



Study Review

Mineral elements in Bamboo shoots and Potential role in Food Fortification

Nirmala Chongtham^{a,*}, Madho Singh Bisht^b, Oinam Santosh^a, Harjit Kaur Bajwa^a,
Aribam Indira^a

^a Department of Botany, Panjab University, Chandigarh, India

^b Department of Environmental Studies, North Eastern Hill University, Shillong, India

ARTICLE INFO

Keywords:

bamboo shoot analysis
minerals
nutrition
micronutrients
fortification
bamboo shoot processing

ABSTRACT

Bamboo shoots are gaining worldwide importance as a health food being a rich repository of nutrients and health promoting bioactive compounds. The young shoots offer a diversity of micronutrients especially mineral elements, exceeding the profiles of several commonly used vegetables and have great potential to combat micronutrient deficiency or hidden hunger. Deficiency of mineral elements is the most common and widespread nutritional disorder globally and has noticeable effects on human health. Minerals are indispensable due to their diverse functions in body metabolism and are critical for many metabolic processes by serving as essential co-factors for a number of enzymes. Bamboo shoots are a good source of macro and micro mineral elements. Apart from being an excellent source of food, bamboo is used in traditional medicines in many Asian countries. Modern research has supported most of the medicinal properties such as antioxidant, antidiabetic, antimicrobial, antitumor and prevention of cardiovascular and neurological disorders. Due to its nutritional and medicinal properties, bamboo shoot is an ideal bioresource for the development of novel functional foods and nutraceuticals. The present paper discusses mineral elements in fresh and processed bamboo shoots and shoot fortified products and the prospects of using bamboo shoots for food fortification.

1. Introduction

Minerals, the major group of micronutrients are indispensable for normal body growth due to their diverse functionalities and potentials in body metabolism and homeostasis and are vital for the normal structural and physiological growth, maintenance of hormonal and regulatory functions of our body and play a significant role in building of muscles and bones (Soetan et al., 2010). They are essential nutrients because they are not synthesized in the body and must be obtained through food or as supplements to meet daily requirements (Awuchi et al., 2020). In the recent past, much attention has been paid to the importance of minerals in human health as it is now well recognized that deficiencies or disturbances of a trace element essential for an enzyme system will have profound effects on metabolism and tissue structure and lead to a variety of diseases. There is a strong biological and physiological rationale which indicates that the long-known involvement of minerals in cellular energy production translates into functional and physiological outcomes in humans, including perceived physical and mental fatigue as well as psychological and cognitive functions (Tardy et al., 2020). Minerals required in greater quantities are referred to as macro

minerals and this group includes calcium, phosphorus, sodium, chlorine, potassium, magnesium and sulfur. Some elements that include cobalt, copper, iodine, iron, manganese, molybdenum, selenium, zinc, chromium, nickel and fluorine are required in trace amounts and are referred to as the micro or trace minerals. The macro-minerals are required in amounts greater than 100 mg/dl and the micro-minerals are required in amounts less than 100 mg/dl (Soetan et al., 2010). Through scientific experiments, it has become increasingly evident that a diet rich in healthful nutrients can help prevent and manage a number of diseases such as diabetes, heart diseases, stroke and cancer (Tolonen, 1990; Branco et al., 2016). Moreover, micronutrient deficiency, an invisible form of malnutrition also known as hidden hunger, is caused by deficiencies in key vitamins and minerals and affects more than 2 billion people globally leading to underweight and malnourished children with reduced productivity and intellectual capacity (Hodge, 2016; Harding et al., 2017). The fundamental reason for global malnutrition is the over reliance of the world population for its basic energy requirement on a few crops such as wheat, maize and rice which are rich in carbohydrates but lack many minerals and health promoting bioactive compounds. As plants are the main source of food, one of the most important challenges

* Corresponding author.

E-mail address: cnirmala10@gmail.com (N. Chongtham).

<https://doi.org/10.1016/j.jfca.2020.103662>

Received 3 July 2020; Received in revised form 12 September 2020; Accepted 20 September 2020

Available online 28 September 2020

0889-1575/© 2020 Elsevier Inc. All rights reserved.

for agriculture, besides enhancing food production, is to provide almost all the essential nutrients to humans for maintenance of good health (Martínez-Ballesta et al., 2010). It is envisaged that mineral malnutrition can be addressed by dietary diversification, mineral supplements, food fortification or biofortification. To effectively combat the health risks arising due to mineral element deficiencies, it is of utmost importance to identify and include food sources that are rich repositories of micro-nutrients along with being a balanced source of energy and wholesome nutrients. Plant-based foods are an important source of essential minerals, nutrients and bioactive compounds and bamboo is one such plant that stands out for its exceptional health benefits (Nirmala et al. 2011; Nirmala et al., 2018; Singhal et al., 2013). Bamboo shoot is considered as one of the health promoting vegetables and also projected as a future health food due to its high content of nutrients and bioactive compounds (Nirmala et al., 2014a). The consumption of bamboo shoots is mainly concentrated in Asia. However, due to the popularity of Chinese restaurants worldwide, the overall consumption of bamboo shoots is more than 2 million tons annually and is widespread in Europe, North America, Oceania and Africa (Choudhury et al., 2011; Ding and Wang, 2018). Nutrient components in the young shoots have been analyzed and the results reveal that they have a good profile of minerals such as potassium, calcium, phosphorus, iron, silicon, magnesium, sodium and selenium (Nirmala et al., 2011; Bajwa et al., 2019).

Although, bamboo shoots are rich in nutrients, minerals, bioactive compounds and antioxidants, an inherent drawback associated with fresh bamboo shoots is the presence of anti-nutrients such as cyanogenic glycosides, thiocyanate, glucosinolate, phytate and tannins. Hence, fresh juvenile shoots need to be processed prior to exploiting them as a food additive and for safe human consumption (Rawat et al., 2015). The major processing techniques, which are used for removal of anti-nutrients, and enhancement of shelf life of bamboo shoots are, soaking, boiling, salting, and fermentation. Boiling for 20 minutes effectively eliminates 97% of cyanogen content of the shoot. Fermentation is also a very effective processing technique commonly followed in Northeastern parts of India that not only remove the toxin and other undesirable characteristics, but also improve the therapeutic properties of the bamboo shoots. The present paper discusses the mineral elements in fresh and processed bamboo shoots and bamboo shoot fortified food products and application prospects of bamboo shoots in food fortification and food additives to combat micronutrient deficiencies.

2. Macro mineral elements

Mineral content in bamboo shoots may vary depending upon the species, growth site, agroclimatic conditions, harvesting season, age of shoot, shoot part and methods used for sample preparation and estimation. Moreover, the different processing techniques utilized for the removal of antinutrients in the shoots often have varied effects on the level of mineral content. Results of the different studies revealed that boiling caused highest loss in the mineral content of the shoots. This might be due to leaching because higher temperature leads to solubilization of pectin which is a major component in the cell wall. This makes the cell more susceptible to rupture and contributes to the dissolution of the middle lamella. The middle lamella contains the highest level of some minerals such as potassium in certain fruits and vegetables which leads to release of minerals from the cells in the water (Asiimwe et al., 2013). Contrarily, bamboo shoot fermentation increased the amount of certain minerals such as magnesium, sulphur, sodium, calcium and iron. The increase in mineral content after fermentation might be due to loss of dry matter as microbes degrade carbohydrates and proteins (Day and Morawicki, 2018). Antinutrients also decrease the bioavailability of minerals because they form complexes with different mineral elements (Nkhata et al., 2018). The antinutrients such as phytate are an effective chelator of positively charged molecules and have the potential to form stable insoluble complexes with minerals (Cheryan, 1980). Fermentation process breaks these complexes and makes them readily bioavailable

(Lopez et al., 1983).

Processing of shoots and different methods used for the analysis of minerals are depicted in Fig. 1. The mineral content in bamboo shoots is determined by different methods such as Atomic absorption spectrophotometer (Tabet et al., 2004; Elangbam, 2006; Feleke, 2013; Sood et al., 2013; Waikhom et al., 2013; Christian et al., 2015), flame photometer (Pandey and Ojha, 2014; Chandramouli and Viswanath, 2015), Wavelength Dispersive X Ray Fluorescence (WDXRF) (Rawat, 2017; Sharma, 2018; Saini et al., 2017; Devi, 2018; Bajwa et al., 2019; Meetei, 2019) plasma spectrometer and Optical Emission Spectrometer method. Mineral content of maximum number of bamboo species have been analyzed using (WDXRF) (Tables 2 and 3, Saini et al., 2017; Devi, 2018)

2.1. Potassium

Bamboo shoots have the highest potassium content followed by chlorine, phosphorus, magnesium and calcium (Table 1). Potassium is a heart healthy mineral and functions in acid-base balance, regulation of osmotic pressure, conduction of nerve impulse, muscle contraction particularly the cardiac muscle and cell membrane function (Soetan et al., 2010). The potassium content in the shoots of nineteen bamboo species (Table 1) ranges from 4190 to 6660 mg/100 g of dry weight (Saini et al., 2017; Devi, 2018). This is much higher than potassium content present in common vegetables (Table 2) with highest level in Asparagus (1094 mg/100 g) followed by beetroot (380 mg/100 g), pea (330 mg/100 g), bean (230 mg/100 g), lettuce (220 mg/100 g) and spinach (157 mg/100 g). Waikhom et al. (2013) reported ten elements in 30 days old shoots of twelve bamboo species and found that all bamboo shoots are rich in potassium and poor in sodium. The potassium content ranged from 1310 to 3533 mg/100 g dry weight, maximum in *D. manipureanus* and minimum in *Schizostachyum dulloa*. A higher range (2670-9630 mg/100 g dry weight) was recorded by Christian et al. (2015) in six species of *Phyllostachys* and *Pseudosasa japonica* whereas Karanja et al. (2015) observed higher potassium content in upper portions of *Yushania alpina* shoots (35,900 µg/g dry weight) compared to lower portions (27,600 µg/g dry weight). Potassium content is also affected by altitude and site as reported by Feleke (2013) who studied two bamboo species *Arundinaria alpina* and *Oxytenanthera abyssinica* growing in different altitudes and zones of Ethiopia. The highest potassium content (9772 mg/100 g dry weight) was found in highland bamboo *A. alpina* whereas, in lowland bamboo *O. abyssinica*, potassium content was much lower. A similar observation was reported by Chandramouli and Viswanath (2015) in shoots growing in two agro climatic zones viz. tropical humid and semi-arid in Peninsular India. Processing affected the potassium content in almost all the species. Bajwa et al. (2019) also reported a significant decrease in potassium content after processing with highest decrease in boiled shoots (37%) followed by fermented shoots (18%) and brine preserved shoots (8%) of *D. hamiltonii*. A similar decreasing pattern in 15 min boiled (water) and 10 min boiled (5% brine solution) shoots based on fresh weight of four bamboo species was reported (Pandey and Ojha, 2014). Amongst different drying methods, freeze drying was the most efficient in retaining potassium content in shoots of *Phyllostachys manii* (Fig. 2) as also reported by Santosh et al. (2019). Sonar et al. (2015) estimated the potassium content of different types of fermented shoots and reported highest retention in the herring form (1457 mg/100 g) compared to the others (Table 4).

2.2. Phosphorus

Phosphorus, the second most abundant element in the human body is also abundant in bamboo shoots. This element is the main constituent of DNA and RNA and is vital in many metabolic processes such as those involving the buffers in body fluids which help in maintaining the acid base balance. Young shoots of some bamboo species were analyzed for

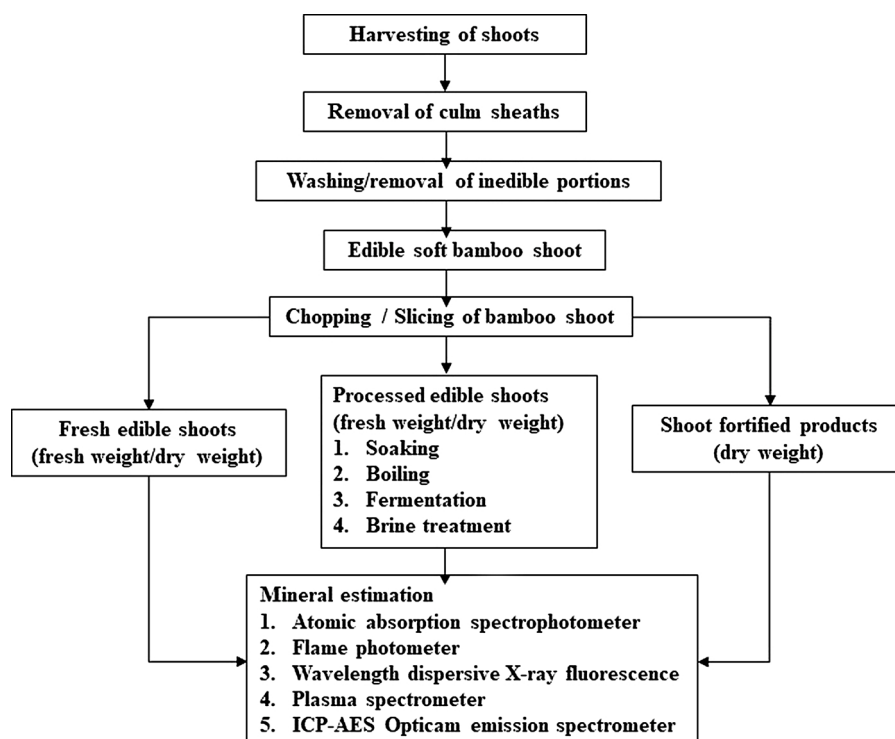


Fig. 1. Schematic flowchart showing the different processing methods of bamboo shoot and various techniques used for the estimation of minerals.

phosphorus content which ranged from 460–930 mg/100 g with the highest content in *Phyllostachys manii* (Table 1). This is higher than most of the commonly consumed vegetables (Table 2). Karanja et al. (2015) reported a significant difference in the amount of phosphorus estimated from upper (763 mg/100 g) and lower portion (481 mg/100 g) of *Y. alpina* shoots. As indicated in Table 3 and Fig. 2, processing techniques has significant impact on the concentration of phosphorus. Highest concentration was observed in the sun-dried shoots of *P. manii* (1100 mg/100 g). Similar pattern was noticed in other bamboo species such as *B. balcooa*, *B. bambos*, *B. nutans*, *D. giganteus*, *D. hamiltonii*, *D. latiflorus* and *D. sikkimensis* analyzed by different researchers using different estimation techniques. Bajwa et al. (2019) analyzed the phosphorus content in boiled, brine preserved and fermented shoots of *D. hamiltonii* by WDXRF and reported highest decrease (48%) in brine preserved shoots followed by boiled shoots (19%) and fermented shoots (12%). Similar trend was reported by Nirmala et al. (2008) and Saini et al. (2017) in the shoots of *D. giganteus* and *B. balcooa* respectively. Pandey and Ojha (2014) estimated the phosphorus content of *B. bambos*, *B. tulda*, *D. asper* and *D. strictus* on fresh weight basis and reported that phosphorus content in shoots decreased when boiling time increased from 10 min to 25 min. Sharma and Barooah (2017) analyzed fermented shoots and found that Kako retained maximum phosphorus content as compared to Jati and Bhuluka (Table 4).

2.3. Magnesium

Bamboo shoot is one of the best sources of magnesium. In nineteen species analyzed species by Saini et al. (2017) and Devi (2018), magnesium content ranged from 130 to 300 mg/100 g (Table 1). Magnesium acts as a cofactor for more than 300 enzymatic reactions in the body that regulate diverse biochemical reactions in the body including protein synthesis, muscle and nerve transmission, signal transduction, blood glucose control and blood pressure regulation (Gröber et al., 2015). In *Yushania alpina* shoots, Karanja et al. (2015) reported magnesium content of 430 mg/100 g in the upper portion. This is much higher than commonly consumed vegetables except spinach with magnesium

content 631 mg/100 g (Table 2). Feleke (2013) reported site variable concentration of magnesium in the shoots of *A. alpina* ranging from 139 to 189 mg/100 g. Chandramouli and Viswanath (2015) estimated the magnesium content in shoots of different bamboo species viz. *B. balcooa*, *B. bambos*, *D. asper*, *D. stocksii*, *D. strictus* and *Guadua angustifolia* growing in two agro climatic zones. Magnesium content decreased after processing but a slight increase was reported after fermentation. Rawat (2017), Saini (2019) and Devi (2018) estimated the magnesium content in shoots of *B. balcooa*, *B. bambos*, *B. nutans*, *D. sikkimensis*, *D. giganteus*, *D. hamiltonii*, *D. membranaceus*, *D. latiflorus*, *P. mannii* and *P. pubescens* using WDXRF and reported the highest value in soaked shoots when compared with the brine preserved, boiled and fermented shoots. Bajwa et al. (2019) also used the same technique and noticed a slight reduction after boiling (160 mg/100 g) and brine treatment (150 mg/100 g) but increase after fermentation (190 mg/100 g) in the shoots of *D. hamiltonii*. Pandey and Ojha (2014) estimated the content on fresh weight basis and reported reduction in the amount of magnesium in the shoots of four bamboo species (*B. bambos*, *B. tulda*, *D. asper*, *D. strictus*) after boiling. Fresh shoots (170 mg/100 g) of all the four species had same amount of magnesium but content decreased when shoots of *B. bambos* were boiled for 10 min in 5% brine solution (150 mg/100 g) and 15 min in plain water (150 mg/100 g). Sun drying is the best method of processing for retaining the magnesium content (Fig. 2, Rawat, 2017).

2.4. Calcium

Calcium is the most abundant anion in extracellular fluid and is an essential element for various functions related to the growth, activity and maintenance of the human. Bamboo shoot is a rich source of calcium. Analysis of macro minerals in shoots of some bamboo species (Saini et al., 2017; Devi, 2018) revealed that the calcium content ranges from 100 to 220 mg/100 g (Table 1) which is much higher than commonly consumed vegetables. Only radish and spinach have higher calcium content (Table 2). The highest value (285 mg/100 g) was reported by Feleke (2013) in the shoots of *A. alpina*. In the shoots of

Table 1
Macro and micro mineral elements (mg/100 g dry weight) in fresh shoots of some bamboo species estimated by Wavelength Dispersive X-ray Fluorescence spectrometry (Saini et al., 2017; Devi, 2018).

Species	K	P	Mg	Ca	S	Na	Cl	Si	Fe	Zn	Cu	Mn	Ni
<i>Bambusa balcooa</i>	4230 ± 60	560 ± 30	210 ± 10	180 ± 10	230 ± 10	20 ± 0.6	1220 ± 40	150 ± 2.8	8.2 ± 0.8	6.8 ± 0.4	2.6 ± 0.4	2.5 ± 0.2	0.9 ± 0.1
<i>B. bambos</i>	5980 ± 60	750 ± 50	230 ± 20	190 ± 10	260 ± 20	20 ± 0.6	1530 ± 40	130 ± 1.8	8.0 ± 0.8	10 ± 0.6	2.5 ± 0.4	3.6 ± 0.2	0.7 ± 0.1
<i>B. cacharensis</i>	4480 ± 50	550 ± 30	180 ± 10	110 ± 10	250 ± 20	10 ± 0.4	1150 ± 40	120 ± 1.8	5.8 ± 0.6	7.2 ± 0.6	2.4 ± 0.4	2.3 ± 0.2	0.7 ± 0.1
<i>B. manipureana</i>	6480 ± 70	670 ± 40	210 ± 20	100 ± 10	260 ± 20	20 ± 0.6	1410 ± 40	110 ± 1.8	5.9 ± 0.6	8.5 ± 0.6	1.6 ± 0.2	1.3 ± 0.1	0.9 ± 0.1
<i>B. nutans</i>	5230 ± 60	580 ± 30	200 ± 10	180 ± 10	250 ± 20	20 ± 0.6	1230 ± 40	160 ± 2.8	8.8 ± 0.8	9.5 ± 0.6	1.9 ± 0.2	9.7 ± 0.8	0.8 ± 0.1
<i>B. tulda</i>	5210 ± 60	640 ± 50	190 ± 10	100 ± 10	280 ± 20	20 ± 0.6	1680 ± 40	120 ± 2.2	7.0 ± 0.8	7.7 ± 0.6	2.4 ± 0.4	2.5 ± 0.2	0.7 ± 0.1
<i>B. vulgaris</i>	4190 ± 50	460 ± 30	130 ± 10	110 ± 10	270 ± 20	10 ± 0.4	1660 ± 40	140 ± 2.2	6.7 ± 0.6	6.0 ± 0.4	2.2 ± 0.4	2.5 ± 0.2	0.8 ± 0.1
<i>Cephalostachyum capitatum</i>	5630 ± 50	610 ± 50	170 ± 10	180 ± 10	200 ± 10	20 ± 0.6	1200 ± 40	80 ± 0.8	6.8 ± 0.6	9.0 ± 0.8	2.6 ± 0.4	6.0 ± 0.6	1.2 ± 0.1
<i>Chimonobambusa callosa</i>	6570 ± 60	750 ± 50	220 ± 10	220 ± 20	280 ± 20	20 ± 0.6	680 ± 20	100 ± 1.8	6.5 ± 0.6	8.0 ± 0.8	3.4 ± 0.6	3.5 ± 0.4	0.9 ± 0.1
<i>Dendrocalamus giganteus</i>	4590 ± 50	540 ± 30	190 ± 10	210 ± 20	270 ± 20	40 ± 0.8	590 ± 20	120 ± 1.6	6.9 ± 0.6	6.1 ± 0.4	5.1 ± 0.8	1.3 ± 0.1	0.8 ± 0.1
<i>D. hamiltonii</i>	5230 ± 60	560 ± 40	200 ± 10	150 ± 10	220 ± 20	40 ± 0.8	870 ± 20	200 ± 2.8	7.4 ± 0.3	6.8 ± 0.4	2.6 ± 0.4	1.2 ± 0.1	0.7 ± 0.1
<i>D. hookerii</i>	5740 ± 60	680 ± 50	220 ± 20	150 ± 10	290 ± 20	30 ± 0.8	1460 ± 40	170 ± 2.8	6.0 ± 0.6	8.4 ± 0.8	2.9 ± 0.4	2.4 ± 0.2	0.7 ± 0.1
<i>D. latiflorus</i>	4390 ± 50	480 ± 30	160 ± 10	120 ± 10	230 ± 20	20 ± 0.6	910 ± 30	170 ± 2.8	4.7 ± 0.4	7.9 ± 0.6	1.9 ± 0.2	3.6 ± 0.4	1.2 ± 0.1
<i>D. longispathus</i>	5610 ± 60	580 ± 30	200 ± 10	130 ± 10	240 ± 20	10 ± 0.4	950 ± 30	140 ± 2.2	6.8 ± 0.6	8.2 ± 0.8	2.1 ± 0.4	2.3 ± 0.2	0.7 ± 0.1
<i>D. manipureanus</i>	6200 ± 70	630 ± 50	240 ± 20	140 ± 10	320 ± 20	20 ± 0.6	1270 ± 40	140 ± 2.6	7.9 ± 0.8	9.0 ± 0.8	2.1 ± 0.4	3.2 ± 0.4	0.8 ± 0.1
<i>D. membranaceus</i>	6120 ± 70	620 ± 40	200 ± 20	160 ± 10	240 ± 20	90 ± 1.2	930 ± 30	150 ± 2.8	6.8 ± 0.6	8.5 ± 0.8	2.2 ± 0.4	1.5 ± 0.1	0.9 ± 0.1
<i>D. sikkimensis</i>	5200 ± 60	530 ± 30	240 ± 20	180 ± 10	270 ± 20	30 ± 0.8	880 ± 20	160 ± 2.6	10 ± 0.8	8.3 ± 0.8	2.5 ± 0.4	4.3 ± 0.6	1.1 ± 0.1
<i>Melocanna baccifera</i>	6480 ± 60	620 ± 40	300 ± 20	210 ± 20	340 ± 10	30 ± 0.8	1350 ± 30	120 ± 2.4	7.2 ± 0.8	10 ± 0.8	2.8 ± 0.4	5.5 ± 0.6	1.0 ± 0.1
<i>Phyllostachys mannii</i>	6660 ± 70	930 ± 60	230 ± 20	130 ± 10	330 ± 20	60 ± 1.2	850 ± 20	70 ± 1.2	9.1 ± 0.8	10 ± 0.8	2.6 ± 0.4	9.0 ± 0.8	0.8 ± 0.1

Data are presented in mean values ± Standard deviation (n = 3)

Y. alpina, upper part had high calcium content (267 mg/100 g) as compared to the lower portion of the shoot (106 mg/100 g) as reported by Karanja et al. (2015). Processing techniques also have significant impact on the calcium concentration in bamboo shoots with maximum recorded in soaked shoots of *D. membranaceus* (Table 3). The highest value of calcium (370 mg/100 g) was reported by Bajwa et al. (2019) in brine preserved shoots of *D. hamiltonii*. Devi (2018) and Rawat (2017) also reported a similar trend of increase in calcium content in brine preserved shoots in *B. nutans*, *D. giganteus*, *D. sikkimensis* and *D. latiflorus*. In *Bambusa balcooa*, Saini (2019) reported increase in calcium content after processing with highest increase in water preserved shoots (240 mg/100 g) followed by boiled shoots for 15 min (230 mg/100 g). Pandey and Ojha (2014) reported a complete depletion of calcium content when shoots of *B. bambos* were boiled for 25 min whereas no change occurred when the shoots were boiled for 10 min in 5% brine solution and 15 min in plain water. Calcium content remained unaffected in *D. asper* when shoots were boiled for 15 min and 20 min.

2.5. Sulphur

Sulphur is the third most abundant mineral in bamboo shoots after potassium and phosphorus. It is an important component of amino acids, carbohydrates and phospholipids. In fresh bamboo shoots, sulphur content ranges from 200 to 340 mg/100 g with highest content recorded in *Melocanna baccifera* (Table 1) followed by *D. hookerii* (290 mg/100 g) and *Chimonobambusa callosa* (280 mg/100 g). During processing, the soaked shoots showed an increased in sulphur content in all the species (Table 3). Saini et al. (2017) reported the sulfur content in *B. bambos* (260 mg/100 g) and *B. balcooa* (230 mg/100 g) fresh shoots which increased significantly by 9–11% after soaking and 8–13% after storage in water for six months but boiling, brine preservation and fermentation caused a significant decrease in the sulphur content of the shoots. Devi (2018) and Rawat (2017) also analyzed the shoots of *B. nutans*, *D. giganteus*, *D. hamiltonii*, *D. latiflorus*, *D. sikkimensis*, *P. mannii* and *P. pubescens* and reported highest content in the soaked shoots compared with boiled, fermented and brine treated shoots. Bajwa et al. (2019) reported a significant increase (11%) after fermentation. Among the different processing methods, the sulphur content increased in the sun-dried shoots of *D. giganteus*, *D. hamiltonii* and *Phyllostachys manii* (Rawat, 2017).

2.6. Sodium

Sodium is the principle cation in extracellular fluid and its important functions include maintenance of membrane potentials, transmission of nerve impulses and the absorptive processes of monosaccharides, amino acids, pyrimidines and bile salts (Soetan et al., 2010). Only a few researchers in recent years have examined the sodium content of bamboo shoots and indicated lower values compared to other macro minerals. Sodium content ranged from 0.19 to 7.34 mg in the fresh shoots (Nirmala et al., 2008; Park and Jhon, 2013; Sood et al., 2013; Hailu and Addis, 2016). A higher content was seen in some species which ranged from 10 to 90 mg/100 g (Table 1) with highest content recorded in *D. membranaceus*. Pandey and Ojha (2014) estimated the sodium content on fresh weight basis using flame photometer and reported highest content in the shoots of *D. asper* and *D. strictus* (90 mg/100 g). A significant difference was reported in the shoots of various bamboo species collected from different locations (Chandramouli and Viswanath, 2015). Bajwa et al. (2019) estimated the sodium content in fresh, fermented, brine preserved and boiled shoots of *D. hamiltonii* and found that content increased after processing with highest increase in brine preserved shoots (1879 mg/100 g) and lowest in the fermented shoots (70 mg/100 g) as compared to the fresh shoots (30 mg/100 g). Similar trend was also reported by Saini (2019) in the shoots of *B. balcooa*, *B. bambos*, *B. nutans* and *D. sikkimensis*. Pandey and Ojha (2014) reported an increase in sodium content when shoots of *B. tulda* were boiled in 5%

Table 2

Macro and micro mineral (mg/100 g) content in commonly consumed vegetables.

Species	K	P	Mg	Ca	Na	Fe	Zn	Cu	Mn	Ni	Cd	Co	References
<i>Abelmoschus esculentus</i> (Okra)	18.13		0.4	4.23	0.4	1.2	0.19			0.12	0.13		James and Emmanuel (2011)
<i>Agaricus bisporus</i> (Mushroom)	320	80	9	6	5	0.6	-	0.72	-	-	-	-	Mayer (1997)
<i>Allium cepa</i> (Onions)	160	30	4	25	3	0.3	-	0.05	-	-	-	-	Mayer (1997)
<i>Asparagus officinalis</i> (Asparagus)	1094	-	-	67	184	19	260	-	-	-	-	-	Aberoumand and Deokule (2009)
<i>Beta vulgaris</i> (Beetroot)	380	51	11	20	66	1	-	0.02	-	-	-	-	Mayer (1997)
<i>Brassica oleracea</i> (Cabbage)	10.45		4.43	7.73	0.5	0.18	0.34	-	-	0.29	0.07	-	James and Emmanuel (2011)
<i>Brassica rapa</i> (Turnip)	280	41	8	48	15	0.2	-	0.01	-	-	-	-	Mayer (1997)
<i>Cucumis sativus</i> (Cucumber)	4.65		3.92	1.8	5.25	4.4	0.55	0.1	0.12	0.18	-	0.114	Ismail et al. (2011)
<i>Cucurbita pepo</i> (Pumpkin)	130	19	10	29	-	0.4	-	0.02	-	-	-	-	Mayer (1997)
<i>Daucus carota</i> (Carrot)	3.85		29.7	2.2	4.9	13.3	0.21	0.14	0.127	0.005	-	0.104	Ismail et al. (2011)
<i>Lactuca sativa</i> (Lettuce)	220	28	6	28	3	0.7	-	0.01	-	-	-	-	Mayer (1997)
<i>Lycopersicon esculantum</i> (Tomato)	83.6	76	-	220	154.8	12	25.6	7.6	20.8	-	-	-	Adenipekun and Oyetunji (2010)
<i>Momordica charantia</i> (Bitter gourd)	6.4	-	4.26	2.85	6.9	11.6	0.4	0.11	0.139	0.13	-	0.114	Ismail et al. (2011)
<i>Phaseolus vulgaris</i> (Bean)	230	38	17	36	-	1.2	0.2	0.01	-	-	-	-	Holland et al. (1991)
<i>Pisum sativum</i> (Peas)	330	130	34	21	1	2.8	-	0.05	-	-	-	-	Mayer (1997)
<i>Raphanus sativus</i> (Raddish)	149.44	-	321.37	860.36	109.50	19.85	11.76	2.9	-	0.711	0.005	-	Linkon et al. (2015)
<i>Solanum tuberosum</i> (Potato)	38.5	-	2.91	2.4	6.6	1.5	0.15	0.13	0.1	0.05	-	0.113	Ismail et al. (2011)
<i>Spinacia oleracea</i> (Spinach)	157.52	-	631.02	229.17	485.57	74.92	29.45	7.55	-	0.973	0.009	-	Linkon et al. (2015)

Note: '-' signifies 'not mentioned'

brine solution for 10 min. The increase after brine treatment might be due to the absorption of sodium content from the preserving medium. Nirmala et al. (2008) reported highest amount of sodium in fermented shoots of *D. giganteus*.

2.7. Chlorine

While a large number of studies have evaluated mineral content of bamboo shoots, few studies have been conducted to estimate the chlorine content in shoots. Deficiency of chloride in diet may lead to alkalosis and reduction in blood chloride level leading to cerebral dehydration that can also affect transportation of oxygen (Morrison, 1990). In shoots of nineteen species analyzed, the chlorine content ranged from 590 to 1680 mg/100 g (Table 1). Saini et al. (2017) estimated the chlorine content in shoots of two bamboo species and found that *B. bambos* shoots had higher amount of chlorine (1530 mg/100 g) as compared to the shoots of *B. balcooa* (1220 mg/100 g). Similarly, Rawat (2017) analyzed the shoots of *D. giganteus*, *D. hamiltonii*, *D. membranaceus* and *P. manii* and reported that chlorine content did not vary significantly among the species. However, processing had a significant effect on the chlorine content in shoots. Bajwa et al. (2019) studied the effect of different processing methods on the chlorine content in shoots of *D. hamiltonii* and observed that content decreased after fermentation (740 mg/100 g) and boiling (510 mg/100 g) but increased drastically in brine preserved shoots (24730 mg/100 g) compared to the fresh shoots (860 mg/100 g). Saini et al. (2017) also studied the effect of processing on chlorine content in shoots of *B. nutans* and *B. bambos* and found a significant decrease after processing except for brine preserved shoots where the content increased immensely.

2.8. Silicon

Bamboo extract is the richest known source of natural silica, containing over 70% organic silica. This is more than 10 times the level found in the widely used Horsetail plant (*Equisetum*) that contains 5% to 7% silica (Law and Exley, 2011). Pure form of silica obtained from bamboo internodes known as Tabasheer, banslochan or bamboo-manna is used in Indian traditional Ayurvedic and Unani medicine. It acts as stimulant, astringent, febrifuge, tonic with antispasmodic and

aphrodisiac properties (Nirmala and Bisht, 2017). Though silica has not been largely documented as an essential trace element, over the past few decades, several biochemical and clinical studies have demonstrated the advantageous effects of silicon and it is now documented as one of the most indispensable trace elements in human metabolism. Silicon provides strength, integrity and flexibility to the connective tissues of skin, bones, nails, hair and arteries and is also considered as an anti-ageing nutrient (Jugdaohsingh, 2007; Martin, 2013). Deficiency of silicon leads to incompatibility in normal growth and skeletal development.

Silicon content in the fresh juvenile shoot ranges from 70–200 mg/100 g in which maximum is found in *Dendrocalamus hamiltonii* (Table 1). Bamboo species such as *B. balcooa*, *B. bambos*, *B. cacharensis*, *B. manipureana*, *B. nutans*, *B. tulda*, *B. vulgaris*, *C. capitatum*, *C. callosa*, *D. hamiltonii*, *D. sikkimensis*, *D. latiflorus*, *D. longispatus*, *D. sikkimensis*, *D. hookeri* and *M. baccifera* have been estimated for their silicon content and it was found that silicon content in bamboo shoots is not less than 100 mg/100 g except the shoots of *P. manii* (70 mg/100 g) and *C. capitatum* (80 mg/100 g). Processing of bamboo shoots has a significant impact on the level of silicon. Decline in silicon content after boiling has been observed by Park and Jhon (2013) in *Phyllostachys pubescens* and *Sinoarundinaria nigra* shoots. The reduction in silicon might be due to solubility of plant based amorphous silicon with processing and storage (Dove et al., 2008). Thus, bamboo shoots being a silicon rich vegetable can offer significant prospects for dietary supplementation and can be used in the nutraceutical and cosmetic industries.

3. Micro mineral elements

3.1. Iron

Bamboo shoot is one of the iron rich foods and many bamboo species have been analyzed for the iron content. Iron is an essential element for almost all living organisms as it participates in a wide variety of metabolic processes. The average daily recommended dose of iron for a normal adult is 18 mg. Deficiency of iron causes anemia and could affect brain functioning (Lorinczova et al., 2020). In fresh shoots of some bamboo species, iron content ranges from 4.7 to 10 mg/100 g (Table 1). Waikhom et al. (2013) reported iron content of 25.8 mg/100 g in *B. tulda* which is higher than most commonly consumed vegetables such as pea, tomato, potato, onion, beans, cabbage and cucumber (Table 2).

Table 3

Changes in total macro and micro mineral content (mg/100 g dry weight) during different processing methods in the edible shoots of some bamboo species. (Saini et al., 2017; Rawat, 2017)

Species		K	P	Mg	S	Ca	Si	Na	Ni	Cu	Fe	Zn	Mn
<i>Bambusa balcooa</i>	S	3700 ± 50	530 ± 30	180 ± 20	250 ± 10	240 ± 20	110 ± 0.8	30 ± 1.4	0.9 ± 0.1	2.8 ± 0.6	7.2 ± 0.8	6.6 ± 0.4	1.9 ± 0.1
	B	2700 ± 40	440 ± 40	120 ± 10	210 ± 10	230 ± 30	100 ± 0.8	20 ± 1.2	0.8 ± 0.1	2.0 ± 0.4	6.8 ± 0.6	6.0 ± 0.4	1.4 ± 0.1
	Fr	3520 ± 40	360 ± 20	120 ± 10	200 ± 10	160 ± 10	120 ± 1.2	30 ± 1.4	0.8 ± 0.1	2.6 ± 0.6	8.2 ± 0.8	5.6 ± 0.4	0.9 ± 0.1
<i>B. bambos</i>	S	3810 ± 50	590 ± 40	190 ± 20	290 ± 20	210 ± 20	90 ± 0.8	30 ± 1.4	0.4 ± 0.1	2.7 ± 0.6	7.0 ± 0.8	10 ± 0.8	2.8 ± 0.2
	B	2770 ± 30	370 ± 20	140 ± 10	240 ± 10	230 ± 20	80 ± 0.8	20 ± 1.2	0.6 ± 0.1	1.7 ± 0.4	5.9 ± 0.6	7.7 ± 0.8	2.0 ± 0.2
	Fr	3370 ± 50	350 ± 20	120 ± 10	200 ± 10	180 ± 20	90 ± 0.8	30 ± 1.4	0.6 ± 0.1	2.4 ± 0.6	8.0 ± 0.8	9.4 ± 0.8	1.9 ± 0.2
<i>B. nutans</i>	S	4120 ± 60	520 ± 40	190 ± 20	290 ± 20	200 ± 20	110 ± 0.8	60 ± 1.8	0.6 ± 0.1	2.5 ± 0.6	9.4 ± 0.8	6.0 ± 0.8	6.2 ± 0.6
	B	3530 ± 40	430 ± 40	140 ± 10	240 ± 10	130 ± 10	110 ± 0.8	-	0.5 ± 0.1	2.2 ± 0.4	10.6 ± 1.0	4.5 ± 0.4	-
	Fr	4500 ± 60	410 ± 40	160 ± 10	230 ± 10	120 ± 10	130 ± 1.2	60 ± 1.8	0.6 ± 0.1	2.6 ± 0.6	12 ± 1.2	5.4 ± 0.4	3.5 ± 0.6
<i>Dendrocalamus giganteus</i>	S	3320 ± 50	530 ± 40	180 ± 20	270 ± 20	190 ± 20	120 ± 1.4	20 ± 1.2	0.8 ± 0.1	2.9 ± 0.6	7.4 ± 0.8	7.2 ± 0.8	1.2 ± 0.2
	B	2790 ± 30	490 ± 30	160 ± 10	250 ± 10	170 ± 10	110 ± 0.8	20 ± 1.2	0.7 ± 0.1	2.7 ± 0.6	7.2 ± 0.8	6.8 ± 0.4	1.1 ± 0.2
	Fr	2310 ± 30	260 ± 20	100 ± 10	190 ± 20	180 ± 20	110 ± 0.8	50 ± 1.8	0.9 ± 0.1	3.3 ± 0.8	6.9 ± 0.6	8.6 ± 0.8	0.8 ± 0.2
<i>D. hamiltonii</i>	S	4810 ± 50	560 ± 30	190 ± 20	290 ± 20	230 ± 20	170 ± 1.8	40 ± 1.2	0.6 ± 0.1	2.8 ± 0.6	7.1 ± 0.8	7.3 ± 0.8	1.0 ± 0.1
	B	4790 ± 60	540 ± 40	170 ± 10	220 ± 10	210 ± 10	150 ± 1.2	30 ± 1.4	0.7 ± 0.1	2.0 ± 0.4	5.6 ± 0.6	6.2 ± 0.4	1.0 ± 0.1
	Fr	3980 ± 40	380 ± 20	130 ± 10	210 ± 10	130 ± 10	140 ± 1.2	50 ± 1.8	0.8 ± 0.1	2.5 ± 0.6	7.4 ± 0.8	6.8 ± 0.4	0.8 ± 0.1
<i>D. latiflorus</i>	S	3930 ± 40	530 ± 40	160 ± 10	250 ± 10	180 ± 20	110 ± 0.8	60 ± 1.8	0.9 ± 0.1	1.9 ± 0.2	6.2 ± 0.6	7.8 ± 0.8	6.4 ± 0.6
	B	3400 ± 40	420 ± 40	150 ± 10	220 ± 10	120 ± 10	110 ± 0.8	30 ± 1.4	0.7 ± 0.1	1.7 ± 0.2	9.1 ± 1.0	7.3 ± 0.8	5.3 ± 0.6
	Fr	3280 ± 40	350 ± 20	110 ± 10	210 ± 10	110 ± 10	150 ± 1.4	50 ± 1.8	0.9 ± 0.1	1.8 ± 0.2	7.7 ± 0.8	7.9 ± 0.8	1.5 ± 0.1
<i>D. membranaceus</i>	S	4730 ± 50	540 ± 30	180 ± 20	240 ± 10	280 ± 20	140 ± 1.4	80 ± 2.2	0.8 ± 0.1	2.6 ± 0.6	6.6 ± 0.6	6.2 ± 0.4	1.2 ± 0.1
	B	4430 ± 60	580 ± 40	180 ± 20	230 ± 20	210 ± 20	120 ± 1.2	60 ± 1.8	0.9 ± 0.1	2.2 ± 0.4	6.5 ± 0.6	7.0 ± 0.8	1.1 ± 0.1
	Fr	5550 ± 70	560 ± 30	190 ± 20	230 ± 10	160 ± 10	140 ± 1.4	90 ± 2.2	0.9 ± 0.1	2.2 ± 0.4	6.7 ± 0.6	7.9 ± 0.8	0.9 ± 0.1
<i>D. sikkimensis</i>	S	4010 ± 30	440 ± 20	190 ± 20	280 ± 20	250 ± 20	100 ± 1.2	80 ± 2.2	0.8 ± 0.1	2.5 ± 0.6	8.6 ± 0.8	5.8 ± 0.4	2.6 ± 0.1
	B	3320 ± 40	320 ± 20	140 ± 10	250 ± 20	150 ± 10	100 ± 1.2	0	0.6 ± 0.1	2.3 ± 0.4	9.8 ± 0.8	4.2 ± 0.4	-
	Fr	4330 ± 50	370 ± 20	150 ± 10	240 ± 20	130 ± 10	120 ± 1.2	60 ± 1.8	0.8 ± 0.1	2.5 ± 0.6	14 ± 0.8	5.1 ± 0.4	2.1 ± 0.1
<i>Phyllostachys mannii</i>	S	5750 ± 60	890 ± 30	210 ± 10	390 ± 10	190 ± 10	70 ± 0.8	20 ± 1.2	0.5 ± 0.1	3.1 ± 0.8	8.5 ± 0.8	9.8 ± 0.8	8.4 ± 0.8
	B	5710 ± 60	870 ± 40	210 ± 20	330 ± 10	180 ± 10	60 ± 0.8	10 ± 1.2	0.8 ± 0.1	2.5 ± 0.6	8.4 ± 0.8	10 ± 0.8	7.6 ± 0.8
	Fr	5380 ± 60	860 ± 30	190 ± 20	310 ± 20	120 ± 10	60 ± 0.8	70 ± 1.8	0.9 ± 0.1	2.5 ± 0.6	9.1 ± 1.0	4.5 ± 0.4	8.2 ± 0.8

Data are presented in mean values ± Standard deviation (n = 3).

Note: '-' signifies 'not detected'; S - 12 hrs soaked, B - 20 min. boiled, Fr - 3 months fermented

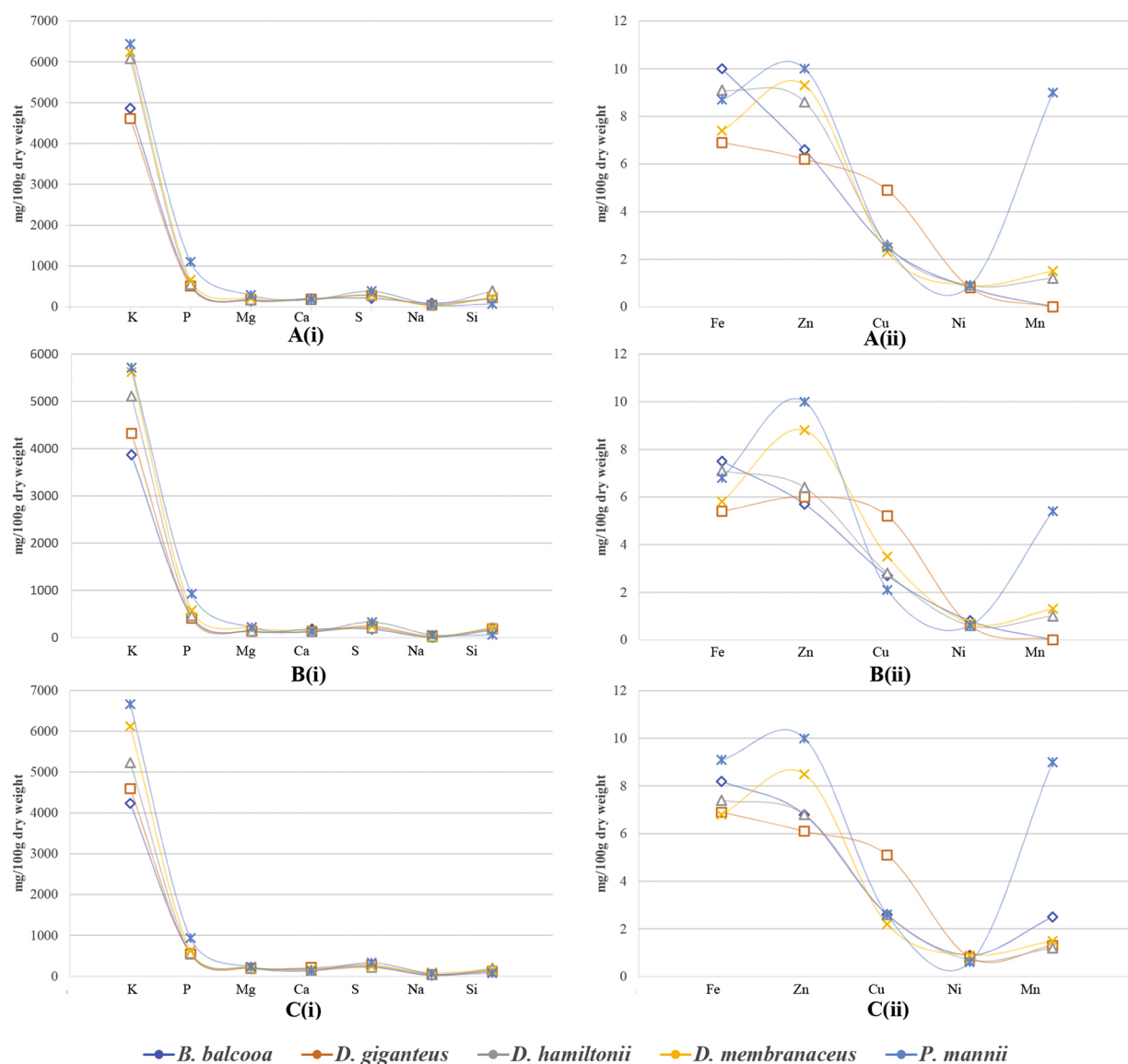


Fig. 2. Effect of different drying methods on the macro and microelements (mg/100 g dry weight) in shoots of some bamboo species. A (i-ii). Sun dried macro and micro-element; B (i-ii). Oven dried macro and micro-element; C (i-ii). Freeze dried macro and micro-element (Rawat, 2017).

Table 4

Comparative account of various mineral elements in fermented shoots from different parts of North East India (mg/100 g).

Fermented Shoots	K	P	Mg	Ca	Na	Fe	Zn	Cu	Mn	Reference
Eup	1331	-	288	-	343	90	312	38	119	Sonar et al. (2015)
Soibum	1345	-	253	-	175	1.0	25	14	39	
Hecche	1336	-	358	-	483	55	63	9.0	48	
Hirring	1457	-	346	-	566	245	77	17	34	
Soidon	1435	-	314	-	265	68	49	6.6	15	
Ekung	1272	-	285	-	218	76	39	11	19	Sharma and Barooah (2017)
Jati	-	10.41	-	1490	-	2.3	-	-	-	
Kako	-	15.99	-	1689	-	2.36	-	-	-	
Bhuluka	-	10.75	-	2007	-	1.72	-	-	-	

Note: '-' signifies 'not mentioned'

Feleke (2013) reported a significant difference in the iron content of *A. alpina* shoots collected from different locations in Ethiopia. Shoots collected from the Marsha region had the highest amount of iron (14.7 mg/100 g) as compared to the Injibara and Tikur Incheny region. Iron content was higher in the upper part (5.21 mg/100 g) of the shoots of *Y. alpina* as compared to the lower portion (3.81 mg/100 g) as

reported by Karanja et al. (2015). Elangbam (2006) reported iron content in the shoots of *B. polymorpha* (4.16 mg/100 g). In processed shoots, fermentation was reported to be the best method for retention of highest amount of iron in bamboo shoots (Saini et al., 2017; Rawat, 2017; Bajwa et al., 2019; Devi, 2018). Sun drying is the most efficient method for retaining iron content in *B. balcooa*, *D. giganteus*, *D. hamiltonii*, *D.*

membranaceous and *P. manii* (Fig. 2).

3.2. Zinc

Zinc deficiency is a global nutritional problem, particularly in children and women living in low- and middle-income countries where the diets are mostly cereal based which reduce absorption of zinc from the intestine (Roohani et al., 2013). This indispensable element is present in adequate amount in shoots of different bamboo species. In fresh shoots, the highest amount of zinc content was reported in *A. alpina* (21.07 mg/100 g) (Feleke, 2013). In nineteen species analyzed by Saini et al. (2017) and Devi (2018) zinc content ranges from 6 to 10 mg/100 g with *B. bambos*, *M. baccifera* and *P. manii* having the highest content (Table 1). This is much higher than the zinc content in vegetables like potato, bean, cabbage, cucumber and carrot which have less than 1 mg/100 g (Table 2). Furthermore, a significant difference was found between the upper and lower portion of the shoot. Upper portion was reported to have highest (1.2 mg/100 g) amount of zinc as compared to the lower part (0.37 mg/100 g) (Karanja et al., 2015).

3.3. Copper

Copper, an essential trace element is a cofactor of many enzymes and is involved in many biological systems including antioxidant defense, neuropeptide synthesis, immune function and is necessary for iron metabolism (Bhattacharya et al., 2016). In fresh bamboo shoots, the highest amount of copper was reported by Christian et al. (2015) in shoots of *P. rubromarginata* (14 mg/ 100 g). Analysis of shoots of some species revealed that *D. giganteus* had highest copper content (Table 1). A slight difference was reported in copper content between the older and the younger part of the shoot (Karanja et al., 2015). When estimated on fresh weight basis, shoots of *B. polymorpha* showed highest (1.08 mg/100 g) copper content (Elangbam, 2006) while, least amount (0.16 mg/100 g) was recorded in the shoots of *D. hamiltonii* and *D. membranaceous* (Nirmala et al., 2007; Elangbam, 2006). Bajwa et al. (2019) reported a remarkable decrease in the copper content after fermentation (8%) and boiling (29%) whereas no significant difference was noticed in brine preserved shoots of *D. hamiltonii*. Nirmala et al. (2008) also reported reduction in copper content in the fermented (0.42 mg/100 g) and canned shoots (0.22 mg/100 g) as compared to fresh shoots (0.56 mg/100 g) of *D. giganteus*.

3.4. Manganese

In fresh bamboo shoots, the amount ranges from 1.2 to 9.7 mg/100 g with the highest recorded in *B. nutans* (Table 1). Biologically, manganese is an important component of many enzyme systems which are involved in the metabolism of carbohydrates, fats, and proteins and is a component of metalloenzymes such as superoxide dismutase, arginase and pyruvate carboxylase (Haugen et al., 2019). On fresh weight basis, highest amount was reported (0.94 mg/100 g) in *B. bambos* shoots collected from Koppa region (Chandramouli and Viswanath, 2015) and least amount was found in shoots of *D. hamiltonii* (0.16 mg/100 g) (Elangbam, 2006). Bajwa et al. (2019) conducted a study on *D. hamiltonii* and reported that maximum content was retained by fermented shoots (8.30 mg/100 g) followed by boiled shoots (5.60 mg/100 g) and brine preserved shoots (3.0 mg/100 g) compared with the fresh form (9.00 mg/100 g). This trend of reduction was also observed by Nirmala et al. (2008) who reported that manganese content was equal for the fresh (3.42 mg/kg fresh weight) and fermented shoots (3.42 mg/kg fresh weight) but lower for the canned shoots (2.40 mg/kg fresh weight) in *D. giganteus*. When different fermented forms were compared, results revealed that Eup was high in Manganese followed by hecche, soibum, hurring, ekung and soidon (Sonar et al., 2015).

3.5. Nickel

Nickel content was estimated in some bamboo species and the observed range was 0.7 to 1.2 mg/100 g (Table 1). The highest amount of nickel was reported in fresh juvenile shoots of *C. capitatum* and *D. latiflorus* (1.2 mg/100 g) and lowest in shoots of six species (0.7 mg/100 g) when estimated on dry weight basis. According to a study by Elangbam (2006), *G. rostrata* had high nickel content (1.56 mg/100 g) whereas *B. tulda* shoots showed a low content (0.48 mg/100 g) when analyzed on fresh weight basis. Nirmala et al. (2007) reported a slight decrease in nickel content with increase in the age of the shoots. However, after processing, a significant change was not observed in nickel content of the shoots (Table 3). Nickel is an essential component of the enzyme urease, which is involved in the decomposition of urea to generate ammonia. The nutritional importance or biochemical function of nickel in humans has not been clearly established (Cunningham, 2017). Nickel causes toxicity when exposed in excess but its depletion leads to several diseases that are caused by human pathogens that rely on nickel-based enzymes to colonize the host (Zambelli and Ciurli, 2013).

3.6. Selenium

Literature on the selenium content of bamboo shoots is scanty. This may be because selenium is not detected by many analytical methods such as WDXRF which is the most widely used method for mineral detection in bamboo. Selenium is an essential trace element, which acts as a co-factor for an enzyme, glutathione peroxidase which is a well-known antioxidant that counteracts cellular oxidative destruction. The dietary recommended intake is 55 µg/day (Zoidis et al., 2018). So far, the selenium content has been estimated in the shoots of about 14 bamboo species including *B. bambos*, *B. kingiana*, *B. nutans*, *B. polymorpha*, *B. tulda*, *B. vulgaris*, *D. asper*, *D. giganteus*, *D. hamiltonii*, *D. brandisii*, *D. membranaceous* and *D. strictus* with highest value (6.80 mg/100 g, fresh weight) in shoots of *D. hamiltonii* (Sood et al., 2013) and the lowest (0.0001 mg/100 g, fresh weight) in the shoots of *B. nutans* (Elangbam, 2006). Nirmala et al. (2008) estimated the selenium content in fermented and canned shoots of *D. giganteus* and reported that canned shoots retained more selenium compared to the fermented form.

4. Mineral elements in bamboo shoot fortified food products

The importance of mineral elements in human nutrition has been well recognized for the maintenance of certain physiochemical processes and also to prevent nutrition related diseases (Soetan et al., 2010). According to the World Health Organization, an estimate of more than 2 billion people mostly from developing countries are facing multiple micronutrient deficiencies. Food fortification is one of the effective strategies to prevent micronutrient deficiencies through existing food delivery systems, without requiring major changes in existing consumption patterns and has been practiced in many developed countries (Alina et al., 2019; Okeyo, 2018). In addition, it is the cheapest, most efficient and effective way to reach large populations with essential micronutrients and can be regarded as the best food-based approach for solving the nutritional problems, especially in developing countries (Dary and Hurrell, 2006). It has been acknowledged by WHO and FAO that micronutrient deficiency of more than two billion people is caused by dietary deficiency of vitamins and minerals. The most efficient way of providing vitamins and minerals is fortification using these substances in popular consumer food products such as flour and bakery products. Ongoing research suggests that micronutrient-rich foods provide a range of antioxidants and probiotic substances that are important for protection against selected noncommunicable diseases and for enhancing immune function. To overcome deficiency, calcium is used in the form of calcium carbonate, calcium lysinate and tricalcium phosphate for

fortifying rice extrudates and noodles, crackers, biscuits and yogurt (Alina et al., 2019). Silicon supplementation in animals and humans has been shown to increase bone mineral density and improve bone strength (Price et al., 2013). It also improves calcium incorporation in bone as indicated by studies in mice. Bamboo shoots in fresh, boiled, fermented extracts, paste and dried powdered form can be used to fortify foods which are naturally lacking or low in silicon levels including meat products. Nowadays, there are various silica supplements offered in market either in tablet or solution form, one such commercially available liquid silicon nutritional supplement is Monomethylsilanetriol (MMST) or CH₃-Si-(OH)₃ (Aguilar et al., 2009; Rawat et al., 2018). However, plant-based foods provide more silicon than any other source and are more suitable for human consumption due to its higher bioavailability (Tripathi et al., 2017). Selenium is used to fortify food products such as yogurt but the most significant is the fortification of cooking salt that reduced the prevalence of Keshan disease in China (Cheng and Qian, 1990).

The quest for finding suitable natural ingredients to make popular healthy food items is gaining momentum. The concern for healthy diets and costs effective health care among people has prompted the food industry to search for plants rich in nutrients and have nutraceutical properties and desirable functional characteristics. Bamboo shoots have been frequently assessed for various bioactivities due to their nutritional and therapeutic importance and overall application in the food industry. The juvenile bamboo shoot being rich in nutrients, health promoting bioactive compounds, vitamins, amino acids and minerals plays a significant role in maintaining good health and has the potential to nourish malnourished people to combat hidden hunger of the world population (Nirmala et al., 2011; Santosh et al., 2019). Bamboo shoot is gaining popularity worldwide as healthy and nutritious food as it is low in fat and calories and rich in edible fiber and mineral elements mainly manganese, potassium, zinc, calcium, copper, chromium, iron, phosphorus and selenium (Shi and Yang, 1992; Nirmala et al., 2007). Recently, bamboo shoot has been used for the production of several value-added products such as pickles candies, nuggets, crackers, chutney, chips, cookies, chappatis, buns, biscuits, noodles and namkeen (Pandey et al., 2012; Bisht et al., 2012; Mustafa et al., 2016; Sood et al., 2013; Choudhury et al., 2012; Santosh et al., 2019). However, detailed analysis of mineral content in most of these fortified products have not been conducted. These products have been analyzed for their sensory and nutritional qualities. Results showed that bamboo shoots improved their nutritional and organoleptic qualities. Similarly, other products such as pork nuggets, chicken nuggets, pork pickle, chips, and biscuits have been prepared, using fresh or fermented shoots of different bamboo species such as *B. auriculata*, *B. bambos*, *B. tulda*, *B. polymorpha*, *B. balcooa*, *B. vulgaris*, *D. asper*, *D. strictus* (Das et al., 2013; Chavhan et al., 2015; Thomas et al., 2014; Thomas et al., 2016). When these products were analyzed for their nutritional and organoleptic qualities, it was found that products containing fresh or fermented bamboo shoots revealed significantly higher mean sensory scores in terms of flavor, texture, juiciness and overall acceptability. Pandey et al. (2012)

estimated some macro mineral elements through AOAC (1990) in bamboo products of nugget, papad and pickle with different formulations utilizing brine treated boiled shoots of *B. bambos*, *B. tulda*, *D. strictus* and *D. asper* (Table 5). Santosh et al. (2018) also investigated the mineral content of freeze-dried bamboo shoot powder fortified biscuits and reported that fortified biscuits are significantly high in potassium (373 mg/100 g dry weight) as compared to the control biscuits (161 mg/100 g dry weight). Similarly, mineral content in biscuit fortified with fresh, boiled and soaked bamboo shoots showed significantly higher content as compared to the control biscuit (Santosh et al., 2019). Pandey et al. (2012) reported potassium content ranging from 1.15–1.80 g/100 g in bamboo shoots fortified products such as nugget, papad, and pickle utilizing different bamboo species.

Bamboo shoot fortified biscuits have been developed using shoots of *D. hamiltonii* that was boiled for 20 min and oven-dried for 24 hrs (Santosh et al., 2019). Results showed a significant increase in the mineral content, both macro and microelements of fortified products as compared to the control products. The highest increase was seen in the potassium content of the products. In biscuits, potassium content increased by 130%, phosphorus 14%, sulphur 12%, magnesium 40%, calcium 32% and iron 10%. Meetei (2019) analyzed mineral content in namkeen and noodles fortified with bamboo shoots (Table 5). Sensory analysis revealed that the fortified, products viz. biscuit, namkeen and noodles with 20 min boiled shoots had highest overall acceptability compared to control and products fortified from unprocessed shoots and 24 hr soaked shoots (Fig. 3). The level of both macro and microelements was enriched in all the fortified products indicating that bamboo shoots have a great potential for usage in food fortification for common consumable food products thereby providing nourishment to malnourished population and help in mitigating hidden hunger. In addition, bamboo shoots can be incorporated in traditional gastronomies as well as in contemporary foods such as yogurt, spreads, cheese, margarine, mayonnaise, milk, chocolate bars, baked goods and meat products. Bamboo shoots have got potentials to prevent micronutrient associated deficiency diseases and can be utilized as an additive in general diet and their preparation and supplementation in other foodstuffs which are deprived of one or more essential micronutrients as well as in pharmaceuticals to substantively improve bioavailability and absorption, which is an effective approach to combat the growing prevalence of hidden hunger.

5. Conclusion

Bamboo shoot being rich in macro and micro minerals has the potential to prevent malnutrition and combat hidden hunger which is presently a matter of great concern. Although required in small quantities, mineral elements are indispensable to the maintenance of life. Bamboo shoots and shoot fortified food products are a good source of potassium, manganese, iron, calcium, chromium, zinc, selenium and phosphorus. Selenium, zinc, copper, iron, and manganese in shoots have a significant influence on the activity of antioxidant enzymes. The

Table 5
Macro and microelements content of bamboo shoot fortified products.

Processed form/ Species	Product	Macro-element (g/100 g)								Micro-element (mg/100 g)					Reference
		K	P	S	Na	Cl	Mg	Ca	Si	Zn	Fe	Mn	Cu	Ni	
Brine treated boiled shoot of <i>D. strictus</i> , <i>D. asper</i> , <i>B. tulda</i>	Nugget	1.16	0.24	-	2.03	-	0.22	0.18	-	-	-	-	-	-	Pandey et al. (2012)
	Papad	1.15	0.24	-	1.72	-	0.16	0.16	-	-	-	-	-	-	
	Pickle	1.80	0.20	-	3.50	-	0.22	0.16	-	-	-	-	-	-	
Freeze-dried powder of boiled <i>D. hamiltonii</i> shoot	Biscuit	0.37	0.11	0.14	0.14	0.21	0.03	0.07	0.03	1.70	4.70	1.57	-	1.80	Santosh et al. (2018)
Boiled shoots of <i>D. hamiltonii</i>	Biscuit	0.18	0.08	0.13	0.15	0.15	0.03	0.04	0.03	1.17	3.58	-	0.85	-	Santosh et al. (2019)
Boiled shoots of <i>D. hamiltonii</i>	Namkeen	0.32	0.14	0.12	0.96	1.74	0.05	0.04	0.02	1.63	3.86	0.83	0.93	0.55	Meetei (2019)
Boiled shoots of <i>D. hamiltonii</i>	Noodles	0.23	0.13	0.13	-	0.09	0.05	0.03	0.01	1.11	3.72	0.73	0.63	0.15	Meetei (2019)

Note: '-' signifies 'not mentioned'

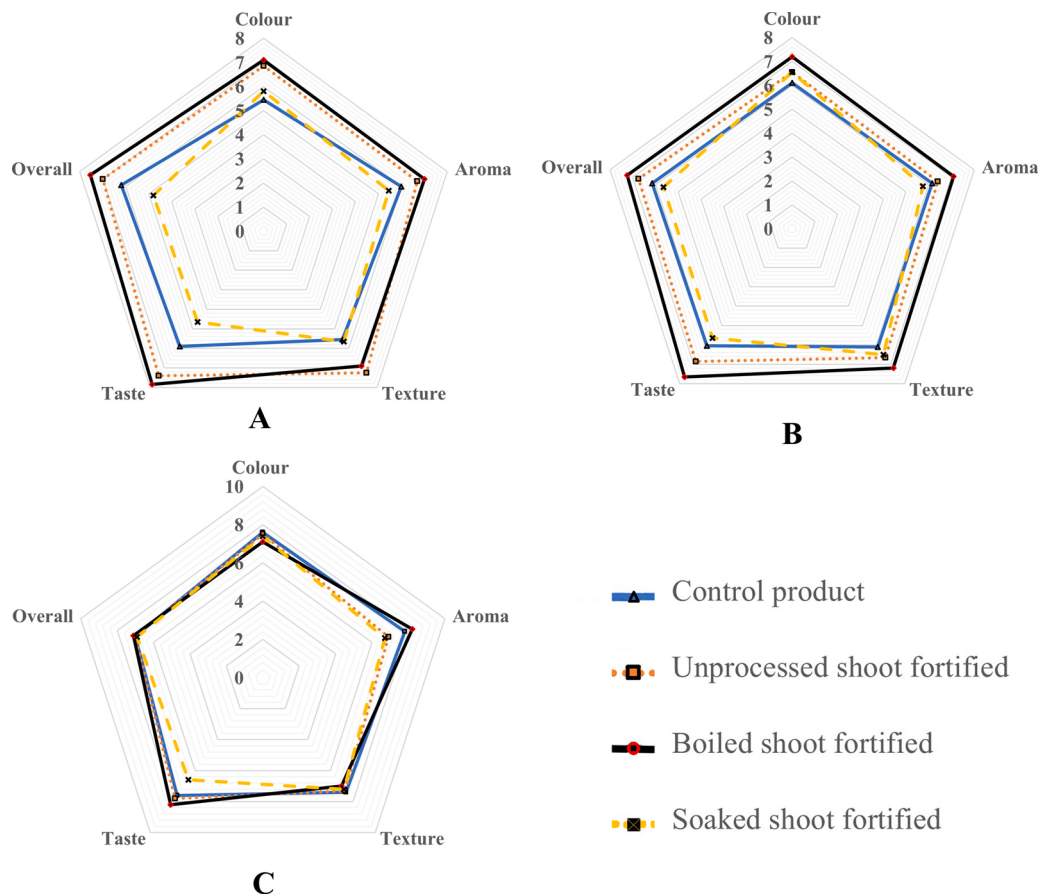


Fig. 3. Radar chart depicting the sensory acceptability of different formulations of oven dried powder of bamboo shoot fortified biscuit. CB – control biscuit; UB – unprocessed shoot fortified biscuit; BB – 20 minutes boiled shoot fortified biscuit; SB – 24 hour-soaked shoot fortified biscuit. The highest acceptability was shown with the black line radar of BB (Meetei, 2019).

current research on bamboo is leading to the emergence of new avenues to utilize different parts of bamboo especially bamboo shoots for the production of novel food products to combat micronutrient deficiency that is widely prevalent especially in the developing countries.

Author Statement

Nirmala Chongtham: Conceptualization, Supervision, Writing-Reviewing and Editing, **Madho Singh Bisht:** Editing, **Harjit Kaur Bajwa:** Data collection, Writing-Reviewing, **Oinam Santosh:** Data analysis, Reviewing and Editing, **Aribam Indira:** Data collection, Draft preparation

Declaration of Competing Interest

The authors report no declarations of interest.

Acknowledgments

The authors are grateful to the Ministry of Food Processing Industries (V45/MFPI/R&D/2000 Vol.IV), Department of Biotechnology, New Delhi (BT/475/NE/TBP/20132), and DST PURSE Grant, Govt. of India, American Bamboo Society and Ned Jaquith Foundation, USA for providing financial assistance to conduct this research work.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.jfca.2020.103662>.

References

- Aberoumand, A., Deokule, S.S., 2009. Determination of elements profile of some wild edible plants. *Food Analytical Methods* 2 (2), 116–119. <https://doi.org/10.1007/s12161-008-9038-z>.
- Adenipekun, C.O., Oyedunji, O.J., 2010. Nutritional values of some tropical vegetables. *Journal of Applied Bioscience* 35, 2294–2300.
- Aguilar, F., Dusemund, B., Galtier, P., 2009. Scientific opinion: monomethylsilanetriol added for nutritional purposes to food supplements. *European Food Safety Authority Journal* 950, 1–12.
- Alina, V.R., Carmen, M.C., Sevastita, M., Andruța, M., Vlad, M., Ramona, S., Georgiana, P., Mihaela, M., 2019. Food Fortification through Innovative Technologies. *Food Engineering*. IntechOpen. <https://doi.org/10.5772/intechopen.82249>.
- AOAC, 1990. *Official Methods of Analysis*, 15th edition. Association of Official Analytical Chemists, Washington, DC.
- Asimwe, J., Sembajwe, L.F., Senoga, A., Bakiika, E., Muwonge, H., Kalyesubula, R., 2013. Overnight soaking or boiling of “Matooke” to reduce potassium content for patients with chronic kidney disease: does it really work? *African Health Sciences* 13 (3), 546–550.
- Awuchi, C.G., Victory, I.S., Ikechukwu, A.O., Echeta, C.K., 2020. Health benefits of micronutrients (vitamins and minerals) and their associated deficiency diseases: A systematic review. *International Journal of Food Sciences* 3 (1), 1–32.
- Bajwa, H.K., Santosh, O., Koul, A., Bisht, M.S., Nirmala, C., 2019. Quantitative determination of microelement and microelement content of fresh and processed bamboo shoots by wavelength dispersive X-ray fluorescence spectrometry. *X-Ray Spectrometry* 48, 637–643. <https://doi.org/10.1002/xrs.3048>.
- Bhattacharya, P.T., Misra, S.R., Hussain, M., 2016. Nutritional Aspects of Essential Trace Elements in Oral Health and Disease: An Extensive Review. *Scientifica* 2016, 1–12.
- Bisht, M.S., Nirmala, C., Vyas, P., 2012. Bamboo shoot a neglected natural resource: A source of food and prosperity for North-East India. In: *Proceedings of National Seminar: Recent Advances in Natural Product Research*. Mizoram University, Aizawl, November 29–December 1, 2012; Mizoram University: Aizawl, pp. 18–22.
- Branco, A.F., Ferreira, A., Simoes, R.F., Magalhães-Novais, S., Zehowski, C., Cope, E., Silva, A.M., Pereira, D., Sardao, V.A., Cunha-Oliveira, T., 2016. Ketogenic diets: from cancer to mitochondrial diseases and beyond. *European Journal of Clinical Investigation* 46 (3), 285–298. <https://doi.org/10.1111/eci.12591>.

- Chandramouli, S., Viswanath, S., 2015. Nutritional composition of edible bamboo shoots of some commercially important bamboo species in Peninsular India. *International Journal of Basic and Life Sciences* 3 (6), 275–287.
- Chavhan, D.M., Hazarika, M., Brahma, M.L., Hazarika, R.A., Rahman, Z., 2015. Effect of incorporation of fermented bamboo shoot on physicochemical and microbial quality of pork pickle. *Journal of Food Science and Technology* 52 (2), 1223–1227. <https://doi.org/10.1007/s13197-013-1082-z>.
- Cheng, Y.Y., Qian, P.C., 1990. The effect of selenium-fortified table salt in the prevention of Keshan disease on a population of 1.05 million. *Biomedical and Environmental Sciences* 3 (4), 422–428.
- Cheryan, M., 1980. Phytic acid interactions in food systems. *Critical Reviews in Food Science and Nutrition* 13, 297–335.
- Choudhury, D., Sahu, J.K., Sharma, G.D., 2011. Bamboo shoot based fermented food products: a review. *Journal of Scientific and Industrial Research (JSIR)* 70 (3), 199–203.
- Choudhury, D., Sahu, J.K., Sharma, G.D., 2012. Value addition to bamboo shoots: a review. *Journal of Food Science and Technology* 49 (4), 407–414. <https://doi.org/10.1007/s13197-011-0379-z>.
- Christian, A.L., Knott, K.K., Vance, C.K., Falcone, J.F., Bauer, L.L., Fahey Jr, G.C., Willard, S., Kouba, A.J., 2015. Nutrient and mineral composition during shoot growth in seven species of *Phyllostachys* and *Pseudosasa* bamboo consumed by giant panda. *Journal of Animal Physiology and Animal Nutrition* 99 (6), 1172–1183. <https://doi.org/10.1111/jpn.12287>.
- Cunningham, E., 2017. What Role Does Diet Play in the Management of Nickel Allergy? *Journal of the Academy of Nutrition and Dietetics* 117 (3), 500. <https://doi.org/10.1016/j.jand.2017.01.001>.
- Dary, O., Hurrell, R., 2006. Guidelines on food fortification with micronutrients. World Health Organization, Food and Agricultural Organization of the United Nations, Geneva.
- Das, A., Nath, D.R., Kumari, S., Saha, R., 2013. Effect of fermented bamboo shoot on the quality and shelf life of nuggets prepared from desi spent hen. *Veterinary World* 6 (7), 419–423. <https://doi.org/10.5455/vetworld.2013.419-423>.
- Day, C.N., Morawicki, R.O., 2018. Effects of fermentation by yeast and amylolytic lactic acid bacteria on grain sorghum protein content and digestibility. *Hindawi Journal of Food Quality* 4, 1–8.
- Devi, T.P., 2018. Edible bamboos of Manipur: Analysis of nutrients, antinutrients and bioactive compounds in young shoots. Ph.D thesis. Panjab University, Chandigarh, India.
- Dove, P.M., Han, N., Wallace, A.F., De Yoreo, J.J., 2008. Kinetics of amorphous silica dissolution and the paradox of the silica polymorphs. *Proceedings of the National Academy of Sciences* 105 (29), 9903–9908. <https://doi.org/10.1073/pnas.0803798105>.
- Elangbam, D., 2006. Nutritive components of Juvenile edible shoots of some Indian bamboos. Ph.D thesis. Panjab University, Chandigarh, India.
- Feleke, S., 2013. Site factor on nutritional content of *Arundinaria Ipine* and *Oxytenanthera abyssinica* bamboo shoots in Ethiopia. *Journal of Horticulture and Forestry* 5 (8), 115–121. <https://doi.org/10.5897/JHF2013.0303>.
- Gröber, U., Schmidt, J., Kisters, K., 2015. Magnesium in Prevention and Therapy. *Nutrients* 7 (9), 8199–8226.
- Hailu, A.A., Addis, G., 2016. The content and bioavailability of mineral nutrients of selected wild and traditional edible plants as affected by household preparation methods practiced by local community in Benishangul Gumuz Regional State, Ethiopia. *International Journal of Food Science* 2016, 7. <https://doi.org/10.1155/2016/7615853>.
- Harding, J.E., Cormack, B.E., Alexander, T., Alsweiler, J.M., Bloomfield, F.H., 2017. Advances in nutrition of the newborn infant. *The Lancet* 389 (10079), 1660–1668. [https://doi.org/10.1016/S0140-6736\(17\)30552-4](https://doi.org/10.1016/S0140-6736(17)30552-4).
- Haugen, M., Frøyland, L., Henjum, S., Løvik, M., Stea, T.H., Strand, T.A., Parr, C.L., Holvik, K., 2019. Assessment of Dietary Intake of Manganese in Relation to Tolerable Upper Intake Level. *European Journal of Nutrition & Food Safety* 9 (2), 91–93. <https://doi.org/10.9734/ejnf/2019/v9i230042>.
- Hodge, J., 2016. Hidden hunger: approaches to tackling micronutrient deficiencies. *Nourishing Millions: Stories of Change in Nutrition*. International Food Policy Research Institute (IFPRI), Washington, pp. 35–43.
- Holland, B., McCance, R.A., Widdowson, E.M., Unwin, L.D., Buss, D.H., 1991. Vegetables, herbs and spices: Fifth supplement to McCance and Widdowson's *The Composition of Foods*, 4th Edition. Royal Society of Chemistry, Ministry of Agriculture, Fisheries and Food.
- Ismail, F., Anjum, M.R., Mamon, A.N., Kazi, T.G., 2011. Trace metal contents of vegetables and fruits of Hyderabad retail market. *Pakistan journal of nutrition* 10 (4), 365–372.
- James, O., Emmanuel, U.C., 2011. Comparative studies on the protein and mineral composition of some selected Nigerian vegetables. *African Journal of Food Science* 5 (1), 22–25.
- Jugdaohsingh, R., 2007. Silicon and bone health. *The Journal of Nutrition, Health and Ageing* 11 (2), 99.
- Karanja, P.N., Kenji, G.M., Njoroge, S.M., Sila, D.N., Onyango, C.A., Koaze, H., Baba, N., 2015. Variation of nutrients and functional properties within young shoots of a bamboo species (*Yushania alpina*) growing in Mt. Elgon region in western Kenya. *Journal of Food and Nutrition Research* 3 (10), 657–680. <https://doi.org/10.12691/jfnr.3-10-10>.
- Law, C., Exley, C., 2011. New insight into silica deposition in horsetail (*Equisetum arvense*). *BMC Plant Biol* 11 (1), 1–9.
- Linkon, K.M., Satter, M.A., Jabin, S.A., Abedin, N., Islam, M.F., Lisa, L.A., Paul, D.K., 2015. Mineral and heavy metal contents of some vegetable available in local market of Dhaka city in Bangladesh. *IOSR Journal of Environmental Science and Toxicology Food Technology* 9, 2319–2399. <https://doi.org/10.9790/2402-09510106>.
- Lopez, Y., Gordon, D.T., Fields, M.L., 1983. Release of phosphorus from phytate by natural lactic fermentation. *Journal of Food Science* 48, 935–954.
- Lorinczova, H.T., Fitzsimons, O., Mursaleen, L., Renshaw, D., Begum, G., Zariwala, M.G., 2020. Co-administration of iron and a bioavailable Curcumin supplement increases serum BDNF levels in healthy adults. *Antioxidants* 9 (8), 645.
- Martin, K.R., 2013. Silicon: the health benefits of a metalloid. *Interrelations between Essential Metal Ions and Human Diseases*. Springer, Dordrecht, pp. 451–473.
- Martínez-Ballesta, M.C., Domínguez-Perles, R., Moreno, D.A., Muries, B., Alcaraz-López, C., Bastías, E., García-Viguera, C., Carvajal, M., 2010. Minerals in plant food: effect of agricultural practices and role in human health. A review. *Agronomy for Sustainable Development* 30 (2), 295–309. <https://doi.org/10.1051/agro/2009022>.
- Mayer, A.M., 1997. Historical changes in the mineral content of fruits and vegetables. *British Food Journal*. ISSN: 0007-070X.
- Meetei, O.S., 2019. Evaluation of bamboo shoot for fortification and production of novel food products. Ph.D. thesis. Department of Botany, Panjab University, Chandigarh, India.
- Morrison, G., 1990. Serum Chloride. In: Walker, H.K., Hall, W.D., Hurst, J.W. (Eds.), *Clinical Methods: The History, Physical, and Laboratory Examinations*, 3rd edition. Butterworths, USA, Boston.
- Mustafa, U., Naeem, N., Masood, S., Farooq, Z., 2016. Effect of bamboo powder supplementation on physicochemical and organoleptic characteristics of fortified cookies. *Food Science and Technology* 4 (1), 7–13. <https://doi.org/10.13189/fst.2016.040102>.
- Nirmala, C., David, E., Sharma, M.L., 2007. Changes in nutrient components during ageing of emerging juvenile bamboo shoots. *International Journal of Food Sciences and Nutrition* 58 (8), 612–618. <https://doi.org/10.1080/09637480701359529>.
- Nirmala, C., Sharma, M.L., David, E., 2008. A comparative study of nutrient components of freshly harvested, fermented and canned bamboo shoots of *Dendrocalamus giganteus* Munro. *Bamboo Science & Culture* 21 (1), 41–47.
- Nirmala, C., Bisht, M.S., Haorongbam, S., 2011. Nutritional properties of bamboo shoots: potential and prospects for utilization as a health food. *Comprehensive Reviews in Food Science and Food Safety* 10 (3), 153–168. <https://doi.org/10.1111/j.1541-4337.2011.00147.x>.
- Nirmala, C., Bisht, M.S., Laishram, M., 2014a. Bioactive compounds in bamboo shoots: Health benefits and prospects for developing functional foods. *International Journal of Food Science and Technology* 49, 1425–1431.
- Nirmala, C., Bisht, M.S., Bajwa, H.K., Santosh, O., 2018. Bamboo: A rich source of natural antioxidants and its applications in the food and pharmaceutical industry. *Trends in Food Science & Technology* 77, 91–99. <https://doi.org/10.1016/j.tifs.2018.05.003>.
- Nirmala, C., Bisht, M.S., 2017. Bamboo: A prospective ingredient for functional food and nutraceuticals. 10th WBC Reports. *Bamboo Journal* 30, 82–99.
- Nkhata, S.G., Ayua, E., Kamau, E.H., Shingiro, J.B., 2018. Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. *Food science & nutrition* 6 (8), 2446–2458.
- Okeyo, D.O., 2018. Impact of Food Fortification on Child Growth and Development during Complementary Feeding. *Annals of Nutrition and Metabolism* 73 (1), 7–13. <https://doi.org/10.1159/000490087>.
- Pandey, A.K., Ojha, V., Choubey, S.K., 2012. Development and shelf-life evaluation of value-added edible. *American Journal of Food Technology* 7 (3), 363–371. <https://doi.org/10.3923/ajft.2010.363.371>.
- Pandey, A.K., Ojha, V., 2014. Precooking processing of bamboo shoots for removal of anti-nutrients. *Journal of Food Science and Technology* 51 (1), 43–50. <https://doi.org/10.1007/s13197-011-0463-4>.
- Park, E.J., Jhon, D.Y., 2013. The nutritional composition of bamboo shoots and the effects of its fiber on intestinal microorganisms. *Journal of the Korean Society of Food Culture* 28 (5), 502–511. <https://doi.org/10.7318/KJFC/2013.28.5.502>.
- Price, C.T., Koval, K.J., Langford, R.J., 2013. Silicon: a review of its potential role in the prevention and treatment of postmenopausal osteoporosis. *International Journal of Endocrinology* 2013. <https://doi.org/10.1155/2013/316783>.
- Rawat, K., Nirmala, C., Bisht, M.S., 2015. Processing techniques for reduction of cyanogenic glycosides from bamboo shoots. 10th World Bamboo Congress, Korea.
- Rawat, K., 2017. Effect of various processing techniques on the nutrient content of juvenile edible shoots of some commercially important bamboos. Ph.D thesis. Panjab University, Chandigarh, India.
- Rawat, K., Nirmala, C., Bisht, M.S., 2018. Quantitative assessment of silicon in fresh and processed bamboo shoots and its potential as functional element in food, nutraceuticals and cosmeceuticals. In: *Proceedings of 11th World Bamboo Congress*, August 14–18, 2018. Xalapa, Mexico. In: www.worldbamboo.net/proceedings/wbcx.
- Roohani, N., Hurrell, R., Kelishadi, R., Schulin, R., 2013. Zinc and its importance for human health: An integrative review. *Journal of research in medical sciences: the official journal of Isfahan University of Medical Sciences* 18 (2), 144.
- Saini, N., Rawat, K., Bisht, M.S., Nirmala, C., 2017. Qualitative and quantitative mineral element variances in shoots of two edible bamboo species after processing and storage evaluated by Wavelength dispersion x-ray fluorescence spectrometry. *International Journal of Innovative Research in Science, Engineering and Technology* 6 (5), 8262–8270. <https://doi.org/10.15680/IJRSET.2017.0605167>.
- Saini, N., 2019. Shelf life enhancement of juvenile shoots of edible bamboo through different processing and preservation techniques and evaluation of their phytochemicals. Ph.D thesis. Panjab University, Chandigarh, India.
- Santosh, O., Bajwa, H.K., Bisht, M.S., Nirmala, C., 2018. Freeze-dried bamboo shoot powder for food fortification: enrichment of nutritional content and organoleptic qualities of fortified biscuits. *MOJ Food Processing & Technology* 6 (4), 342–348.
- Santosh, O., Bajwa, H.K., Bisht, M.S., Nirmala, C., 2019. Functional biscuits from bamboo shoots: Enrichment of nutrients, bioactive compounds and minerals in bamboo shoot

- paste fortified biscuits. *International Journal of Food Science and Nutrition* 4 (1), 89–94.
- Sharma, N., Barooah, M., 2017. Microbiology of khorisa, its proximate composition and probiotic potential of lactic acid bacteria present in Khorisa, a traditional fermented Bamboo shoot product of Assam. *Indian Journal of Natural Products and Resources (IJNPR)* 8 (1), 78–88.
- Sharma, V., 2018. Changes in bioactive components and anti-nutrients during processing of bamboo shoots. Ph.D thesis. Panjab University, Chandigarh, India.
- Shi, Q.T., Yang, K.S., 1992. Study on relationship between nutrients in bamboo shoots and human health. In: *Proceedings of the International Symposium on Industrial Use of Bamboo*. International Tropical Timber Organization and Chinese Academy, Beijing, China: Bamboo and its Use, pp. 338–346.
- Singhal, P., Bal, L.M., Satya, S., Sudhakar, P., Naik, S.N., 2013. Bamboo shoots: a novel source of nutrition and medicine. *Critical Reviews in Food Science and Nutrition* 53 (5), 517–534. <https://doi.org/10.1080/10408398.2010.531488>.
- Soetan, K.O., Olaiya, C.O., Oyewole, O.E., 2010. The importance of mineral elements for humans, domestic animals and plants-A review. *African Journal of Food Science* 4 (5), 200–222.
- Sonar, N.R., Vijayendra, S.V.N., Prakash, M., Saikia, M., Tamang, J.P., Halami, P.M., 2015. Nutritional and functional profile of traditional fermented bamboo shoot-based products from Arunachal Pradesh and Manipur states of India. *International Food Research Journal* 22 (2), 788–797.
- Sood, S., Walia, S., Gupta, M., Sood, A., 2013. Nutritional Characterization of Shoots and Other Edible Products of an Edible Bamboo—*Dendrocalamus hamiltonii*. *Current Research in Nutrition and Food Science Journal* 1 (2), 169–176.
- Tabet, R.B., Oftedal, O.T., Allen, M.E., 2004. Seasonal differences in composition of bamboo fed to giant pandas (*Ailuropoda melanoleuca*) at the National Zoo. In: *Proceed. Fifth Comparison of Nutrition Society Symposium*. Hickory Corners, Michigan, pp. 176–183.
- Tardy, A.L., Pouteau, E., Marquez, D., Yilmaz, C., Scholey, A., 2020. Vitamins and Minerals for Energy, Fatigue and Cognition: A Narrative Review of the Biochemical and Clinical Evidence. *Nutrients* 12 (1), 228. <https://doi.org/10.3390/nu12010228>.
- Thomas, R., Jebin, N., Barman, K., Das, A., 2014. Quality and shelf life evaluation of pork nuggets incorporated with fermented bamboo shoot (*Bambusa polymorpha*) mince. *Meat Science* 96 (3), 1210–1218. <https://doi.org/10.1016/j.meatsci.2013.10.035>.
- Thomas, R., Jebin, N., Saha, R., Sarma, D.K., 2016. Antioxidant and antimicrobial effects of kordoi (*Averrhoa carambola*) fruit juice and bamboo (*Bambusa polymorpha*) shoot extract in pork nuggets. *Food Chemistry* 190, 41–49. <https://doi.org/10.1016/j.foodchem.2015.05.070>.
- Tolonen, M., 1990. *Vitamins and Minerals in Health and Nutrition*. Elsevier.
- Tripathi, D., Dwivedi, M.M., Tripathi, D.K., Chauhan, D.K., 2017. Silicon bioavailability in exocarp of *Cucumis sativus* Linn. *Biotech* 7 (6), 386. <https://doi.org/10.1007/s13205-017-0960-x>.
- Waikhom, S.D., Louis, B., Sharma, C.K., Kumari, P., Somkuwar, B.G., Singh, M.W., Tallukdar, N.C., 2013. Grappling the high altitude for safe edible bamboo shoots with rich nutritional attributes and escaping cyanogenic toxicity. *BioMed Research International* 2013. <https://doi.org/10.1155/2013/289285>.
- Zambelli, B., Ciurli, S., 2013. Nickel and human health. *Interrelations between Essential Metal Ions and Human Diseases*. Springer, Dordrecht, pp. 321–357.
- Zoidis, E., Seremelis, I., Kontopoulos, N., Danezis, G.P., 2018. Selenium-Dependent Antioxidant Enzymes: Actions and Properties of Selenoproteins. *Antioxidants (Basel, Switzerland)* 7 (5), 66. <https://doi.org/10.3390/antiox7050066>.