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Bamboo shoot based fermented food products: a review

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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 world over every year, mostly in Asian countries[1]. Every year USA imports 30000 t of canned BSs as food items[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[3,4]. 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[6-7]. About 5% of growing stock of bamboo resource in India is only available in Nagaland[8] from 448000 ha of land. Consumption of BSs is as follows: Asian countries[1], 2 million; Taiwan[4], 80000; USA[2], 44000; China[6], 1.7 million; Australia[9], 8000; Mizoram[10] (NE India), 433; Arunachal Pradesh[10] (NE India), 1979; and Meghalaya[10] (NE India), 2188 t/y. This paper reviews bamboo shoot based fermented food products.

Bamboo shoots (BSs)

BSs are tender bamboo plants[11] (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[12-16] (Table 1). BSs contain cyanogenic glycoside, taxiphyllin [2-(β-D-glucopyranosyloxy)-2-(4-hydroxyphenyl) acetonitrile] and are, therefore, bitter and need to be leached or boiled (8-10 min) before consumption[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[18]. Methods practiced by indigenous tribes for removal of bitterness from BSs have been elaborately explained[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

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Table 1—Nutritional analysis of some important edible raw bamboo species[8]

Nutrients	*Bambusa balcooa*	*Bambus polymorpha*	*Melocanna bambusoides*	*Dendrocalamus Strictus*	*Dendrocalamus hamiltonii*	*Dendrocalamus giganteus*	*Bamusa pallida*
Water, %	91.65	91.65	91.22	85.98	92.37	91.19	92.29
Minerals, %	0.99	0.91	0.98	1.14	1.01	0.89	1.12
Phosphorus, mg/100g	30.99	15.06	14.28	58.13	27.76	12.57	32.27
Calcium, mg/100g	24.01	180.69	47.58	139.5	44.16	26.93	21.17
Iron, mg/100g	1.02	1.53	0.879	2.917	1.65	1.06	1.11
Protein, %	2.74	2.10	3.29	1.98	2.60	2.59	2.31
Carbohydrates, %	3.90	4.86	3.93	9.94	4.00	4.78	3.83

Table 2—Detailed nutrient component comparison of fermented shoots and fresh shoots of *D. giganteus*[16]

Nutrients	Fermented shoots g/100g	Fresh shoots g/100g
Dietary fibers		
Cellulose	1.882	1.589
Lignin	1.398	0.560
Hemicelluloses	0.900	0.495
Proteins	2.170	3.108
Amino Acids	2.005	3.863
Carbohydrates	1.504	5.103
Starch	0.455	0.506
Fats	0.315	0.387
Minerals and trace elements		
Sodium	3.620	8.220
Potassium	2.70	2.88
Calcium	3.644	6.802
Copper	0.420	0.560
Iron	2.122	2.433
Zinc	0.540	1.086
Manganese	0.340	0.342
Others		
Vitamin C	1.090	3.280

of time, depending upon the product desired. Shelf-life of obtained product is about one year with no crash of colour, flavour and texture. Pieces are used as pickles or just additives to pre-cooked curries and juice can be used for flavouring vegetables[20,21]. Pickled pieces may however, also be dried, grinded and nutrient-fortified to form powders to be used as flavouring and texturising agents in soups, curries, chutneys and bread dough. This powder can be further processed to form nuggets and ready-to-eat snacks. Following boiling and brining, pieces can be drained and canned after heating to a 100-120°C, cooled and marketed. Sun-drying is still another choice of preserving and processing BS pieces. Nutrient analysis of processed BSs[22] is as follows: protein 2.4%, fat 0.18%, dietary fibres 1.5%, Na 268 mg/100 g, K 228 mg/100 g, uric acid 25 mg/100 g, and calorie 14 Kcal/100 g.

Fermentation as a Definite Strategy for Processing Bamboo Shoots (BSs)

Ethnic people living in sub-Himalayan regions, Nepal and Bhutan consume varieties of domesticated and wild BS fermented products[23,24]. For hot and mouth-watering BS pickle or chutney, shoots are grated and minced finely and left for a few days for fermentation, squeezed hard and sautéed in a pan with different spices until total mass turns brown, then appropriate amount of sugar is added and cooled at room temperature and stored under refrigeration. However, fermentation length depends on native communities / tribes as well as the product desired. In spite of decrease of some constituents in fermented shoots, compared to fresh shoots, an increase[16] was observed (Table 2) in fiber content (4.18%, fresh wt) and cellulose content (1.8% fresh wt in fermented shoots, 1.589% in fresh shoots). Antimicrobial activity of fermented BS is also highly appreciative[25,26].

Conventional Fermented BS Food Items

There are various ways of preparing BS items. In Indonesia, bamboo shoots are added with thick coconut milk and spice to make *gulei rebung* or mixed with other vegetables to prepare *sayur ladeh* or fried and mixed with other vegetables to make *lun-pia*[27] (Table 3). In Phillipinese, cuisines are called *labong* and are taken with coconut milk and chillies *Ginataang Labong*[28]. In Nepal, BSs are fermented with turmeric and oil and cooked with potatoes to prepare an item called *alu tama*. In Bhutanese cuisine, a millet beer (*Tchang*) is served in bamboo mugs to preserve its flavor. *Tama*, a non-fermented bamboo shoot curry, is very familiar in Sikkim and this unique and classic Sikkimese curry is made from some varieties of young BSs commonly grown in Sikkim Himalayas. In certain other parts of the country, BSs are taken as fries, cooked with oil and spices in open pans. Different BS pickled foods consumed by different tribes of India has been reported[19]. Though, carbohydrate

Table 3—Traditional bamboo shoot items of different countries

Country	Items
Indonesia[6]	*Gulei rebung, Sayur ladeh*
Thailand[28,29]	*Naw-mai-dong, naw-mai-dorng*
Vietnam[30]	*Used as vegetables, in stir-fry dishes*
Philippines[28]	*Labong, Ginataang Labong, Dinengdeng na Labong*
Nepal and Bhutan[23,24,27,31,32]	*Alu-tama, Tchang, Mesu*
India[10,24,27,32]	*Khorisa-tenga, Ushoi, Soibum, Soidon, Iromba, Ekung, Hiring. Kardi, Amil, Hendua*

(in *Dendrocalamus giganteus*)[16], fat[15] and protein content[15,16] of BSs decrease after canning and fermentation, but after fortification these can be alternated for rich nutritional substitutes.

Lactic Acid Bacteria (LAB) in Fermented Bamboo Shoots

Fermented BS product (*naw-mai-dong*) of Thailand contained *Lactobacilli, Leuconostocs* and *Pediococci*[28,29]. Fermented bamboo shoot products of Manipur (NE India) are reported[30]. Lactic acid produced by LABs during fermentation improves microbiological stability and imparts probiotic characteristics to respective food. A total of 327 strains of LAB representing *L. plantarum, L. brevis* and *P. pentosaceus* were isolated from samples of BS pickle (*mesu*). *Mesu* is dominated by *L. plantarum* followed by *L. brevis,* with *P. pentosaceus* isolated less frequently and recovered from only 40-50% of *mesu* samples[31]. Predominant lactic acid bacteria, isolated from traditional fermented vegetable products of Eastern Himalayas, have been reported[32]. LAB has a wide number of commercial applications in food industry with each fermented product being associated with unique groups of microflora that increase level of proteins, vitamins, essential amino acids and fatty acids[33-35]. Fermentation of BSs produces 29 aroma-active compounds of total 70 volatile compounds[36]. *B. subtilis, B. licheniformis, B. coagulans* and *M. luteus* from '*soibum exudates*' is involved in microbial bioconversion of phytosterol during fermentation of succulent shoots[10]. At the same time, unwanted bacterial species (*Bacillus cereus*, *B. subtilis*, *B. pumilus, Carnobacterium* sp., *Enterococcus faecium* and *Pseudomonas fluorescens*) in non-salted *soidon* contaminates lacto-fermentation, with *B. cereus* posing a risk to biosafety of pickle[37]. Degradation of sensory quality of fermented BS pickles, due to production of surface film yeast, has been studied[38]. Biochemical characterization of LAB obtained from other pickled vegetables was carried out[39]. Chemical changes and sensory attributes of *soibum* during fermentation were studied[10,40-42].

Quality Maintenance: Challenge to Food Technologists

BSs, after harvest, are usually stored at normal temperature or under refrigeration at 8°C and sold unpackaged into local markets, but processing of the same is seen to impact quality parameters of end-product. To control physical and sensory qualities, processed shoots should be packed at low temperature to prevent excessive moisture loss[43] and maintain a decreased respiration rate (< 4.08 mmol CO_2 $kg^{-1}h^{-1}$ at 20°C)[44]. Respiration rate of *P. pubescens* was shown to increase initially, after cutting, but gradually decreased during storage at 4°C[45]. Effect of vacuum and hydro cooling followed by vacuum drying boosts shelf life and protects freshness value of shoots[46]. Effect of fungicide on polythene film packed BS increased their shelf life to 62 days at 0°C[47]. Discoloration due to standing[48] and microbial deterioration on post harvest storage of BSs was shown[49]. Processing did not influence non-protein nitrogen and crude fiber content of BSs, but carbohydrate content was increased[15]. Various conditions for removal of HCN has also been defined; optimum cooking conditions critical for removal of initial HCN yield (97% removal) at 98-102°C for 148 -180 min[14,50].

Conclusions

BSs are amenable to easy processing technologies to generate high value added products, but due to need of proper research, it is being implausible to ensure ecological and economic security through establishment of a BS based food industry. Preferred species for BS plantations are *Dendrocalamus asper*, *Bambusa balcooa* and *Dendrocalamus hamiltonii*. Attempts being directed in engaging neighborhood population in cultivating, harvesting and processing of BSs for production of BS based value-added food products along

with development of rural sector. Therefore, focus may be directed for following aspects for sustainable development of a bamboo shoot-based food industry: i) Identification and selection of most suitable edible species; ii) Recommendation of proper package of practice for bamboo cultivation; iii) Appropriate fermentation technology of edible bamboo shoots; iv) Groove management procedures (plantation, maintenance, and harvesting); v) Materials processing (grading, cleaning, and drying); vi) Product manufacturing (equipments, foods, jigs, dyes, paints, varnishes); and vii) Marketing (customer identification, distribution, advertisements).

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