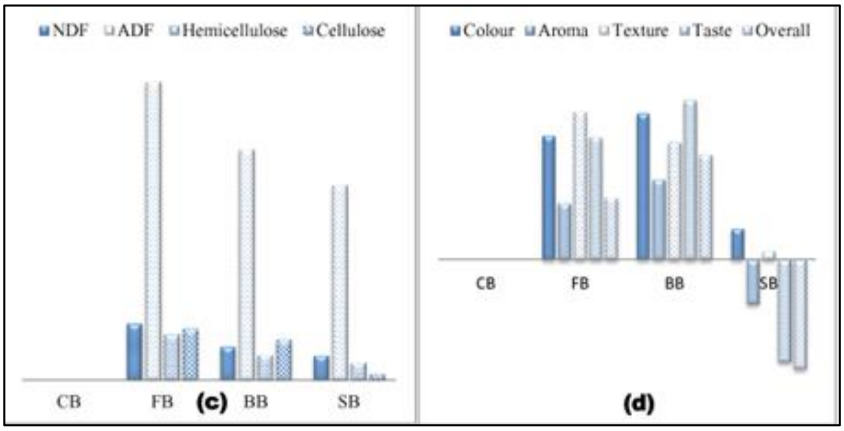


Fig 1: Changes in nutrients (a), bioactive compounds (b), dietary fiber (c) and sensory parameters (d) in biscuits fortified with bamboo shoot paste compared to the control; (CB-Control biscuit; FB-Fresh shoot fortified biscuit; BB-20 min boiled shoot fortified biscuit; SB- 24hr soaked shoot fortified biscuit)

Regarding mineral elements in the fortified biscuits (Table 3), Na, Al, and Fe content increased significantly ranging from 87-100%, 66-133%, 20-131% respectively. The increment of potassium (12-25%), silica (200%) and copper (33-66%) was also quite appreciable. Iron deficiency is very prevalent in many parts of the world, particularly in developing countries like India [38] and fortification of common and popular food items like biscuits with bamboo shoots can increase the iron content. In the present experiment iron content increased from 2.9 mg/100g of CB to 6.7 mg/100g (131.04%) in FB. Bamboo shoot is also a rich source of potassium, a heart-friendly mineral that helps to maintain normal blood pressure and a steady heartbeat. Other important mineral elements found in bamboo shoot are cadmium, cobalt, copper, nickel, manganese, selenium, and zinc [9, 39]. The deficiency of Zn may lead to the retarded skeletal development and immunodeficiency disorders. In FB, the increment of zinc was around 9.09%. Similarly, copper content increased significantly, ($P<0.05$) by 33% in BB and 67% in FB. Silicon content increased drastically in both FB and BB (186%). Other bamboo shoots fortified food products such as candy, nuggets, papad and pickles were also analyzed for their mineral content and reported a significant increase in K, Na, P, Ca and Mg content [10-12]. It was concluded that, bamboo shoots, being rich in macro- and micro-elements could provide an alternative fortified snacks to help alleviate malnutrition in older adults.

Table 3: Macro- and micro-element analysis data of biscuits

Parameter (mg/100g)	Biscuits		
	CB	FB	BB
	Macro		
K	163.67±3.51^c	199.33±4.04^a	181.33±3.21^b
P	109.33±4.04^a	80.00±6.56^b	80.00±6.56^b
S	128.67±1.53^b	168.67±3.21^a	130±3.61^b
Na	79.67±4.51^a	158.33±2.89^b	148.67±7.09^b
Cl	60.00±2.00^c	198.67±3.21^a	150±3.21^b
Mg	30.00±5.51^a	30.00±5.51^a	30.00±5.51^a
Ca	40.00±3.61^a	40.00±3.61^a	40.00±3.61^a
Al	35.33±8.39^c	68.67±3.21^a	50.00±3.61^b
Si	10.00±3.61^b	28.67±3.21^a	28.67±3.21^a
	Micro		
Zn	1.25±0.05^a	1.31±0.11^a	1.17±0.08^a
Fe	2.33±0.21^c	6.72±0.06^a	3.58±0.09^b
Cu	0.60±0.10^c	1.06±0.06^a	0.85±0.05^b
Ru	1.90±0.10^b	2.24±0.05^a	2.33±0.03^a

Values are expressed as mean ± SD (n = 03). Mean followed by different letters in the same row differs significantly ($P<0.05$).

3.3 Sensory evaluation of biscuits

Sensory acceptance of the food product is equally important along with fortification and enrichment with various nutrient elements [40]. Processing bamboo shoots for food is cumbersome and many do not like the bitter taste and pungent smell of the shoots. Converting of shoots into a paste for the fortification of food products is one of the best ways of enhancing the nutrients in the food products. Fig 2 shows the results of sensory analysis of the biscuits. In the present experiment, the acceptability in all the selected parameters viz. colour, aroma, texture, taste and overall was quite high in FB and BB whereas a significant ($P<0.05$) decrease was observed in the acceptability of SB in all the parameters recorded (Fig 1d). It was observed that BB had the highest sensory score and overall acceptability ($P<0.05$) while CB had the lowest compared to the FB and SB. BB score for colour, aroma, taste and overall acceptability was 7.1, 7.0, 7.8 and 7.5 respectively. The biscuits and cookies fortified with bamboo shoot powder were also analyzed for their nutritional and organoleptic properties and found that fortified food products had highest nutrient content and sensory score compared to the control sample [12, 13].

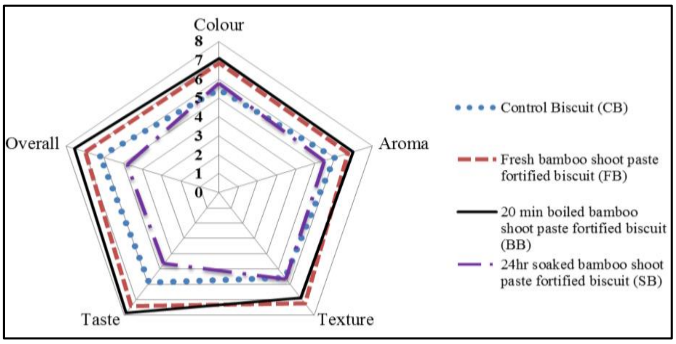


Fig 2: Sensory analysis radar chart on the average scores of the biscuits samples using a 9-point Hedonic scale (1-Extremely dislike to 9- Extremely like; n=20).

4. Conclusion

The biscuits fortified with bamboo shoot paste were richer in the nutrients and bioactive compounds compared to the control biscuits. Though the nutrient content of FB was better but the acceptability was more in BB. For food fortification, pure or mixed synthetic oral nutritional supplements are generally used to meet consumer demand for functional food. Bamboo shoots with high content of nutrients and bioactive compounds are very promising source of raw material for developing value-added food products or healthy snacks and could help in tackling the problem of hidden hunger and also contribute to the present consumer demand for natural additives in functional foods and nutraceuticals.

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