Publications
Moisture sorption isotherms, heat of sorption and properties of sorbed water of raw bamboo (Dendrocalamus longispathus) shoots

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ABSTRACT

Moisture sorption isotherms of raw bamboo shoots were determined by static gravimetric technique based on isopiestic transfer of water vapor at 20, 30 and 35 °C. Inorganic saturated salt solutions in the range of 11.2–97.2% were used to create the required controlled humidity environment in a closed chamber. In the study, the sorption isotherms obtained were of sigmoid shape and of BET II type classification. Out of three sorption models i.e., BET, Caurie and GAB, fitted to the experimental data, Caurie model was found superior in interpreting the moisture sorption characteristics of bamboo shoots at three temperatures. The monolayer moisture content \( M_1 \), as estimated by the best fitted Caurie’s model for the sorption processes were 6.012%, 5.801%, 5.014%, and 5.987%, 5.816%, 4.998% (dry basis) at 20, 30 and 35 °C, respectively. The isosteric heats of sorption for both the adsorption and desorption process of bamboo shoots were found to increase with decrease in moisture content suggesting endothermic reaction at lower moisture content and it approached the value of heat of vaporization of free water at higher moisture content.

1. Introduction

Bamboo shoots are consumed as one of the preferred food items in different countries in the world. Compositionally, bamboo shoots are low in saturated fat and cholesterol content, and high in potassium, carbohydrates and dietary fibers (Park and Jhon, 2009). Many nutrients and active materials such as \( \alpha \)-Tocopherol, Vitamin C, Vitamin B6, thiamin, riboflavin, niacin, amino acids and anti-oxidants such as flavones, phenols and steroids are found in bamboo shoots. With 17 different types of amino acids, bamboo shoot contains over 10 kinds of mineral elements like Cr, Zn, Mn, Mg, Ni, Co, Cu etc (Choudhury et al., 2010).

Bamboo shoots have excellent anti-microbial qualities and can be extracted to make capsules and tablets. Shoots of \( B. \) arundinacea contain choline, betain, nuclease, urease, cyanogens, glucosides and are used in the treatment of diarrhea, thread worm and cough. Boiled bamboo shoots are used as appetizers; the decoction of shoots is used for cleaning wounds and maggot infected sores and ulcers, and curing jaundice (Burkill, 1935).

Bamboo shoots are valuable in pharmaceutical and food processing industries and can be processed into beverages, medicines, additives and health foods. However, the processing of the same into various edible products is too rudimentary, unorganized and traditional, and lacks quality control over the final products. Bamboo shoots are high moisture products (moisture content = 85.98–92.37% d.b.), so development of molds, fungi and other microorganisms is a common phenomenon during storage of bamboo shoots. Owing to such technological gap in the field of bamboo shoot processing, there is hardly any product that has yet created its way into the national or international market.

Despite availability of a variety of water-based criteria, which can give indicators of stability of food, water activity is one of the most effective and useful measurements of water in food, with particular regard to microbial growth and enzyme activity. Moisture sorption isotherm of a food describes the equilibrium relationship between water activity and moisture content of a food at constant temperature and gives an insight into the moisture-binding characteristic of a food. Therefore, knowledge of moisture sorption characteristics of a food is quite essential for prediction of technological performance and quality of stored foods (Chirife and Buer, 1994; Nelson and Labuza, 1994; van den Berg and Bruin, 1981; Palou et al., 1997). The moisture sorption isotherm of various foods have been extensively reviewed by Gal (1987); van den Berg and Bruin (1981); Wang and Brennan (1991); McMinn and Magee (1999); Singh and Singh (1996); Palou et al. (1997) and Vilades et al. (1995).

Various two and three parameter moisture sorption isotherms like Brunauer–Emmett–Teller ( BET), Modified BET, Guggenheim–Anderson–de Boer ( GAB), Hasley, Henderson, Igle­sias and Chirife, Kuhn, Mizrahi, Oswin and Smith have been used to represent sorption behavior of various foods such as cereal grains (Chung and Pfost, 1967; Chen and Jayas, 1998), milk powder...
and milk products (Sawhney et al., 1991; Jouppila and Roos, 1994; Stenci, 1999; Sahu and Das, 2010), starchy foods (Iglesias and Chirife, 1976) and vegetables (Sahu and Tiwari, 2007).

The value of monolayer moisture content of a food gives an indication of the total number of polar groups, binding water and level of hydration at which the mobility of small molecules become apparent. The importance of knowing the water activity at which the monolayer exists is that, it appears to be the most stable water content of a food in relation to its shelf life, because a food prepared and maintained at moisture content just above the monolayer value of 2.5 cm × 1 cm × 1 cm, and washed with tap water. The composition of the slices was analyzed by using standard methods; moisture content was determined by vacuum oven method (AOAC, 1990), total carbohydrate content was estimated by Anthrone method (Hedge and Hofreiter, 1962), reducing sugar, free amino acids and non-protein content by Sadasivam and Manickam (1996), ash and crude fibre contents by standard AOAC (1970) method. The values of three readings were averaged and they are represented in Table 1.

2. Determination of equilibrium moisture content (EMC)

The static gravimetric technique based on isopiestic transfer of water vapor was adopted to obtain the moisture sorption characteristics of bamboo shoots (Suthar and Das, 1997). Saturated salt solutions in inorganic nature was prepared to generate controlled humidity environment in a closed chamber giving a range of relative humidity at 20, 30 and 35 °C, as mentioned in Table 2.

The sliced bamboo shoot samples (triplicate) were weighed in the respective moisture boxes and then placed in the vacuum desicators with a stopcock arrangement. Each desiccator had respective saturated salt solutions used to obtain constant relative humidity environment (Greenspan, 1977; Weisser, 1986; McMinn and Magee, 1999). Partial vacuum was created inside the desiccators to accelerate the sorption process. The desiccators were kept in a temperature controlled cabinet at 20, 30 and 35 ± 1 °C in subsequent runs. Samples were weighed with an accuracy of 0.001 g every two days.

### Table 1

<table>
<thead>
<tr>
<th>Composition</th>
<th>Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>47.85</td>
</tr>
<tr>
<td>Reducing sugar</td>
<td>1.32</td>
</tr>
<tr>
<td>Total free amino</td>
<td>0.44</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>3.15</td>
</tr>
<tr>
<td>Ash</td>
<td>0.05</td>
</tr>
<tr>
<td>Non-protein</td>
<td>0.03</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>0.96</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>4.84</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Salt</th>
<th>Relative humidity (RH)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 °C</td>
</tr>
<tr>
<td>Lactic acid</td>
<td>11.4</td>
</tr>
<tr>
<td>Potassium acetate</td>
<td>23.1</td>
</tr>
<tr>
<td>Magnesium chloride</td>
<td>33.1</td>
</tr>
<tr>
<td>Potassium carbonate</td>
<td>43.2</td>
</tr>
<tr>
<td>Magnesium nitrate</td>
<td>54.1</td>
</tr>
<tr>
<td>Potassium iodide</td>
<td>69.9</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>75.5</td>
</tr>
<tr>
<td>Ammonium sulphate</td>
<td>81.3</td>
</tr>
<tr>
<td>Potassium sulphate</td>
<td>97.2</td>
</tr>
</tbody>
</table>

Please cite this article in press as: Choudhury, D., et al., Moisture sorption isotherms, heat of sorption and properties of sorbed water of raw bamboo (Dendrocalamus longispathus) shoots. Ind. Crops Prod. (2010), doi:10.1016/j.indcrop.2010.10.014
2.5. Heat of sorption

The heat required to be removed in excess of latent heat of vaporization, where, $AH_v$ is the net isosteric heat (kJ kg$^{-1}$) is the latent heat of vaporization of pure water, for extracting sorbed water at particular moisture content. The value of $q_{st}$ (kJ kg$^{-1}$) can be computed by using the Clausius-Clapeyron type equation (Labuzza et al., 1985; Rizvi, 1986; Resio et al., 1999) as given below.

$$
\ln \left( \frac{a_{w1}}{a_{w2}} \right) = \frac{1000q_{st}}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)
$$

(4)

where, $a_{w1}$ and $a_{w2}$ are the water activity values (decimal) at temperature $T_1$ and $T_2$ (K), respectively. $q_{st}$ (kJ kg$^{-1}$) is the net isosteric heat of sorption, and $R$ is the universal gas constant (8.314 J mol$^{-1}$ K$^{-1}$). The isosteric heat of sorption $Q_{st}$ (kJ kg$^{-1}$) is calculated from the following relationship:

$$
Q_{st} = q_{st} + \Delta H_v
$$

(5)

where, $\Delta H_v$ (kJ kg$^{-1}$) is the latent heat of vaporization of pure water at the mean value of any two temperatures used in the study.

3. Results and discussion

3.1. Sorption isotherm of bamboo shoots

The initial moisture content of the bamboo shoot samples was 87.83 ± 0.085% (d.b.). The change of the EMC with the equilibrium relative humidity is presented in Figs. 1 and 2. In the figure, both adsorption (Fig. 1) and desorption (Fig. 2) isotherms demonstrate a concurrent increase in the EMC value with increase in values of equilibrium relative humidity. This characteristic is manifested in the form of sigmoid shaped curve thus reflecting Type II, according to the BET classification isotherms characteristics (Brunauer et al., 1940). Similar behavior has been reported by various authors for different foods (Sanni et al., 1997; McLaughlin and Magee, 1998).

According to van den Berg and Bruin (1981), this type sorption isotherm can be divided into three different parts: ranges I ($a_w = 0.02$), II ($a_w = 0.22-0.73$) and III ($a_w = 0.73-1.0$). In the range II and III, water molecules penetrate newly created pores of the already swollen structure and are mechanically entrapped in the void spaces. Therefore, water uptake particularly at higher water activity values is expected to be reduced.
activity would be markedly influenced by the stability of the microporous structure. The figures also showed that EMC decreased with increasing temperature, at a constant equilibrium humidity thus indicating that bamboo shoots became less hygroscopic. This trend may be due to a reduction in the total number of active sites for water binding as a result of physical and/or chemical changes in the product induced by temperature (Mazza and LeMaguer, 1980). The analysis of variance (ANOVA) showed that the effect of temperature on moisture content was significant (P>0.05).

Fig. 3 shows the adsorption and desorption isotherms of bamboo shoots at 20, 30 and 35 °C. The figure indicates the effect of hysteresis between adsorption and desorption observed over entire range of water activity at the three temperatures. The samples present relatively large loop, over almost entire relative humidity range with the degree of hysteresis becoming more pronounced in the high water activity regions. Such kind of hysteresis effect was also observed by Wolf et al. (1972) and Swami et al. (2005) for starches and black gram. The ANOVA showed that adsorption and desorption data was significantly different (P>0.05).

3.2. Modeling of sorption isotherms

Tables 4 and 5 show the values of constants of three models i.e., BET, Caurie and GAB fitted to the desorption and adsorption data along with their $R^2$ and $R_d$ values, respectively. Of three models fitted to the experimental data, Caurie model was found superior in predicting the adsorption and desorption processes as exhibited by higher $R^2$ and lower $R_d$ values. The table also shows that the values of monolayer moisture content $M_m$, estimated for each models, decreased concurrently with increase in temperature from 20 to 35 °C for both the adsorption and desorption processes. The ANOVA showed that adsorption and desorption data at the three temperatures was significantly different (P>0.05). The values of $M_m$ as calculated by the best fitted Caurie's model for desorption and adsorption processes were 6.012%, 5.801%, 5.014%, and 5.987%, 5.816%, 4.98% (d.b.) at 20, 30, and 35 °C, respectively. However, the values of model constants increased constantly with increase in temperature for both the adsorption and desorption process. The result has a good agreement with the findings reported by Wang and Brennan (1991); McMinn and Magee (1999); Suthar and Das (1997); Chen and Jayas (1998); Swami et al. (2005); Arslan and Togrul (2006).

Table 4
Computed values of constants of isotherms models fitted to desorption data of bamboo shoot.

<table>
<thead>
<tr>
<th>Isotherm models</th>
<th>Temperature (°C)</th>
<th>Model constants</th>
<th>$R^2$</th>
<th>$R_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BET</td>
<td></td>
<td>$C_p = 3.374$</td>
<td>0.935</td>
<td>11.251</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$M_m = 7.187$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C_p = 3.741$</td>
<td>0.948</td>
<td>10.825</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$M_m = 6.675$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C_p = 3.894$</td>
<td>0.941</td>
<td>9.982</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$M_m = 6.103$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caurie</td>
<td>20</td>
<td>$C_p = 2.170$</td>
<td>0.963</td>
<td>9.124</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$M_m = 6.012$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>$C_p = 2.310$</td>
<td>0.965</td>
<td>9.124</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$M_m = 5.801$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>$C_p = 2.563$</td>
<td>0.965</td>
<td>9.124</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$M_m = 5.014$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GAB</td>
<td>20</td>
<td>$C_p = 1.033$</td>
<td>0.958</td>
<td>10.641</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$M_m = 7.885$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>$C_p = 1.213$</td>
<td>0.958</td>
<td>10.641</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$M_m = 6.784$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>$C_p = 1.819$</td>
<td>0.950</td>
<td>10.813</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$M_m = 6.720$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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3.3. Properties of sorbed water

Table 6 and 7 represent the values of density of sorbed water, number of sorbed monolayers, percent bound water and surface area of sorbent as calculated by Cavie model at 20, 30 and 35 °C for desorption and adsorption process, respectively. The table indicates that for both desorption and adsorption processes, the values of density of sorbed water, number of sorbed monolayers, percent bound water and surface area of sorbent decreased with the increase in temperature of sorption from 20 to 35 °C. Similar behavior has been observed by Swami et al. (2005); Sahu and Das (2010).

3.4. Isothermic heat of sorption

The evaluation of isothermic heat of sorption \( \Delta Q \) as a function of equilibrium moisture content at average storage temperature of 27.5 °C \([35 + 20] \times 0.5\) of samples was carried out by using Eq. (4) by using the best-fit Cavie model. Fig. 4 represents the variation of isosteric heat of sorption both for adsorption and desorption processes with equilibrium moisture contents. The figure shows that the isosteric heats of desorption and adsorption were higher than the latent heat of vaporization of pure water, indicating that the energy of binding between the water molecules and sorption sites was higher than the energy which holds the water molecules together in the liquid phase. Also, the figure reveals that the heat required for the desorption process was greater than that for the adsorption process. The isosteric heats of desorption and adsorption decreased exponentially as the moisture content increased and the trend seemed to become asymptotic at lower moisture content. This confirms the fact that, at higher moisture levels, the strength of water binding decreases. Different polar groups of the water bind in a layer where the sorption sites are usually active. Similar trends have been reported for the isosteric heat of some foods (Palou et al., 1997; Aviara et al., 2002; Ajibola et al., 2003; McMinn and Magee, 2003). The difference of heats of adsorption and desorption was almost equal with increase in moisture content. These changes are probably due to changes in molecular structure during sorption which affects the degree of activation of sorption sites (Al-Muhtaseb et al., 2004; Togrul and Arslan, 2006).

4. Conclusion

Moisture sorption characteristics of raw bamboo shoot could be predicted agreeably with Cavie model. The equilibrium moisture content was found to decrease with increase in temperature at constant water activity; conversely, they were found to increase with increasing water activity at constant temperature. Hysteresis was observed over the entire range of water activity. The values of monolayer moisture content as estimated by the best fitted Cavie’s models for desorption and adsorption processes were 6.012%, 5.801%, 5.014%, and 5.987%, 5.816%, 4.98% (d.b.) at 20, 30, and 35 °C, respectively. The isosteric heat of sorption of bamboo shoot was found to increase with decrease in moisture content suggesting
endothermic reaction at lower moisture content and it approached the value of heat of vaporization of free water at higher moisture content.

Acknowledgement

The authors are thankful to the University Grants Commission (UGC), New Delhi for providing financial support for carrying out the research work.

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VALUE ADDITION TO BAMBOO SHOOTS: A REVIEW

DEBANGANA CHOUDHURY • JATINDRA K. SAHU • G. D. SHARMA

ABSTRACT Bamboo shoots form a traditional delicacy in many countries. Being low in fat content and high in potassium, carbohydrate, dietary fibres, vitamins and active materials, bamboo shoots are consumed in raw, canned, boiled, marinated, fermented, frozen, liquid and medicinal forms. Although the fresh bamboo shoots of species like Dendrocalamus giganteus are healthier and nutritionally rich, the young shoots, after fortification, can be consumed by processing into a wide range of food products with longer shelf-life and better organoleptic qualities. However, the consumption pattern of bamboo shoots in most of the countries is traditional, non-standardized, seasonal and region-specific with little value addition. Therefore, there exists a great opportunity, especially for the organized food processing sectors to take up the processing of bamboo shoot-based food products in an organized manner. The present article gives an insight into the global scenario of bamboo shoot-based food products and their consumption pattern, the quality attributes, and the opportunities for value addition along with future prospects in view of international food safety, security and nutrition.

KEYWORDS Bamboo shoot • Value addition • Shelf stability • Fermented foods • HCN

INTRODUCTION

Basically a grass, belonging to family Poaceae, bamboo is spread over 1,250 species under 75 genera in the world (Upreti and Sundriyal 2001). Out of these, about 136 species under 23 genera are available only in India (Sharma 1980). The versatile and evergreen plant is found almost everywhere in the world, but the frozen poles.

Bamboo shoots are the new culms that just emerge from the ground and constitute a range of traditional delicacies. The freshly harvested bamboo shoot is cream yellow in color. When a newly harvested bamboo shoot is peeled, it gives a strong smell and bitter taste (Sharma 1980). The bitter taste in bamboo shoots is due to the presence of cyanogenic glycoside taxiphyllin, which is toxic in nature. All species of bamboo shoots available in the world are not edible. Out of 136 species available in India, the most commonly edible bamboo species are Bambusa pallida, Bambusa tulda, Bambusa polymorpha, Bambusa balcooa, Dendrocalamus hamiltonii, Dendrocalamus giganteus and Melocanna bambusoides (Sharma 1980). The edible genera of bamboo shoots available in USA are Phyllostachys, the important being Phyllostachys dulcis, Phyllostachys edulis, Phyllostachys bambusoides, Phyllostachys pubescens, Phyllostachys nuda and Phyllostachys viridis (Rubatzky and Yamaguchi 1997).

GLOBAL SCENARIO OF BAMBOO SHOOTS

The edible bamboo shoots have a matchless taste and flavor. In many parts of the world, bamboo shoots form a part of the conventional cuisine and are consumed in various forms (Daphne 1996; Tamang et al. 1988; Caitlin and Miles 2000; Tamang 2005; Bal et al. 2008; Pande and Pandey 2008).
However, bamboo grows naturally or is cultivated in homesteads and farms, and is one of the underestimated natural resources in the international scenario.

In international markets, China earns 6,500 million Indian rupees every year from export of edible bamboo shoots, with import of USA at around 44,000 tonnes accounting for 14.5% of the total world import (Lobovikov 2003). Every year USA imports 30,000 tonnes of canned bamboo shoots from Taiwan, Thailand, India and China for domestic consumption as food items (Daphne 1996). *Dendrocalamus asper* and *Dendrocalamus lactiferous* and *Bambusa oldhami* are the most important edible species in Thailand (Fu et al. 1979) and Taiwan (Tai 1985), respectively. The import of Australia is estimated about 8,000 tonnes per annum (Cahill 1999). Taiwan consumes about 80,000 tonnes of bamboo shoots annually constituting a value of 2,500 million Indian rupees, covering 30,000 ha of land of bamboo shoots under cultivation, producing total 380,000 tonnes of bamboo shoots per year (Tai 1985). In Japan, the present annual consumption of bamboo shoots is 3 kg per person, compared to 1.2 kg per person in 1950s (Yang et al. 2008). At present, over two million tonnes of edible bamboo shoots are consumed in the world in each year (Yang et al. 2008; Vaiphei 2005). Statistic shows that about 26.2, 435 and 426.8 tonnes of bamboo shoots are harvested annually in the north eastern states of India like Sikkim, Meghalaya and Mizoram, respectively, where about 20 30 million tonnes of bamboo shoots are utilized for production of canned bamboo shoots annually (Bhatt et al. 2003; 2005a; b).

India’s size of domestic bamboo economy currently is estimated at 2,000 million Indian rupees. The market potential of bamboo in India is estimated at present at 450 million Indian rupees, which will increase to 26,000 million Indian rupees by 2015, thus enabling five million families of artisans and farmers, crossing the poverty line (Farooquee et al. 2007).

### Bamboo shoots

Depending upon species, bamboo shoots are usually 20–30 cm long and taper to a point. A bamboo shoot at the time of harvest normally weighs more than 1 kg. However, their size and weight depend considerably upon the location, depth, pH and nutrition of the soil, irrigation and drainage conditions, climate, rainfall, temperature and soil type and fertility. Cold tolerance is a limiting factor in the growth of certain bamboo species (Dollo et al. 2009; Gangwar and Ramakrishnan 1987; Maikhuri 1996; Anderson and Ingram 1993; Kigomo 2007).

Various constituents like acids, proteins, carbohydrates, starch, fat, dietary fibre, vitamins and minerals have been systematically analyzed and reported by various authors (Lee and Takahashi 1966; Bradford 1976; Mcreddy et al. 1958; Goering and Van Soest 1970; Baker et al. 1980; Nirmala et al. 2008; Reiss 1993). Although bamboo shoots are found during the monsoons, there are normally two types of bamboo shoots available in a year; winter shoots and spring shoots depending on the seasons of a year. The spring shoots are normally larger, tougher and more superior compared to the winter shoots.

#### Quality attributes of bamboo shoots

Bamboo shoots are becoming one of the preferred food products in the world, but there is hardly any organized bamboo shoot processing and marketing industry to serve this exceeding need of the caterers and restaurants in considerable quantities. In the following sub-sections, an attempt has been made to compile the physical, chemical, nutritional, sensory, and anti-microbial qualities of bamboo shoots in order to understand the qualities of the products derived and/or to be derived from them.

**Physical quality**

The shooting period of a bamboo varies from species to species. In general, the temperate-climate-bamboos are runners, which shoot in the spring, while the tropical and sub-tropical species are clumpers, which shoot in the late summer and fall.

Bamboo shoots are tender, soft, crispy, generally ivory yellow in color. The sheaths covering the shoots are black, brown, yellow or purple. The white meat that is revealed, once the culm sheath is peeled off, turns yellowish when it is cooked. The edible tender shoots look like coiled springs and have an astringent flavor. The shoots of some species are known to contain cyanogenic glycosides, called taxiphyllin, \[2-(b-D-glucopyranosyloxy)-2-(4-hydroxyphenyl)acetonitrile\] which, therefore, develops acrid taste in bamboo shoot (Fu et al. 2002; Sarangthem and Singh 2003; Anonymous 2004).

**Chemical quality**

Bamboo shoots are low in fat content, but contain considerable amount of carbohydrate, potassium and dietary fibres. Many nutritious and active materials such as Vitamins, amino acids and anti-oxidants such as flavones, phenols and steroids can be extracted from the bamboo shoots (Shimada 1972; Sarangthem and Singh 2003). Bamboo shoots can be processed into a wide variety of beverages, medicines, additives and health foods (Lobovikov 2003; Majumdar 2006). However, there is hardly any product that has created its way into the market. A shoot contains about

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90% of water at the time of harvest. However, carbohydrate, fat and protein content were observed to decrease after canning and fermentation (Kumbhare and Bhargava 2002; Ninnala et al. 2008). Table 1 shows the chemical analysis of commonly edible raw bamboo shoots.

Nutritional quality

Bamboo shoot is a good source of potassium, Vitamin E (α-Tocopherol), Vitamin C, Vitamin B6, thiamin riboflavin, niacin, iron, phosphorus and dietary fibers like hemicelluloses, cellulose, pectin, lignin (Tripathi 1998; Park and John 2009). With 17 different types of amino acids, bamboo shoots contain about ten types of minerals like Cr, Zn, Mn, Mg, Ni, Co, Cu, etc. and lysine, one of the limited amino acids, which is helpful for growth and development of children is found in bamboo shoots (Shimada 1972; Reiss 1993; Fu et al. 2002; Bhatt et al. 2005a, b; Ninnala et al. 2007). Germaclinium in shoots has been reported to carry anti-aging properties (Sarangthem and Singh 2003). Ash of bamboo shoots has been reported in use in Ayurveda medicines in India (Puri 2003). Table 2 shows the detailed nutritive values of processed bamboo shoots.

Sensory quality

The bamboo shoots of some species, owing to the presence of cyanides, develop an acrid flavor (Midmore 1998; Sue 1995). The new shoots are free from acrid taste and are brilliant for human consumption. HCN is a crash product of cyanogenic glycosides which breakdown upon disruption of the plant cell. The quantity of cyanides in bamboo shoots, however, varies depending upon the species, for instance, the amount of cyanides is 894 mg/kg in Dendrocalamus giganteus (Ferreira et al. 1995). It has been reported that up to 0.16% of total cyanide is contained in the tip of the shoot, reducing to 0.01% in the base (Haque and Bradbury 2002). Table 3 shows the hydrogen cyanide (HCN) content (mg/g of bamboo shoot) of some of the commonly edible bamboo shoot species. Cyanogenic glycosides can produce both acute and chronic toxicity, but degrades readily by boiling in water. Nearly 70% of HCN is removed by boiling bamboo shoots for 20 min at 98 °C and about 96% is removed by boiling at this temperature for longer interval (Ferreira et al. 1995).

Bamboo shoot and value addition

There is a growing demand for processed and packaged bamboo shoots in the national and international markets. Shelf life of freshly harvested bamboo shoots is 9 and 23 days in water and brine, respectively (National Mission for Bamboo Applications, India 2009). During storage, a bitter taste develops in the bamboo shoots, if stored for a longer period of time, or exposed to sunlight. It has been reported that bamboo shoots, preserved in plastic bags have a risk of contamination by the materials present in the plastic bags (Chiangthong and Chayawat 2009).

Bamboo shoots containing carbohydrates, proteins and minerals can be expected as part of a healthy diet in fresh, canned and fermented forms. Whether as an accompanying vegetable or as main ingredient, bamboo shoots make a brilliant totaling to many pickled condiments, stir fries, soups and beverages. Bamboo shoots can be dried, marinated and sauteed, can be formed powders, nuggets and can be used as medicines. Moreover, production of bamboo being seasonal with high demand throughout the year, especially in China, Japan, USA, Canada, Thailand, Nepal, Bhutan, Australia and India, there is a need to develop process technologies to preserve the bamboo shoots in consistent and imperishable forms to be used during the off-seasons.
Table 2 Various constituents in processed bamboo shoots (Young 1954)

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Quantity per 100 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dietary fibers</td>
<td>1.5 g</td>
</tr>
<tr>
<td>Lignin</td>
<td>46 mg</td>
</tr>
<tr>
<td>Proteins</td>
<td>21.45 g</td>
</tr>
<tr>
<td>Essential amino acids</td>
<td>7.51 g</td>
</tr>
<tr>
<td>Non-essential amino acids</td>
<td>10.08 g</td>
</tr>
<tr>
<td>Cellulose</td>
<td>850 mg</td>
</tr>
<tr>
<td>Monosaccharide</td>
<td>307 mg</td>
</tr>
<tr>
<td>Polysaccharides</td>
<td>288 mg</td>
</tr>
<tr>
<td>Saturated fatty acids</td>
<td>50 mg</td>
</tr>
<tr>
<td>Monounsaturated fatty acids</td>
<td>0.7 mg</td>
</tr>
<tr>
<td>Polyunsaturated fatty acids</td>
<td>120 mg</td>
</tr>
<tr>
<td>Long chain fatty acids</td>
<td>181 mg</td>
</tr>
<tr>
<td>Sodium</td>
<td>268 mg</td>
</tr>
<tr>
<td>Potassium</td>
<td>224 mg</td>
</tr>
<tr>
<td>Calcium</td>
<td>17 mg</td>
</tr>
<tr>
<td>Iron</td>
<td>0.5 mg</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.18 mg</td>
</tr>
<tr>
<td>Sodium Chloride</td>
<td>68 mg</td>
</tr>
<tr>
<td>Uric acid</td>
<td>25 mg</td>
</tr>
</tbody>
</table>

Fresh bamboo shoots as foods

People consume fresh bamboo shoots in various forms. Bamboo shoot can be eaten fresh after boiling. In Indonesia, bamboo shoots are eaten with thick coconut milk and spices, which are called gulei rebung; sometimes also mixed with other vegetables, called sayur lade (Bhatt et al. 2003). Sweet pickles, chutney and candies are prepared from the pith of the bamboo shoots in the region. The sap of young stalks tapped during the rainy season is simply made into a soft drink in China (Yang et al. 2008). In Manipur, the fresh bamboo shoots are taken with dry fish (Tamang and Tamang 2009). The edible bamboo species in Western Ghats of India are extensively used as snacks, fried food stuffs, and curries (Bhatt et al. 2003). Tama, a non-fermented bamboo shoot curry is very familiar among the people of Sikkim (Tamang 2009). In Singapore, people consume bamboo shoots in form of canned or frozen (Pan 1995).

Table 3 Hydrogen cyanide (HCN) content of some of the commonly edible bamboo shoot species (mg/g of bamboo shoot)

<table>
<thead>
<tr>
<th>Region of the shoot</th>
<th>Bamboo species</th>
<th>D. hamiltonii</th>
<th>B. pallida</th>
<th>B. nilio</th>
<th>B. balcooa</th>
<th>M. bambussoides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tip</td>
<td></td>
<td>2.42</td>
<td>0.27</td>
<td>0.17</td>
<td>2.15</td>
<td>1.81</td>
</tr>
<tr>
<td>Middle portion</td>
<td></td>
<td>0.86</td>
<td>0.17</td>
<td>0.83</td>
<td>1.38</td>
<td>0.68</td>
</tr>
<tr>
<td>Base</td>
<td></td>
<td>0.15</td>
<td>0.13</td>
<td>0.28</td>
<td>0.62</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Dried bamboo shoots

Drying is the oldest and simplest food processing technology in the food industry. Extensive research work has been carried out on drying technology. However, very little work is reported on drying of bamboo shoots. Nevertheless, it has been reported that there is a 95.1% decrease in the moisture content of dried bamboo shoots (Satya et al. 2010). Water content of fresh bamboo shoots is 92.6/100 g of fresh weight compared to 4.6/100 g in dried bamboo shoots (Muchtadi and Adawiyah 1996). Cheng (2006) reported a multi-stage vacuum pressure preserving technique combined with hydrocooling could reduce the temperature of bamboo shoots efficiently. The author suggested that the process has the advantage of minimizing the energy consumed by the vacuum system. A comparative study of various methods for drying of bamboo shoot along with their advantages and disadvantages has been systematically reported by Majumdar (2006) and Satya et al. (2010). Bal et al. (2010) studied the effect of microwave power on drying kinetics of bamboo shoots. The authors suggested that increasing microwave output power, the effective moisture diffusivity values increased from $4.153 \times 10^{-10}$ to $22.835 \times 10^{-10}$ m$^2$s$^{-1}$.

It may be noted that in selecting or designing an appropriate drying technology, it is important to explore energy, environmental and cost issues. Different technologies may be appropriate at different geographical locations depending on local socio-cultural conditions. Quality attributes of end product using multi-stage drying technologies, such as solar-assisted heat pump drying, solar drying with thermal energy storage, microwave assisted vacuum drying, refractive drying and super heated steam drying may be explored for drying bamboo shoots.

Canned bamboo shoots

High moisture content of bamboo shoots make them easily perishable giving space for the growth of undesirable micro-organisms like bacteria, molds and yeasts. Canning has been observed to be effective in abating rancidity and preventing the growth of micro-organisms in bamboo shoots (Fu et al. 2002). Canned bamboo shoots can be satisfactorily preserved and can be used
Fermented food items

Traditionally, various fermented bamboo shoot products are consumed in the world. Ethnic people living in sub Himalayan regions, Nepal and Bhutan prepare and consume a variety of domesticated and wild bamboo shoots and their fermented products (Sharma 1989; Tamang and Tamang 2009; Tamang et al. 1988; Tamang 2000; Vaiphei 2005). A traditional fermented bamboo shoot product of the eastern hills of Nepal and Bhutan is mesu (Tamang and Sarkar 1996). Use of mesu as a pickle and as a base in curries is a conventional dish among the Nepalis, Bhutias and the Lechhas of the Darjeeling hills and Sikkim (Tamang 2005). Delicacies in Indian cuisines include ushoi, soidon, soibum, soijim, iromba, ekung, eup, hiring lung-siej and syrwa (Giri and Jammejay 1987; Tamang 2000, 2009; Mao and Odyuo 2007; Agrahar-Murungkar and Subbulaskellmi 2006; Jeyaram et al. 2009). Ushoi, a fresh bamboo shoot, is one of the popular food products among the Manipuris and Apa Tanis of Arunachal Pradesh. Soibum, a fermented bamboo shoot, is an exceptional delicacy of the Meities of Manipur, eaten as pickle and curry mixed with fish. Similar fermented bamboo shoot product called naw-mai-dong or nor-mai-dong is consumed in Thailand (Phithakpol et al. 1995). Soidon is another fermented bamboo shoot product in Manipur, prepared from the tip of matured bamboo shoots and consumed both as a curry and pickle. Soijim is another type of fermented bamboo shoot product developed by submerged fermentation in Manipur. Iromba is a fermented or boiled bamboo shoot taken with fish and other vegetables by Khasi tribes in Meghalaya (Agrahar-Murungkar and Subbulaskellmi 2006).

The sap of young stalks tapped during the rainy season is fermented to prepare ulanzi (a sweet wine), which is used by Chinese as a delicious liquor (Qing et al. 2008). In central India, the young shoots are grated and fermented to prepare kaudi or amil, a sour vegetable soup. In the region, the bamboo shoots are dried, ground into powder and used as a garnish called hendua, which is commonly preferred liquor among the tribal people (Panda and Padhy 2007; Bal et al. 2009). In Nepal, bamboo shoots are fermented with turmeric and oil, and cooked with potatoes to prepare an item called alu tama (Tamang 2009).

Bamboo shoot based powder

Bamboo shoot, from its constituents, indicates that it contains considerable amount of carbohydrate and dietary fibers. During boiling, the polysaccharides get hydrolyzed into simple sugars and gives sweet taste to the shoots (Kumbhare and Bhargava 2007). The key advantages of using dried bamboo shoot powder is its low moisture content which may allow its direct use into various dry food items, and preparing chutney and beverages. Other advantages of using dried bamboo shoot based powder may include free-flowing, ease of handling and weighing, reduced storage space, ease of cleaning and sanitary aspects. In Japan, bamboo shoot-based powder is used as an essence in cookies and various other food items. Japanese use bamboo powder in standard bread flour and also recommends a 3-8% addition of the powder to any food products (Hua 1987). In China, bamboo juice produced by pressure-cooking, is used to make beverages and specific liquors, apart from medicines (Qing et al. 2008). With a characteristic bamboo aroma and beer flavor, bamboo juice beers show a good number of health benefits by lowering blood lipids and fighting heart ailments (Shi and Yang 1992; Satya et al. 2009b).

Medicines

Bamboo shoot has been in use in medicine, since time immemorial by the tribal people in various regions. With different flavones, glycosides, bamboo shoots have good anti-oxidant, anti-free-radical and anti-aging agents, and can be extracted to make capsules and tablets (Shi and Yang 1992; RFRI 2008). In the traditional system of Ayurveda, the silicious concretions found in the bamboo shoots is called banslochan and in the Indo-Persian and Tibetan system of medicine, it is called as bamboo manna and is known to be a good tonic for respiratory disorders. Bambusa arundinacea species is considered as the excellent source of bamboo manna (Puri 2003).

In China, bamboo shoots are used for treating infections. The juice of pressed bamboo shoots possesses protease activity that helps in digestion of protein. The boiled bamboo shoots are used as appetizers. Decoction of the shoots are used for cleaning wounds and maggot infected sores, ulcers etc. Bamboo shoots, mixed with palm-jaggery, are known to induce parturition or abortion (Shi and Yang 1992; Puri 2003). In Java, sap from inside the shoots of Bambusa vulgaris is used for curing jaundice (Burkill 1957). Bamboo salt tablets used in Korea are known to help treat certain internal maladies. These are prepared by sealing salt in bamboo shoots using uncontaminated yellow clay and then baking them eight times in a specially designed furnace. This allows the salt to absorb highly therapeutic trace elements including Cu, Zn and Fe and also eliminates any impurities and heavy metals from the salt that can cause any damage to the body. It serves as a natural detoxifying agent with a strong anti-microbial property and
also provides energy and nutrients to the body (Liu 1992). Korea markets a delicious bamboo sea salt, which is used as an alternative to table salt in cooking (Cost 1988). Korea is even reported of marketing bamboo shoot-based cosmetics such as cleansing agent called bamboo bath salts (Cost 1988).

Future prospects

A thriving economy revolves around bamboo resource. Bamboo is well placed to address the food security through bamboo-based agro-forestry systems by maintaining the fertility of adjoining agricultural lands, and as a direct food source like edible bamboo shoots. Bamboo shoots hold the prospect of value added economic activities at industrial and society levels through cultivation, processing, packaging and commercialization. However, the preparation of various bamboo shoot-based food products is traditional, local, unorganized and based on the taste of the local people. There is no standardized process technology for preservation of the raw bamboo shoots into various food items in an organized manner. This calls for the development of appropriate technologies for preservation of bamboo shoots in various forms. In India, there is yet neither major approach for promotion of shoots nor is there well thought-out market or supply chain for the raw or processed bamboo shoots. Focus should be directed for following aspects for sustainable development of a bamboo shoot-based food industry.

- Identification and selection of most suitable edible species
- Recommendation of proper package of practice for bamboo cultivation
- Appropriate fermentation technology of edible bamboo shoots
- Groove management procedures (plantation, maintenance, and harvesting)
- Materials processing (grading, cleaning, and drying)
- Product manufacturing (equipment, foods, jigs, dyes, paints, varnishes)
- Marketing (customer identification, distribution, advertisements)

Conclusion

Bamboo is a plant species that incorporates several economic, ecological and social benefits in the day to day life of human beings. Therefore, organized cultivation for bamboo shoot may be encouraged. This requires the use of a different package of practice which normally holds better soil, water and light conditions, and more intensive management. Plantation of the most edible and adventurous species, preferably Dendrocalamus giganteus, Dendrocalamus asper; Bambusa balcooa and Dendrocalamus hamiltonii may be adopted. Standardized cultivation practices at various locations may be encouraged by government and non-government organizations, especially in tribal areas in order to harmonize the international food safety, security and nutrition.

Acknowledgement The authors are thankful to the University Grants Commission (UGC), New Delhi for providing financial support to carry out the research work.

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ABSTRACT
Bamboo is a natural resource in the world. The young and tender bamboo shoot, called bamboo shoot, is utilized as one of the ingredients in many industries all over the world including cookery and pharmaceuticals. Although a thriving economy exists around bamboo shoots, the utilization and consumption pattern of bamboo shoots is too traditional, non-standardized, unorganized and region-specific with little value addition. Therefore, there is requirement of development of viable processing strategies to conserve this renewable yet unexplored natural resource. The present article disclose an insight into bamboo shoots and their statistics of production and consumption in the world, quality characteristics, processing opportunities and challenges in supporting and establishing bamboo shoot based processing units. It is expected that despite of the numerous challenges, the article will help in bringing up of an organized bamboo shoot based food processing industry.

Keywords: Bamboo shoots, fermented and canned bamboo shoots, snacks, HCN

1. INTRODUCTION
Bamboo shoots are the new, edible culms that have just emerged from the ground. Bamboo shoots constitute a wide range of long established delicacies of various continents like North eastern states of India, China, Japan, Korea, Thailand, Taiwan, Bhutan, Nepal, USA, Australia, and New Zealand (Choudhury et al., 2010). The freshly harvested bamboo shoot is basically cream yellow in color. When peeled, it has a strong smell and is sweet in taste, if they are eaten on the day of harvest. Bamboo shoot contains cyanogenic glycoside which is toxic in nature and is responsible for the bitter taste of the bamboo shoot. Almost all species of bamboo shoots available worldwide are edible. Out of 136 bamboo species available, the most edible bamboo species in India include B. pallida, B. tulda, B. polymorpha, B. balcooa and D. hamiltonii, D. giganteus and M. bambusoides (NBM, India).

2. GLOBAL SCENARIOS OF BAMBOO SHOOTS
Bamboo is a very seasonal plant and mostly grows during the rainy season. Although all bamboo species are not edible, more ever, at present, over two million tonnes of bamboo shoots are consumed around the world in each year, mostly in Asian countries (Vaiphei, 2005). About 427 tonnes of bamboo shoots are harvested annually in the north eastern states of India (North-East India Business Summit, Mumbai, 2002). According to the Forest Survey of India (1988 - 89), the bamboo stock in Mizoram shares 14% of India's total bamboo stock and about 5% of the growing stock of bamboo resource in Nagaland (NBM, Nagaland). India's size of domestic bamboo economy currently is estimated at US$ 41 million. The market potential of bamboo in India is, however, estimated at present at US$ 90 crores, which will increase to US$ 520 million by 2015 (NBM, India, 2003).

In the international scenario, D. asper and D. lacteolrus and B. oudhami are the most important species for shoot production in Thailand (Fu et al., 1987) and in Taiwan (Tai, 1985), respectively. Taiwan only consumes 80,000 tonnes of bamboo shoots annually constituting a value of US$ 50 million with, 30,000 hectare of land of bamboo shoots under cultivation, producing 3,820,000 tonnes per year (Tai, 1985). In Singapore, people mostly consume canned bamboo shoots; however, frozen cooked shoots are also used (Pan, 1995). In Japan, the annual per capita consumption of bamboo shoots is now 3 kg per person presently, compared to 1.2 kg per person in 1950s. China earns US$130 million every year from exports of edible bamboo shoot, with imports of US at around 44,000 tonnes accounting for 14.5% of the total world imports. It has been estimated that every year US imports 30,000 tonnes of canned bamboo shoots from Taiwan, Thailand and China to be consumed as food items (Daphne, 1996).

3. BAMBOO SHOOTS
Bamboo shoots are usually 8 - 12 inches long and narrow to a point and weigh up to a pound. Their size and weight however depends upon the location, depth and nutrition of the soil, watering and drainage conditions, rainfall, temperature and soil fertility. There are normally two types of bamboo shoots available in a year; winter shoots and spring shoots depending on the seasons of a year. The spring shoots are larger, tougher and more superior compared to the winter shoots (Vinning, 1995). Followings are some of the morphological characteristics of some of commonly available bamboo shoots.

Genus Characteristic
- Acidosasa shoots are green; glabrous and sheaths turn from green to brown; shoots are edible and delicious; includes species like A. edulis, A. giganteum.
- Arundinaria genus of small to medium sized running bamboo; usually hardy with numerous branches at each node and persistent culm sheath; shoots are edible ones;
- Bambusa genus of tropical and sub-tropical clumping bamboo; shoots of some species are edible; includes B. balcooa, B. bambos, B. beecheyana, B. blumeana, B. edulis, B. gosa, B. tulda, B. vulgaris.
- Dendrocalamus shoots are edible; include species like D. asper, D. brandisii, D. hamiltonii, D. sikkimensis, D. strictus.
- Melocanna A genus native to clumpers with long-necked rhizomes; edible species include M. baccifera.
- Oxytenanthera edible species; include O. braunii.
- Phyllostachys edible species; include P. atrovaginata, P. aurea, P. alata, P. bambusoides, P. dulcis, P. pubescens, P. nidulalis, P. nuda.

4. BAMBOO SHOOT QUALITIES
The edible tender shoots look like coiled springs and have an aromatic flavour. The shooting period of bamboo varies from species to species. In general, the temperate climate bamboos are runners, which shoot in the spring, while the tropical and sub-tropical species are clumpers, which shoot in the late summer and fall. Bamboo shoots are low in cholesterol and saturated fat contents (total fat 0.5%), high in carbohydrate (5.70%) with a considerably high value of protein (3.9%), minerals (1.1%) and moisture (88.8%) (Satya et al., 2009). It is a good source of potassium, Vitamin E (α-Tocopherol), Vitamin C, Vitamin B6, thiamin riboflavin, niacin, iron, phosphorus and dietary fibers like hemicelluloses, cellulose, pectin, lignin (Park and John, 2009). Table 1 shows the chemical analysis of commonly edible bamboo shoots.
In Bhutanese cuisine, Tchang’a millet beer is fermented with turmeric and oil, and cooked with potatoes to prepare shoot based food items in the world and its demand is growing day-by-day served in bamboo mugs to preserve its flavor. In certain other parts along hillside, crushed and packed in bamboo containers (a customary many countries. A thriving economy exists for bamboo and bamboo its popularity is growing day-by-day as main or secondary food item in ‘khorisa tenga’ people. In Assam, bamboo shoots are commonly called ‘khoris^, vegetable soup. In the region, shoots that have turned a little fibrous shoots are grated and fermented to prepare ‘soibum’, prepared with dry fish, called ‘so/don’ is consumed locally and ‘ushof’ Indian cuisines include (fresh cooked and fermented bamboo technologies may also be appropriate at different geographical locations can be dried, marinated, or sauteed and used in various processes to examine energy, environmental as well as cost issues. Different then (1996) kept in mind, the quality features of the end product, hybrid technologies, such as solar-assisted heat pump assisted drying, solar drying with thermal energy storage, microwave assisted vacuum drying technologies, retractive drying and super heated steam drying may be used which are more cost effective for drying of bamboo shoots.

### 6.1. Dried Bamboo Shoot based Products

Traditionally, people consume bamboo shoots in various forms. In Indonesia, bamboo shoots are eaten with thick coconut milk and spices, which is called ‘gulei rebung’, sometimes also mixed with other vegetables, called ‘sayur ladeh’. Sweet pickles, chutney or candies, used as condiment are prepared from the pith of the bamboo shoots. The sap of young stalks tapped during the rainy season is fermented to prepare ‘ulanzi’ (a sweet wine), or simply made into a soft drink, called ‘hendua’, a green coloured Chinese liquor. Delicacies in Indian cuisines include ‘ushof’ (fresh cooked and fermented bamboo shoots) among the Manipuris and Apa Tanis of Arunachal Pradesh. In China, bamboo shoots are used for treating infections. The juice of bamboo, they have excellent anti-oxidant, anti-free-radical and anti-infected sores.

#### 6.2. Canned Bamboo Shoot based Products

The high moisture content of bamboo shoots make them easily perishable giving space for the growth of undesirable micro-organisms and activity of various undesirable food enzymes. Canning has been observed to be effective in abating rancidity and prevent the growth of micro-organisms in bamboo shoots. Canned bamboo shoots can be satisfactorily preserved and can be used frequently in various items such as vegetables or pickle condiments.

#### 6.3. Fermented Bamboo Shoot based Products

Various fermented bamboo shoot products are consumed by people all over the world today. Especially ethnic people living in sub-Himalayan regions, Nepal and Bhutan prepare and consume a variety of domesticated and wild bamboo shoots and their fermented products (Sharma, 1969; 1988). Various fermented bamboo shoot products consumed by people all over the world have been documented by various authors, although none of the processes has been standardised for the development of appropriate technologies for preservation of bamboo shoots in various fermented forms.

#### 6.4. Bamboo Shoot based Powders

Dried food powders today are considered as convenient foods because of their long storage life at ordinary temperature, free-flow, ease of handling and weighing, reduced storage space, ease of cleaning and sanitary aspects. In Japan, bamboo powder is used as an essence in cooking. Bamboo shoot is used to produce nuggets that may be used in diet or curry as that of soybean. Some food grade additives may be added during the process or the product may be fortified with some food nutrients, in order to increase the sensory quality of the nuggets.

#### 6.5. Bamboo Shoot based Nuggets

Besides, its use as pickles and condiment, bamboo shoots can also be used to produce nuggets that may be used in diet or curry as that of soybean. Some food grade additives may be added during the process or the product may be fortified with some food nutrients, in order to increase the sensory quality of the nuggets.

#### 6.6. Ready-to-eat (RTE) Snack Foods

Ready-to-eat (RTE) snack/fried foods have become a significant food item of modern people (Shukla, 1994). In India, several RTE products are available in the market. And there is still an increasing demand for more nutritious and low calorie based snack food in the international market. Therefore, keeping in mind the various process parameters, a technology for the production of bamboo shoot based snacks, can be followed.

#### 6.7. Medicines

Bamboo shoot has been in use in medicine, since time immemorial by the tribal people in various regions. With different flavones, glycosides in bamboo, they have excellent anti-oxidant, anti-free-radical and anti-aging agents, and can be extracted to make capsules and tablets. In China, bamboo shoots are used for treating infections. The juice of pressed bamboo shoots possesses protease activity that helps in digestion of proteins. The boiled bamboo shoots are used as appetizers. Decontaminations of shoots are also used for cleaning wounds and maggot infected sores.

---

**TABLE 1: Chemical analysis of commonly edible bamboo shoots (N MBA, India)**

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Bamboo species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A. M. bambusoides</td>
</tr>
<tr>
<td>Water (%)</td>
<td>91.65</td>
</tr>
<tr>
<td>Minerals (%)</td>
<td>0.59</td>
</tr>
<tr>
<td>Phosphorus (mg/100g)</td>
<td>30.99</td>
</tr>
<tr>
<td>Calcium (mg/100g)</td>
<td>24.01</td>
</tr>
<tr>
<td>Iron (mg/100g)</td>
<td>1.02</td>
</tr>
<tr>
<td>Hydroxyacid (%)</td>
<td>0.071</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>2.74</td>
</tr>
<tr>
<td>Nicotin (mg/100g)</td>
<td>1.40</td>
</tr>
<tr>
<td>Carbohydrates (%)</td>
<td>3.50</td>
</tr>
</tbody>
</table>

---

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Ready-to-eat (RTE) snack/fried foods have become a significant food item of modern people (Shukla, 1994). In India, several RTE products are available in the market. And there is still an increasing demand for more nutritious and low calorie based snack food in the international market. Therefore, keeping in mind the various process parameters, a technology for the production of bamboo shoot based snacks, can be followed.

**6.7. Medicines**

Bamboo shoot has been in use in medicine, since time immemorial by the tribal people in various regions. With different flavones, glycosides in bamboo, they have excellent anti-oxidant, anti-free-radical and anti-aging agents, and can be extracted to make capsules and tablets. In China, bamboo shoots are used for treating infections. The juice of pressed bamboo shoots possesses protease activity that helps in digestion of proteins. The boiled bamboo shoots are used as appetizers. Decontaminations of shoots are also used for cleaning wounds and maggot infected sores.

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7.2. Rat Control

The various agroforestry products that can be derived from bamboo include timber, craftwood, fiber crops, livestock forage, bamboo shoots and charcoal products have been manufactured, for purifying drinking water and indoor air, adjustment of humidity in rooms, odor adsorption and radioactive emission, acts as an atmospheric pollution controller. The waste bamboo generated from processing operations can be used for bio-fuel for transportation activities, which has lower operating cost. And the activated bamboo charcoal obtained from this thermo-chemical process has a very high adsorption capacity. The gasification of waste bamboo thus offers exciting prospects for value addition and offers an exciting avenue for utilization of bamboo resources in industrial and utility areas. At present various bamboo charcoal products have been manufactured, for purifying drinking water and indoor air, adjustment of humidity in rooms, odor adsorption and bamboo charcoal based lsoods etc.

7.1. Sustainability of the Bamboo Plant

Bamboo is an economically strong plant that grows without the assistance of fertilizers, pesticides or any chemicals and the shoots are naturally pest resistant. They need plenty of water and a well drained system, to grow optimally. However, various factors, such as cold, drought etc limit the growth of the plant and therefore it is to explore a successful bamboo shoot based venture, proper package of practice should be recommended for sustainability of this natural plant.

7.2. Rat Control

Rat population outbreaks following gregarious bamboo flowering is a well-accepted phenomenon in countries like India, Bangladesh and Malaysia, whose bamboo is most naturally grown. This expansion of the rat population is caused by excessive production of the seeds and that when the store is exhausted, they come out to the households or granary, thereby causing a famine. Therefore, rat control is a primary issue to the bamboo farmers and this is always a tough and challenging activity. The major rat control steps can be through baiting, trapping and poisoning.

7.3. Management of Bamboo Leaves

Bamboo leaves are rich in flavones and glycosides and the leaf paste and deccotions are used to treat various infections and internal maladies. Also bamboo leaves, stem and shoots are foremost in energy production and bamboo energy being free from green house gasses and radioactive emission, acts as a atmospheric pollution controller.

7.4. Process Upgradation

The various agroforestry products that can be derived from bamboo such as timber, craftwood, fiber crops, livestock forage, bamboo shoots etc, Bamboo shoots carry the prospect of value added economic activity at both formal and informal sectors of the society. Different processing methods such as fermentation, roasting, boiling, blanching, canning, pickling etc, have been reported as bamboo shoot are consumed in various form either dried, powdered, canned or fermented or simply boiled. Major research work on this aspect has been carried out during the past 2-3 years only (Kumbhare and Bhargava, 2007; Nirmala et al., 2008). These studies seem to be however insufficient to draw any significant conclusion, but certainly provide guidelines for in depth scientific work on this important aspect of food quality.

7.5. Waste Utilization

The waste bamboo generated from processing operations can be used for as bio-fuel for transportation activities, which has lower operating cost. And the activated bamboo charcoal obtained from this thermo-chemical process has a very high adsorption capacity. The gasification of waste bamboo thus offers exciting prospects for value addition and offers an exciting avenue for utilization of bamboo resources in industrial and utility areas. At present various bamboo charcoal products have been manufactured, for purifying drinking water and indoor air, adjustment of humidity in rooms, odor adsorption and bamboo charcoal based lsoods etc.

8. CONCLUSION

A thriving economy revolves around bamboo resource. Bamboo is well placed to address four major global challenges (i) shelter security, (ii) livelihood security, (iii) ecological security and (iv) food security, through setting up of a bamboo-based agro-forestry system. None-the-less, a series of plans attempted through the IDRC, UNIDO, UNIDO, INBAR and NABARD have created a strong foundation for producing bamboo shoots and bamboo shoot based food industry.

Acknowledgement

The authors are thankful to the University Grants Commission (UGC), New Delhi for providing financial support to carry out the research work.

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Biochemistry of Bitterness in Bamboo Shoots

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Abstract

Bamboo is a natural resource in the world. The young and tender bamboo plant, called bamboo shoot, is utilized as one of the food items in many countries. Consumption of bamboo shoots in most of the countries is in dried, canned, boiled, fermented or medicinal forms. Bamboo shoots are low in fats and cholesterol contents, but very high in potassium, carbohydrates and dietary fibers. However, due to presence of hydrocyanine (HCN) develops bitterness in the bamboo shoots, which limits the interest of many people for this renewable and yet unexplored natural food item. The present article present the various qualities of bamboo shoot, biochemistry of bitterness in bamboo shoots and processing challenges in supporting and establishing bamboo shoot based R&D sectors.

Keywords: Bamboo Shoot, Bitterness, HCN, Superheated Steam Dying, Canning.

Introduction

Bamboo shoots are the young and tender culms of bamboo that are consumed for various food items after harvesting. Bamboo shoots form a traditional delicacy of many countries. The freshly harvested shoot is cream yellow in color, has a strong smell and is sweet in taste. However, all species of bamboo shoots available worldwide are not edible. The utilization pattern of the bamboo shoots in most of the countries indicates that it is consumed in forms of raw, dried, canned, boiled, fermented or medicinal. Bamboo shoots are very seasonal, short-lived and perishable in nature.

The total potential of bamboo worldwide is estimated at $10 billion. In the international market, China earns US$130 million every year from exports of edible bamboo shoot, with imports of US at around 44,000 tonnes accounting for 14.5% of the total world imports) and import of Australia is at 8,000 tonnes per annum (Cahill, 1999). It has been observed that every year US imports 30,000 tonnes of canned bamboo shoots from Taiwan, Thailand and China to be consumed as food items (Lewis, 1996). Taiwan consumes 80,000 tonnes of bamboo shoots annually constituting a value of US$ 50 million (Tai, 1985). In Singapore, mostly consumed are the canned shoots; however, frozen cooked shoots are also used (Pan, 1995). In Japan, the annual per capita consumption of bamboo is now 3 kg per person presently, compared to 1.2 kg per person in 1950s.

Bamboo Shoots Qualities

Bamboo shoots are presently among the most favorite food items among people all over the world, but there is hardly any organized bamboo shoot processing and marketing industry. Therefore, the product is being far off from standardization or globalization. In the following sub-sections, an attempt has been made to highlight the quality attributes i.e., physical, chemical, nutritional, sensory, and anti-microbial qualities of bamboo shoots and the subsequent qualities of the products derived or to be derived from them.
Bamboo shoots are generally 8-12 inches long, taper to one end and grow extraordinarily. However, their size and weight depend considerably upon the location, depth and nutrition of the soil, watering and drainage conditions, rainfall, temperature, pH and soil fertility. Broadly, the temperate climate bamboos are runners, which shoot in the spring, while the tropical and sub-tropical varieties are dumpers, which shoot in the late summer and fall. Bamboo shoots look like coiled springs and have an acerbic flavour.

Bamboo shoots are low in fats and cholesterol contents, but very high in potassium, carbohydrates and dietary fibers. Many nutritious and active materials such as vitamins, amino acids, and antioxidants such as flavones, phenols and steroids are present in the bamboo shoots. Bamboo shoots are valuable in pharmaceutical and food processing industries and can be processed into beverages, medicines, additives or health foods. In attendance, however, hardly any product has created their way into the markets. Table 1 represents the chemical composition of commonly edible bamboo shoots. The table shows that the water, protein, carbohydrate, mineral and hydrocyanic acid contents of bamboo shoots vary from 85.98-92.37%, 1.98-3.29%, 3.89-9.94%, 0.89-1.14% and 0.032-0.13%, respectively.

Table 2 shows that bamboo shoots are low in cholesterol and saturated fats contents (total fats 0.5%), are high in carbohydrate (5.70%), protein (3.9%), minerals (1.1%) and moisture (88.8%) (Satya et al., 2009). It is a good source of Vitamin E (d-α-Tocopherol), Vitamin C, B6, thiamin, riboflavin, niacin and dietary fibers like hemicelluloses, cellulose, pectin, lignin (Park and John, 2009). It has been reported that bamboo shoots can significantly decrease serum total and serum LDL cholesterol in rats and total liver lipids including liver cholesterol by 16.1 mg/dl. With 17 different types of amino acids, it contains over 10 kinds of mineral elements i.e., Cr, Zn, Mn, Mg, Ni, Co, Cu; Lysine, Germaclinium, many nutritious and active materials.

Bamboo shoots are soft and crispy and develop an acrid flavor, if not harvested as soon as they come out of the ground (Sue, 1995). They contain a potentially toxic glycoside of α-hydroxynitrile, called taxiphyllin. (Anonymous, 2004) which is turned on by the hydrolytic enzyme: α-glycosidase, upon disruption of the plant cell (Ermans et al., 1980, Nahorstedt, 1993). Taxiphyllin further breaks down to form cyanohydrins and sugar, which rapidly decomposes into hydrocyanic acid and an aldehyde or a ketone. In D. giganteus, it varies upto 894 mg/kg (Ferreira et al., 1995), in M. bambusoides, 0.14 mg/g, in B. pallida, 0.04 mg/g, respectively. The new shoots are almost free from acridity and are brilliant for human consumption. Homogenetic acid is, however, also responsible for the pungent taste of the shoots (Bhargava et al., 1996). But the taste also depends on the total sugar content, total amino acid content like aspartic acid (Asp), glutamic acid (Glu), glycine (Gly) and tannin contents; while the amino acids increase the deliciousness of bamboo shoots, tannins decrease the same by increasing the offensive taste (Xia-Bo, 2006).

With different flavones and glycosides, bamboo shoots have excellent anti-microbial qualities and can be extracted to make capsules and tablets. In the traditional system of Indian medicine, the silicious concretions found in the shoots are called ‘banslochan’; and in the Indo-Persian and Tibetan system of medicine, it is called ‘tabashir’ or ‘tawashir’; commonly in English, it is called ‘bamboo manna’. Earlier obtained from M. bambusoides, it is known for its unique healing properties, but is very hard to get. Presently it is replaced by synthetic salicic acid.

Shoots of B. arundinacia/B. bambos contain choline, betain, nucleuse, urease, cyanogens, glucosides and are used in the treatment of diarrhoea, thread worm and cough; shoots and dried pith of D. strictus contain silicious matter and have tonic and astringent action. The juice of pressed bamboo shoots possesses protease activity that helps in digestion of proteins. Boiled bamboo shoots are used as appetizers and the decoction of shoots are used for cleaning wounds and maggot infected sores, ulcers etc; mixed with palm-jaggery, it is known to induce parturition and abortion (RFRI, 2008). In Java, sap from inside the shoots of B. vulgaris is used for curing
jaundice (Burkill, 1935). Bamboo is filled with antimicrobial qualities and its shoots are used in preparation of steroidal drugs (Sarangthem, 2003).

**HCN in Bamboo Shoots**

Bamboo shoot is one of the common food items in many countries and its popularity is growing day-by-day, as main or supplementary foodstuff. A thriving economy exists around bamboo and bamboo shoot based food item in the international market in terms of food security and nutrition. There exists great opportunity especially in an organized food processing sector to take up plantation, harvesting, processing and marketing of bamboo and bamboo shoots- based food products. Bamboo shoots can be dried, marinated, or sautéed to prepare various food items. Although fresh shoots (of *D. giganteus*) are healthier and nutritionally richer, (Nirmala et al., 2008) the younger shoots, later fortified, can be utilized for various small scale cottage industries by processing them into a wide range of long-standing products. It should, however, be noted that, in selecting an appropriate process technology for the bamboo shoots, it is important to examine energy, environment as well as cost issues. Different technologies may be appropriate at different geographical locations and local socio-economic conditions. Due to increase in population, raised attention towards urbanization and industrialization and drastic climatic change, potential of this natural resource is declining day-by-day.

Cyanogenic glycosides are nitrogenous phytoanticipins (Zagrobelny et al., 2004) and are used by various plants as effective defensive mechanism against predators (Thomsen and Brimer, 1997; Jones, 1998; Francisco and Pinotti, 2000). A mechanisms responsible for the formation of HCN has been formulated by Miller and Conn (1980), and it has been found that in most of the species it is the degradation of the cyanogenic glycosides (Conn, 1979) that produces HCN; and the enzyme responsible for this are found out to be ß-cyanoalanine synthase (EC 4.4.1.9) which is found in a number of plant species (Blumenthal et al., 1968; Floss et al., 1965), apart from Rhodanese (thiosulphate-cyanide sulphur transferase EC 2.8.1.1) and Formamid hydrolyase (EC 4.2.1.66). The steps that catalyze the reaction through ß-cyanoalanine synthase are (Miller et al., 1980):

\[
\text{HSCH}_2\text{CHNH}_2\text{CO}_2\text{H} + \text{HCN} \rightarrow \text{NCCH}_2\text{CHNH}_2\text{CO}_2\text{H} + \text{H}_2\text{S}
\]

\[
\text{Cystein cyanuronine}
\]

\[
\text{S}_2\text{O}_3^- + \text{CN} \rightarrow \text{ISO}_3^- + \text{SCN}
\]

\[
\text{HCN} + \text{H}_2\text{O} \rightarrow \text{HCONH}_2
\]

Bamboo shoots contain 0.3 to 0.8% HCN (Poulton, 1983; Tripathi, 1998; Anonymous, 2004). Out of which, up to 0.16% of the total cyanide is contained in the tip, reducing to 0.01% in the base (Haque and Bradbury, 2002), with highest in leaves of young plants, but dropping rapidly after pollination. However, subsequent processing helps in fighting the cyanide concentration, though incomplete cooking result in glycoside hydrolysis and higher release of HCN, but the total amount of HCN in the shoots can be eliminated/detoxified by boiling/cooking for two hours (Anonymous, 2004). Table 3 shows the HCN content of edible bamboo shoot species.

Cyanogenic glycosides were assessed by various authors and organizations (Simeonova and Fishbein, 2004; Gettler and Baine, 1938; Halstrom and Moiler, 1945, Satya et al., 2007; NMBA, 2009; JECFA, 1993; Speijers, 1993; ATSDR, 2006). Subsequent detoxification and potential toxicity of cyanoglycosides resulting in acute cyanide poisoning in human, bird, fish, wildlife and livestock has been documented (Conn, 1979a, b; Oke, 1979, 1980; Ballantyne, 1987a; Wilson, 1983; Yamamoto et al., 1989). The intermediate degradation of cyanogenic glycosides and their products – the cyanoxydryns – are only addressed in some of the reviews and articles (WHO, 1993; EFSA 2004; Majak, 1992; Brimer and Rosling, 1993; Hernandez et al., 1995). Functionally, taxiphyllin in presence of α-glucosidase breaks down to form HCN and aldehyde or ketone. The HCN, so formed, inhibits cytochromoxidase which then stops the oxidative phosphorylation and utilization of intracellular oxygen ceases and there is cardiac arrest in human body (Conn, 1979).

**Remedies for Bitterness**

Cyanide content, naturally, is reported to decrease substantially following harvesting (Nirmala et al., 2007). Different indigenous methods of reducing
acidity/bitterness from fresh bamboo shoots has been reported and some of them include chopping of tender shoots into small pieces, partial drying of fresh shoots, boiling in water/salt water and draining or keeping shoots in hot water for 10 - 15 min or in water for a week at ambient temperature, etc.

Adi women of Arunachal Pradesh used banana leaves for semi-fermentation of shoots and pressed under stones near water stream for 3 - 4 months to reduce bitterness (Bhardwaj et al., 2005; Bal et al., 2005). Similarly, Bhatt et al., (2007) reported unique traditional processing of bamboo shoot fermentation to reduce the cyanide percentage. Ferreira, (1995) reported the optimum cooking conditions that resulted in 97% reduction of HCN were 98 - 102°C for 148 - 180 min. Subsequently, Tripathi (1998) mentioned that removal of HCN can be done by steaming bamboo shoot. Bhargava et al., (1996) reported removal of this during cooking shoots by changing water several times or by pre-soaking for a long time by subsequent changing 2% salt solution. Wongsakpairod (2000) reported superheated steam drying under low temperature removes HCN from bamboo shoot as Taxiphyllum decomposes at around 116°C.

**Conclusion**

In spite of the fact that, bamboo shoot has been an integral part of diet of the tribal community, scientific validation of traditional processing methods in terms of food quality and safety has not been attempted. The integration of traditional processes after scientific validation would go a long way in developing a suitable system for storage and preservation of this perishable commodity for rural entrepreneurship. Also, processing techniques to take care of the food safety aspect would enhance the export potential of this wonderful product. In this context, efficacy of discarded toxic extract as bio-pesticide needs to be explored. The use of hybrid technologies, such as solar-assisted heat pump dryer, solar dryer with thermal energy storage, microwave assisted drying may be more cost effective to get the desired quality products.

**Acknowledgement**

The authors are thankful to the University Grants Commissions (UGC), New Delhi for providing financial support to carry out the research work.

**Table 1:** Chemical analysis of commonly edible bamboo shoots (NMBA, India)

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>B. balcooa</th>
<th>B. polymorpha</th>
<th>M. bambusoides</th>
<th>D. strictus</th>
<th>D. hamiltonii</th>
<th>D. Giganteus</th>
<th>B. pallida</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (%)</td>
<td>91.65</td>
<td>91.65</td>
<td>91.22</td>
<td>85.98</td>
<td>92.37</td>
<td>91.19</td>
<td>92.29</td>
</tr>
<tr>
<td>Minerals (%)</td>
<td>0.99</td>
<td>0.99</td>
<td>0.98</td>
<td>1.14</td>
<td>1.01</td>
<td>0.89</td>
<td>1.12</td>
</tr>
<tr>
<td>Phosphorus (mg/100g)</td>
<td>30.99</td>
<td>15.06</td>
<td>14.28</td>
<td>58.13</td>
<td>27.76</td>
<td>12.57</td>
<td>32.27</td>
</tr>
<tr>
<td>Calcium (mg/100g)</td>
<td>24.01</td>
<td>180.69</td>
<td>47.58</td>
<td>139.5</td>
<td>44.16</td>
<td>26.93</td>
<td>21.17</td>
</tr>
<tr>
<td>Iron (mg/100g)</td>
<td>1.02</td>
<td>1.53</td>
<td>0.879</td>
<td>2.917</td>
<td>1.65</td>
<td>1.06</td>
<td>1.11</td>
</tr>
<tr>
<td>Hydrocyanic acid (%)</td>
<td>0.071</td>
<td>0.032</td>
<td>0.056</td>
<td>0.13</td>
<td>0.070</td>
<td>0.044</td>
<td>0.106</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>2.74</td>
<td>2.10</td>
<td>3.29</td>
<td>1.98</td>
<td>2.60</td>
<td>2.59</td>
<td>2.31</td>
</tr>
<tr>
<td>Niacin (mg/100g)</td>
<td>1.40</td>
<td>2.60</td>
<td>6.70</td>
<td>2.10</td>
<td>2.60</td>
<td>6.40</td>
<td>1.40</td>
</tr>
<tr>
<td>Carbohydrates (%)</td>
<td>3.90</td>
<td>4.86</td>
<td>3.93</td>
<td>9.94</td>
<td>4.00</td>
<td>4.78</td>
<td>3.83</td>
</tr>
</tbody>
</table>
Table 2. Nutrient analysis of processed bamboo shoots (Choudhury, Sahu and Sharma, 2010)

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Quantity per 100g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dietary fibers 1.5 g</td>
<td>1.5 g</td>
</tr>
<tr>
<td>Lignin 46 mg</td>
<td>46 mg</td>
</tr>
<tr>
<td><strong>Proteins</strong></td>
<td></td>
</tr>
<tr>
<td>Animal protein</td>
<td>2145 mg</td>
</tr>
<tr>
<td>Plant Proteins</td>
<td></td>
</tr>
<tr>
<td><strong>Amino acid</strong></td>
<td></td>
</tr>
<tr>
<td>Essential amino acids</td>
<td>751 mg</td>
</tr>
<tr>
<td>Non-essential amino acids</td>
<td>1008 mg</td>
</tr>
<tr>
<td><strong>Carbohydrates</strong></td>
<td></td>
</tr>
<tr>
<td>Cellulose</td>
<td>0.85 g</td>
</tr>
<tr>
<td>Monosaccharide</td>
<td>307 mg</td>
</tr>
<tr>
<td>Polysaccharides</td>
<td>288 mg</td>
</tr>
<tr>
<td><strong>Fatty acids</strong></td>
<td></td>
</tr>
<tr>
<td>Saturated fatty acids</td>
<td>0.05 g</td>
</tr>
<tr>
<td>Monounsaturated fatty acids</td>
<td>0.007 g</td>
</tr>
<tr>
<td>Polyunsaturated fatty acids</td>
<td>0.12 g</td>
</tr>
<tr>
<td>Short chain fatty acids</td>
<td>0 mg</td>
</tr>
<tr>
<td>Long chain fatty acids</td>
<td>181 mg</td>
</tr>
<tr>
<td><strong>Minerals and trace elements</strong></td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>268 mg</td>
</tr>
</tbody>
</table>

Table 3. Detailed HCN content of commonly edible bamboo shoot species

<table>
<thead>
<tr>
<th>Species</th>
<th>Region of the shoot</th>
<th>Concentration of HCN in edible parts of the shoot (mg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Dendrocalamus hamiltonii</em></td>
<td>Tip</td>
<td>2.42</td>
</tr>
<tr>
<td></td>
<td>Middle portion</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>Base</td>
<td>0.15</td>
</tr>
<tr>
<td><em>Bambusa pallid</em></td>
<td>Tip</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>Middle portion</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>Base</td>
<td>0.13</td>
</tr>
<tr>
<td><em>B. tulda</em></td>
<td>Tip</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>Middle portion</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>Base</td>
<td>0.28</td>
</tr>
<tr>
<td><em>B. balcooa</em></td>
<td>Tip</td>
<td>2.15</td>
</tr>
<tr>
<td></td>
<td>Middle portion</td>
<td>1.38</td>
</tr>
<tr>
<td></td>
<td>Base</td>
<td>0.62</td>
</tr>
<tr>
<td><em>Melocanna bambusoides</em></td>
<td>Tip</td>
<td>1.81</td>
</tr>
<tr>
<td></td>
<td>Middle portion</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>Base</td>
<td>0.35</td>
</tr>
</tbody>
</table>
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Bamboo shoot based fermented food products: a review

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Received 22 September 2010; revised 11 January 2011; accepted 17 January 2011

This paper reviews fermented bamboo shoots as a brilliant fixing to numerous delicious dishes, of not only the Indian sub-continent but also China, Thailand, Nepal and Bhutan. Low in calorie and high in carbohydrate, proteins and minerals, bamboo shoots are consumed in raw, canned, boiled, fermented, and stir fried forms. It is anticipated that process optimization with further validation will help to grow an independent bamboo shoot based food industry.

**Keywords:** Fermented bamboo shoots, LAB, Lactofermentation, Quality control

**Introduction**

Bamboo shoots (BSs) are consumed as cooked, dried, fermented, pickled, and in shredded form. At present, over two million t (tonnes) of BSs are consumed worldwide every year, mostly in Asian countries\textsuperscript{1}. Every year USA imports 30000 t of canned BSs as food items\textsuperscript{2} from Taiwan, Thailand and China. With *Dendrocalamus asper* as the most important species for shoot production in Thailand and with *D. lactiferous* and *B. oldhami* as the most important edible species of Taiwan, the later consumes 80000 t of BSs annually constituting a value of Rs 2.312 billion with 30000 ha of land of BSs under cultivation, producing 380000 t/y\textsuperscript{3}. In India, BSs are harvested annually in Sikkim (26.2 t), Meghalaya (435 t) and Mizoram (426.8 t). Around 20-30 million t of BSs are utilized for annual production of canned BSs\textsuperscript{4}. About 5% of growing stock of bamboo resource in India is only available in Nagaland\textsuperscript{5} from 448000 ha of land. Consumption of BSs is as follows: Asian countries\textsuperscript{6}, 2 million; Taiwan\textsuperscript{4}, 80000; USA\textsuperscript{2}, 44000; China\textsuperscript{7}, 1.7 million; Australia\textsuperscript{8}, 8000; Mizoram\textsuperscript{9} (NE India), 433; Arunachal Pradesh\textsuperscript{10} (NE India), 1979; and Meghalaya\textsuperscript{11} (NE India), 2188 t/y. This paper reviews bamboo shoot based fermented food products.

**Bamboo shoots (BSs)**

BSs are tender bamboo plants\textsuperscript{12} (20-30 cm long, narrow to a point, wt. > 1 kg); size and weight depend considerably upon location, depth and nutrition of soil, watering and drainage conditions, rainfall, temperature and soil fertility. Depending upon indication of tips budding from soil, edible BSs are harvested just at the point of attachment of rhizome. BSs are low in fats and cholesterol, but very high in potassium, carbohydrates and dietary fibers. Many nutritious and active materials (vitamins and amino acids) and anti-oxidants (flavones, phenols and steroids) can be extracted from BSs. Essential qualities along with dietary and therapeutic traits of different BS species have been systematically analyzed, compared, and reported\textsuperscript{13-16} (Table 1). BSs contain cyanogenic glycoside, taxiphyllin [2-(P-D-glucopyranosyloxy)-2-(4-hydroxyphenyl) acetonitrile] and are, therefore, bitter and need to be leached or boiled (8-10 min) before consumption\textsuperscript{17}. Though incomplete cooking results in glycoside hydrolysis and higher release of HCN content; total amount of HCN in shoots can be eliminated/ detoxified by boiling/ cooking for 2 h\textsuperscript{18}. Methods practiced by indigenous tribes for removal of bitterness from BSs have been elaborately explained\textsuperscript{19}.

**Processing Strategies of Bamboo Shoots (BSs)**

Pickling with salt is a familiar practice and it generates most shelf-stable and organoleptically sound foods. Because of its conceited taste and flavor, BS pickles are most accepted; processing of BS pickles starts with washing, cleaning, slicing and trimming of shoots, followed by boiling for 10-15 min and subsequently storing in a glass / bamboo container in 5% brine with a suitable starter culture. Container mouth is then tightly stuck and left under anaerobic condition for a determined period.
Bamboo shoot: Microbiology, Biochemistry and Technology of fermentation - a review

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Received 17.05.2010: revised 13.07.2010

Dried-fermented, canned bamboo shoots and fermented-sliced bamboo shoots form a customary grace of different cookeries of the South-East Asian countries. Bamboo shoots are high moisture product, low in fat, cholesterol and high in carbohydrates and dietary fibers. Many nutrients and active materials can be extracted from them. Hence, bamboo shoots are more valuable in pharmaceutical and food processing industries, and can be processed into different beverages, medicines, additives and health foods. The production of bamboo shoots is however, very seasonal and processing of bamboo shoots into various fermented products is too rudimentary, unorganized, non-standardized, region specific and lacks quality control over the final products. There is hardly any product that has created their way into the national and international markets, which is due to the lack of technological advancement in the field of bamboo shoot processing. In this article, the quality attributes of bamboo shoot, its biochemistry and microbiology with note on various traditional fermented food items has been well documented. It is expected that, further study on these aspects help to promote establishment of a bamboo shoot based processing units and will boost the socio-economic and cultural status of the people, along with preservation of the diverse dietary cultures of various ethnic tribes of the country.

Keywords: Bamboo shoots, Canned bamboo shoots, Fermentation, Bamboo shoot bitterness, Hydrogen cyanine

IPC Int. Cl.5: C12, C12P, C12N, A21, A23

Bamboo shoots are cured as food items after harvesting. Bamboo shoots form a traditional delicacy of many countries like China, Japan, US, North East India, Thailand, Nepal, Bhutan, Korea, Australia, New Zealand, Malaysia and Indonesia. The freshly harvested shoot is cream yellow in color, has a strong smell and tastes sweet, if eaten on the day of harvest. However, all species of bamboo shoots available worldwide are not edible. The utilization pattern of the bamboo shoot in most of the countries indicates that it is consumed in the forms of raw, dried, canned, boiled, fermented or medicinal, which is traditional, non-standardized, unorganized and region-specific with little value addition. Bamboo shoots are seasonal, perishable, short-lived and unpreserved. At the same time, they are becoming one of the preferred food items among the people all over the world; thus, implying that there is a need to explore a well organized bamboo shoot processing venture making them available all throughout the year.

Bamboo shoots

Bamboo shoots are the young, edible bamboo plants that have just emerged from the ground. Bamboo shoots are generally 20-30 cm long, tapering at one end and weigh almost to a pound. The shooting period of bamboo varies from species to species; their size and weight depending noticeably on location, depth and nutrition of the soil, watering and drainage conditions, temperature, pH and soil fertility. Broadly, the temperate climate bamboos are runners, which shoot in the spring, while the tropical and sub-tropical varieties are clumpers, which shoot in the late summer and fall. Growing of their own, no transparent above ground growth is noticed in the first few budding years and then in one brief season they are seen to burst out with growth. It is during this period that, the plant puts its utmost energy into the root system, and in the following summer and fall, the species manufactures and stores sugars in their rhizomes that produce the roots, insist on top growth, and bear new rhizomes. If allowed to grow well above the surface, they become tough and woody and lose their
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NATIONAL PATENT PROTECTION SCHEME

APPLICATION FORM FOR FINANCIAL ASSISTANCE FOR PATENTING IN INDIA

1. Title of Invention: A Process for Production of Bamboo Shoot based Nuggets

2. Particulars of Inventors

<table>
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<tr>
<th>Sl. No</th>
<th>Name (with initial expanded)</th>
<th>Qualification</th>
<th>Designation</th>
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<tr>
<td>1</td>
<td>JATINDRA KUMAR SAHU</td>
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<td>ASSOCIATE PROFESSOR</td>
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<td>DEBANGANA CHAUDHURY</td>
<td>M01</td>
<td>DOCTORAL FELLOW</td>
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<tr>
<td>3</td>
<td>GAURI DUTT SHARMA</td>
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</tbody>
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3. Corresponding Inventor’s Name and Address

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<tbody>
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5. Status of Development: Lab Scale (LS). The invention has been fully developed in the laboratory.
16. Details of processing fee

Draft No. Date: Bank: Amount:
“283291” 16/01/2013 State Bank of India 500/-

17. Undertaking and Signature of all the Inventors with date

Undertaking

In pursuance to the rules and regulations of National Patent Protection Scheme of NRDC, We hereby declare and undertake that:

1. The above information is true to the best of our knowledge and belief.
2. We have secured Financial Assistance from funding agency for the development.
3. If the information provided in the application or later on during prosecution of patent application is found to be incorrect or the application is abandoned by not providing clarifications to the queries raised at any stage before the grant of the patent, NRDC has the right to recover all the expenditure incurred on this application.
4. We will pay patent annuity, which becomes due at the time of grant and subsequently maintain it at our own cost.
5. We have gone through the rules and regulations of the Scheme and will abide by them.
6. We hereby further undertake to indemnify NRDC against any claim for breach of intellectual property rights of third party by our patentable technology or the product developed under the patentable technology.

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<th>Sl #</th>
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<td>1.</td>
<td>JATINDRA KUMAR SAHU</td>
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From: BKSahu <bksahu@nrdc.in>
Date: Mon, Mar 25, 2013 at 12:23 PM
To: "Dr. J. K. Sahu" <pjksahu@gmail.com>
Cc: Nagrur Lakshminarayan <lnarayan@nrdc.in>

Dear Dr Sahu,

This is to acknowledge the receipt of your above-mentioned proposal for patent application for FA sent to us for filing in India. Your application for FA "A process for the production of bamboo shoot based nuggets" will be evaluated and we will inform accordingly after the approval of Competent Authority.

Please quote No.XXX/XX/XXXXX- X/XXXX in your future communication. If you have any query in this context, please feel to contact me at any time over either phone 011-29240401-08 (Extn.225) bmail:bksahu@nrdc.in.

Thanking you,

Yours faithfully,

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