QUALITY EVALUATION AND VALUE ADDITION OF EDIBLE BAMBOO SHOOTS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Quality evaluation and value addition of edible bamboo shoots"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Certified that this thesis, entitled **"Quality evaluation and value addition of edible bamboo shoots"** is a record of research work done independently by **Miss. Mittu Mathew,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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CONTENTS

LIST OF TABLE

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

INTRODUCTION

1. INTRODUCTION

Bamboo is not merely a poor man's timber but is also the rich man's delicacy. It is one of the fastest growing commercial plants, which makes it ideally suited for promotion as a food crop for domestic consumption as well as for export. The use of edible tender bamboo in Indian recipes has been confined to North- East, Chattisgarh and Orissa. Fresh, fermented and roasted tender bamboo shoots are considered culinary treats. They are consumed as vegetables, pickles, salads and in various forms in several countries (Christine and Wetterwald, 1992).

India is next to China and Japan in its diversity of bamboo species. According to SWBC (2004) in India, there are about 136 bamboo species distributed in 75 genera, 25 species among these are edible types and are consumed by tribal communities. The study estimated that 10.3 million hectares or 12.8 per cent of the country's total forest cover is under bamboo plantations. Currently, China and Taiwan are the main exporters of bamboo shoots. There is perceptible untapped demand for bamboo shoots in countries like Japan, Thailand, Denmark, Philippines, Malaysia, Singapore and Australia. The tribal economy revolves generally around bamboo because of its multifarious uses for food, shelter, furniture, handicrafts, medicines and for various religious purposes.

Bamboo shoots are excellent vegetable food and find place in culinary delicacies in many countries. They are crisp, tender and delicious. They contain about 90 per cent water, low fat and calories but good in fibre and a rich source of phytosterol. It is also reported that bamboo shoots have cancer prevention properties. The regular use of bamboo shoots as food is known to prevent many physiological disorders and diseases. The high cellulosic content of bamboo shoot stimulates appetite and prevents constipation. The fresh bamboo shoots provide resistance against cough, phlegm, fever and sore throat. It is also found to be effective in decreasing blood pressure and cholesterol (Shi, 1990).

In Kerala, it is mostly the tribal communities who utilize bamboo shoots. Though usage of bamboo shoot in urban areas, especially in Chinese food is gaining popularity, all the demand is met through canned products from North Eastern states. However, bamboo shoot farming has immense potential in the rural sectors of Kerala. This can provide job opportunities and additional income to women. There is a high demand for bamboo shoots in international market, so promising edible species should be introduced in forest plantations and in agro forestry to boost farm income (Kumar, 2009).

Since edible bamboos in India have great potential to contribute to the rural economy and boost export earnings, an attempt has been made to evaluate the quality of edible bamboo shoots of four bamboo species and to develop acceptable value added products. Hence, the present study entitled "Quality evaluation and value addition of edible bamboo shoots" has been undertaken with the following objectives:

1. To evaluate the biochemical constituents of selected edible species of fresh and processed bamboo shoots.
2. To develop value added products.
3. To evaluate the quality attributes of developed products.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The literature pertaining to the study entitled "Quality evaluation and value addition of edible bamboo shoots" is presented under the following sub headings.

2.1 Potential of edible bamboo shoots
2.2 Chemical constituents of bamboo shoots
    2.2.1 Moisture
    2.2.2 Protein and total free amino acids
    2.2.3 Carbohydrates
    2.2.4 Vitamins and minerals
    2.2.5 Anti nutritional factors
2.3 Effect of processing on the quality of bamboo shoots
2.4 Health benefits of bamboo shoots
2.5 Value added products from bamboo shoots

2.1 Potential of edible bamboo shoots

India accounts for about half the total bamboo areas of the world and about 100 species are indigenous belonging to 20 genera (Sharma, 1980). Vermah and Bahadur (1980) indicated bamboo as a valuable gift to India, extending an area of about 10 million hectres and about 72.8 per cent of the total forest area of the world.

According to Mauriya and Arora (1988) the north eastern region of India had 50 per cent of the bamboo species with greater genetic diversity in *Arundinaria, Bambusa, Cephalostachyum and Dendrocalamus* species. Joshi *et al.* (1994) indicated *Dendrocalamus strictus* as the principle economic species in India occupying over 53 per cent of the total area under bamboo cultivation.

About 136 bamboo species distributed in 75 genera were reported to be in India and among these, 25 species are considered as edible types consumed by tribal communities (SWBC, 2004). Sankaran *et al*. (2007) indicated that 125 bamboo species belonging to 23 genera are available in India and seventy seven species belonging to 19 genera are distributed in north eastern states. The authors also reported that about 60 percentage of total forest area in Tripura was occupied by bamboo and out of 11 species grown in the state, *Melacona bambusaides* was commonly used for vegetable purpose.

Accoording to Dutt (2007) India has the largest bamboo forest in world, and two-third are in the north eastern states. The author also indicated that bamboo occupies 8.96 million hectres forest areas in India which accounted 12.8 per cent of the total forest area and observed a huge potential of bamboo for the welfare of the country.

Bhatt *et al*. (2003) indicated that apart from household level consumption, about 980 tonnes of bamboo shoot per year is consumed through market places in Meghalaya, Mizoram and Sikkim states. Singh *et al.* (2003) indicated $45 million as the annual income from edible shoots in Manipur.

Twenty eight species and two varieties of bamboo belonging to six genera were recorded as natives of Kerala by Sreekumar (2007) which included genera like *Bambusa, Dendrocalamus, Pseudoxytenanthera, Schizostachyum, Sinarundinaria* and *Ochlandra*. The author also indicated that *Bambusa bambos* is the species distributed throughout Kerala at an elevation between 50 - 1000 meters and *D. strictus* is distributed in the forests of Attapady, Nilambur, and Chinnar at an altitude of 150-750 meters above sea level.

The edible bamboo shoot production per hectre was estimated to be 10-20 tonnes in Japan (Suzuki and Ordinario, 1977), about 10 tonnes in Korea and 15-30 tonnes in China (Hedge, 1990). Taiwan was found to be the major producer and exporter of edible shoots in the world followed by the Republic of China and Thailand (Potharam and Panchatri, 1985). Thammincha (1988) indicated well established bamboo farming for edible shoot production in Taiwan, Thailand, China, Japan, Phillippines and Korea. The author also indicated that in Thailand people migrate temporarily to forest areas to harvest bamboo shoots and collect about 50-100 kg shoots per person a day

Phyllostachys reticulate and *P. edullis* are reported to be the main edible bamboos in Japan (Xia, 1989). The author also indicated that about 123000 hectres of bamboo forests mostly managed privately by farmers were set aside for edible shoot production.

China has 3.20 million hectres areas under bamboo and *Phyllostachys pubescens* was reported to be the most valuable and widely planted bamboo constituting 70 per cent of all bamboo plantations (Hegde, 1990).

Two monopodial species like *Phyllostachys dulcius* and *Phyllostachys praecox* were cultivated for tender shoot production in China. (Hedge, 1990)

In Japan one hectre of bamboo plantation managed for edible shoot production provided a returns of US $ 1500-3000 (Francisco *et al.,* 1980) while in China, the annual income from the plantation managed exclusively for bamboo shoots was reported to be above 200,000 Yuan per hectre (Hedge, 1990).

In Japan about 40-50 thousand tonnes of canned tender bamboo shoots were marketed every year constituting 70-80 per cent of the total production (Xia, 1989).

Thammincha (1988) indicated good income and high economic returns through bamboo cultivation. In China, the market price of bamboo shoots during off season has been compared with that of meat and the cash value of bamboo shoot was found to be higher than that of rice (Qiu, 1990 and Tewari, 1993). The expenditure involved in the cultivation of bamboo shoots was reported to be nearly 1/10th to 1/3rd of the returns (Tewari, 1993).

Japan was reported to be the main market for steamed bamboo shoots (Potharam and Panchatri, 1985). Ninety bamboo shoot based industries existed in Zhejiang, provenance of Thailand, a well developed marketing system for bamboo shoots in Thailand was indicated by Thammincha (1988)

In the Asian countries fast expansion in bamboo shoot based food industry has been noticed (Qiu, 1990). Nirmala *et al*. (2007) indicated growing market potential for processed and packaged bamboo shoots, representing an opportunity for the establishment of commercially run processing units

2.2 Chemical constituents of bamboo shoots

2.2.1 Moisture

The moisture content of tender shoots of *Bambusa bambos* was found to be 88.8 per cent (Young, 1954). Resource Bureau Reference data no.34 (1960) indicated a moisture content of 92.5 per cent in *phyllostachys edulis* bamboo shoots. Tamolang *et al.* (1980) reported a moisture content of more than 75 per cent in bamboo shoots while Chaozong (1985) observed moisture content of 90.83 per cent in *Phyllostachys pubscens* bamboo shoots and also indicated an increase in the moisture content of *Phyllostachys pubscens* bamboo shoots with an increase in age.

Bhargava and Kumbhare (1996) indicated moisture content in the range of 19 to 84 per cent in bamboo shoot species like *Bambusa vulgaris, Malocanna bacifera, Bambusa polymorpha, Dendrocalamus longispathus, Bambusa bambos.* According to Qiu *et al.* (1999) the moisture content of *Phyllostachys heteroclada* shoots is about 91 per cent. Das and Puzari (2007) also indicated 90 per cent moisture in bamboo shoots.

2.2.2 Protein and total amino acids

Average protein content of bamboo shoots was found to be 2.6 per cent (Young, 1954) and indicated a protein content of 3.9 per cent in *Bambusa bambos.* The crude protein content of *Phyllostachys edulis* shoot was found to be 2.5 per cent in the fresh matter (Resource Bureau Reference Data no.34, 1960).

Protein content of different bamboo shoots varied from 2.0 to 4.4 per cent. According to, Duke and Atchley (1986), Anon (1988), Xia (1989) and Dransfield and Widjaja (1995) the protein content in the range of 1.26 to 4.79 per cent in bamboo shoots. Shi (1990) observed a high protein content of about 15.23 per cent in Chinese bamboos (*Phyllostachys* spp.). Han and Koo (1993) indicated that bamboo shoot contained 3.05 per cent protein.

The protein content of bamboo shoots like *Bambusa vulgaris, Melocanna baccifera, Bambusa polymorpha, Dendrocalamus longispathus* and *Bambusa bambos* varied from 3.20 to 7.46 per cent (Bhargava and Kumbhare, 1996). Among various bamboo species, the protein content was found to be high in *Dendrocalamus hamiltoni* (Bhatt *et al.,* 2005).

Nirmala *et al.* (2007) showed a protein content of 2.4 per cent in edible bamboo shoots while Sankaran *et al.* (2007) indicated a crude protein content of 14.60 – 27.30 per cent in bamboo shoots. Kumbhare and Bhargava (2007) observed a protein content in the range of 9.6 to 17.2 per cent on fresh weight basis and 19.2 to 25.8 per cent on dry weight basis in bamboo shoots.

Visuphaka (1985) showed high protein content in the soft tissue of bamboo shoots close to apex when compared to the lower parts. Ferreira *et al.* (1992) showed a protein content of 46.1 and 40.4 per cent in the apical and basal portions of *Dendrocalamus gigantenus* shoots.

Chaozong (1985) observed 18 varieties of protein hydrolysate amino acids in *Phyllostachys pubescens* shoots. Qiu (1990), Fitzgerald (2008) and Nirmala *et al.* (2007) indicated variety of different amino acids, including essential amino acids in bamboo shoots.

Kumbhare and Bhargava (2007) reported that the free amino acids content in fresh bamboo shoots ranged from 0.11 to 0.70 per cent equivalent of leucine in species such as *Bambusa nutans, Bambusa vulgaris, Dendrocalamus strictus* and *Dendrocalamus asper*.

Chaozong (1985) indicated a tyrosine content of 4.8 per cent in bamboo shoots ten days after the appearance of sprouts on the ground and also a decrease in the protein and amino acids in *Phyllostachys pubescens* shoots with an increase in age. Bhatt *et al.* (2005) observed a tryptophan content in the range of 0.4 to 1.7 g/16g N and methionine in the range of 0.3 to 0.8 g/16g N in bamboo shoots.

Yuan *et al.* (1999) indicated a high protein and amino acid content in Xiaozhong bamboo shoots than winter bamboo shoots.

2.2.3 Carbohydrates

Young (1954) indicated a mean total digestable carbohydrate content of 4.5 per cent in various species of bamboo shoots. The author also observed 5.7 per cent carbohydrate in the tender shoots of *Bambusa bambos*.

The carbohydrate content of *Phyllostachys edulis* shoots was found to be 3.9 per cent on fresh weight basis (Resource Bureau Reference Data no.34, 1960). While Bhargava and Kumbhare (1996) indicated 2.0 -21.0 per cent carbohydrate in *Bambusa vulgaris, Melocanna baccifera, Bambusa polymorpha, Dendrocalamus longispathus* and *Bambusa bambos.*

According to Bhatt *et al*. (2005) the carbohydrate content of edible bamboo shoot varied between 4.5 and 5.2 per cent. Studies of Kumbhare and Bhargava (2007) indicated carbohydrate content in the range of 2.6 to 3.4 per cent in *Dendrocalamus strictus* and *Bambusa vulgaris* raw shoots. However, Sankaran *et al.* (2007) indicated carbohydrate content in the range of 36.10 to 56.90 per cent.

According to Duke and Atchley (1986) and Dransfied and Widjaja (1995) the fibre content of bamboo shoots ranged from 0.7 to 1.9 per cent. Shi (1990) indicated 6.8 per cent digestable fibre with high cellulose content of about 0.02 to 1.2 per cent in Chinese bamboo *(Phyllostachy* spp.). Qiu *et al.* (1999) observed 0.63 to 0.71 per cent coarse fibre in *Phyllostachys heteroclada* shoots.

Blethen *et al.* (2001) indicated a fibre content of 2.5 per cent in one cup of sliced bamboo shoots which provided about 10 per cent of the recommended dietary allowance per day. According to Bhatt *et al.* (2005) the crude fibre content of edible bamboo shoots ranged between 23.1 and 35.5 per cent. Kumbhare and Bhargava (2007) indicated a crude fibre content of 0.71 to 0.98 per cent in the raw bamboo shoots.

Visuphaka (1985) observed less coarse fibres in the soft tissues of bamboo shoots close to apex when compared to the lower parts. Chen *et al.* (1989) indicated that in shoots of *Bambusa oldhamii* the fibre content increased quickly from the cut end towards the tip. Ferreira *et al.* (1992) observed 0.96 and 0.97 per cent crude fibre on fresh weight basis in the apical and basal portion of *Dendrocalamus giganteus* and 10.1 and 10.3 per cent, respectively on dry weight basis.

Chaozong (1985) indicated a total sugar and soluble content of 13.3 per cent in *Phyllostachys pubescens* shoots which increased to 32.2 per cent during ageing. Total sugar content of bamboo shoot was found to be 2.5 per cent (Nirmala *et al.,* 2007).

Devi and Singh (1986) observed a reducing sugar content of 0.04 per cent in *Melocanna humilis* shoots. Xia (1989) indicated reducing sugar content in the range of 1.65 to 5.67 per cent in bamboo shoots. Kumbhare and Bhargava (2007) indicated a reducing sugar content of 0.72 to 1.14 per cent in fresh shoots of *Dendrocalamus strictus* and *Dendrocalamus asper,* respectively.

The reducing sugar content of *Dendrocalamus giganteus* in the basal and apical portions of the shoots varied from 1.1 to 1.2 per cent on fresh weight basis and 11.9 to 12.8 per cent respectively on dry weight basis (Ferreira *et al.*, 1992).

2.2.4 Vitamins and Minerals

Bamboo shoots were found to be good sources of thiamin and fair sources of niacin (Young, 1954). The author also indicated that *Bambusa bambos* contained 0.08 mg thiamin, 0.19 mg riboflavin, 0.2 mg niacin and 5.0 mg vitamin C per 100 g. Retinol, thiamin and vitamin C content of *Phyllostachys edulis* were found to be 50 I.U, 0.10 mg and 10 mg respectively in 100 g fresh matter (Resource Bureau Reference Data no.34, 1960).

Bhargava and Kumbhare (1996) indicated vitamin C content in the range of 7.5-12.5 mg/100g^{-1} in *Bambusa vulgaris, Melocanna baccifera, Bambusa polymorpha, Dendrocalamus longispathus* and *Bambusa bambos*.

Young (1954) reported 20 mg calcium, 65 mg phosphorous, 32 mg magnesium, 91 mg sodium and 0.19 mg copper in 100g of *Bambusa bambos* shoots. Resource Bureau Referance Data no.34 (1960) indicated 43 mg phosphorus and 7 mg iron in *Phyllostachys edulis* shoots. The iron content of *Phyllostachys pubescens* bamboo shoots was found to be in the range of 0.29 mg to 0.44 mg per 100 g (Chaozong, 1985).

Chen (1990) indicated very high content of iron and zinc in the shoots of *Phyllostachys pubescens* with small amounts of copper, manganese, lead, molybdenum etc. Bhargava and Kumbhare (1996) indicated the presence of sodium (0.02-0.40 mg), potassium (0.24-1.40 mg), calcium (0.32-0.56 mg), magnesium (0.05-0.19 mg) and phosphorus (0.08-0.22 mg) in 100 g of *Bambusa vulgaris, Melocanna baccifera, Bambusa polymorpha, Dendrocalamus longispathus* and *Bambusa bambos*.

Qiu (1990) reported the presence of iron, zinc, manganese, copper, cobalt and nickel in bamboo shoots. Blethen *et al.* (2001) indicated that one cup of bamboo shoots provided 640 mg of potassium, which met 18 per cent of the recommended dietary allowance. Young edible bamboo shoots were also found to be rich in macronutrients, particularly calcium (1.2- 1.9 per cent), potassium (0.02 to 0.03 per cent), phosphorous (0.5 to 1.0 per cent) and magnesium (0.04 to 0.05 per cent) (Bhatt *et al.,* 2005). Sankaran *et al.* (2007) observed a Calcium and Phosphorous content of 0.33 to 0.97 per cent respectively in edible bamboo shoots.

2.2.5 Antinutritional factors

Tewari (1992) reported the presence of cyanogens in *Bambusa bambos, Melocanna baccifera and Dendrocalamus gigantus* with the highest content in *Dendrocalamus gigantus* and lowest in *Bambusa bambos*.

Bhargava and Kumbhare (1996) indicated that bamboo shoots contained cyanogenic glucosides, which on endogenic hydrolysis produced toxic hydrocyanic acid, varying from 0.05 to 0.03 per cent. According to Bhatt *et al*. (2005) the hydrocyanic acid content of bamboo shoots varied from 0.01 to 0.02 per cent.

Chandra *et al.* (2005) indicated that bamboo shoots had highest cyanogenic glucoside and thiocyanate contents followed by cassava, cauliflower, cabbage, radish etc. Shridhar and Narayana (2006) reported the presence of cyanide in bamboo shoot water extract.

Ferreira *et al*. (1990) observed a hydrogen cyanide content of 1000 mg/kg in the apical part of bamboo shoots. WHO (1993) reported about 80000 mg/kg of hydrogen cyanide in the immature shoot tip of bamboo. Where as on an average it was found that *Dendrocalamus giganteus* contained, 894 mg/kg of hydrogen cyanide (Ferreira *et al.,* 1995). Haque and Bradburry (2002) indicated total cyanide content of 1600 ppm at the tip of the bamboo shoots and 110 ppm in the base.

Bhargava and Kumbhare (1996) isolated a toxic constituent namely taxiphyllin from the shoots of *Bambusa guadua, Bambusa vulgaris, Bambusa bambos, Dendrocalamus gigantenus and Dengrocalamus hamiltonii.* The presence of homogentisic acid responsible for the disagreeable pungent taste in bamboo shoots was also reported.

Chandra *et al*. (2005) reported the presence of naturally occurring goitrogenic compounds in bamboo shoots.

The oxalate content of bamboo shoot (*Bambusa* spp.) was found to be more than 150 mg/100g^{-1} (Judprasong *et al.,* 2006)

2.3 Effect of processing on quality of bamboo shoots

Meredith and Dull (1979) indicated a loss of free amino acids through leaching or due to the reaction of amino acids with sugars. A decrease in the protein and free amino acid content of bamboo shoots was also indicated by Kumbhare and Bhargava (2007). An increase in the carbohydrate content and a decrease in the reducing sugar content of bamboo shoots after boiling were reported by Kumbhare and Bhargava (2007). The authors also indicated that the crude fibre content in boiled shoots of *Bambusa nutans, Bambusa vulgaris, Dendracalamus strictus* and *Dendrocalamu asper* varied from 0.70 to 0.97 per cent, which was found to be almost similar to the crude fibre content of raw shoots.

Zhimin (2003) indicated that refining and washing of bamboo shoot did not produce any significant effect on the loss of protein, cellulose and phosphorous but the amino acid content decreased significantly.

A reduction in the browning index in minimally processed and packed bamboo shoot during storage at 4° c with a shelf life of up to 15 days was indicated by

Yaguang *et al*. (2003). The author also observed a shelf life up to 18 days with good appearance in minimally processed bamboo shoots coated with 1.5 per cent chitosan.

Chang and Yen (2006) indicated retention of soluble solids and ascorbic acid with minimum change in colour of the cut surface in *Bambusa oldhamii* shoots packed in poly ethylene bags of 0.06 mm thickness.

Chaozong (1985) indicated loss of vitamin C in iced edible bamboo shoots while Devi and Singh (1986) reported an increase in the vitamin C content from 0.51 to 0.55 mg / $100g^{-1}$ in bamboo shoot which was fermented for five days.

A decrease in the toxic constituents of bamboo shoots was observed by soaking the thin pieces in different changes of salt water of 2 per cent concentration for several hours (Anon, 1988). Cooking bamboo shoots in boiling water in an uncovered pan for 20 minutes decreased the compounds which cause bitterness (Blethen *et al.,* 2001). Judprasong *et al*. (2006) reported a significant decrease in the oxalate content of bamboo shoot (*Bambusa* spp) after cooking by boiling.

The optimum conditions which resulted in the reduction of hydrogen cyanide in bamboo shoots were found to be boiling at 98-102° C for 148-180 minutes. (Food standards Australia New Zealand, 2004)

2.4 Health benefits of bamboo shoots

Shi (1990) indicated that regular use of bamboo shoots as food prevented many physiological disorders and diseases. The author indicated that the high cellulose content of bamboo shoot is effective to stimulate appetite and to prevent constipation and the fresh bamboo shoots provided resistance against cough, phlegm, fever and sore throat.

Fermented bamboo shoots were used as a starting material in the production of steroid drugs (Srivastava, 1999). Kumar (2005) and Das and Puzari (2007) indicated the effectiveness of bamboo shoot in cancer prevention, increasing appetite and lowering blood pressure and cholesterol levels.

The effectiveness of bamboo shoots for treating various ailments like intestinal disorders, promoting healthy body functions like female menstrual cycle, helping in digestion of proteins and promoting stomach functions was reported by Fitzgerald (2008).

Prevention of chronic diseases due to the presence of high levels of dietary fibre, in bamboo shoots was indicated by Daniells (2009). The microorganisms from fermented succulent bamboo shoots were used to obtain a direct precursor of steroidal drug by pharmaceutical industries (Sarangthem and Singh, 2003)

Sarangthem and Srivastava (1997) observed high content of phytosterol in fermented bamboo shoots of *D. hamiltonii* and *D. strictus.* In Ayurveda, the silcious secretion found in the culms of the bamboo stem was found to be useful in curing respiratory diseases (Puri, 2003). The author also indicated that in Indian literature *bambusa bambos* is described as the source of bamboo manna.

2.5 Value added products from bamboo shoots

Bambusa polymorpha shoots were ranked as the best in the world for their tenderness and distinctly sweet flavour when consumed raw (Kennard and Freyre, 1957 and Vivekanandan, 1987)

Tender shoots of *Bambusa bambos*, *Dendrocalamus hamiltonii and D. giganteus* were consumed in a variety of ways like vegetables and in processed forms (Mitra and Nayar, 1972., Janmejay, 1986 and Das, 1988).

Young and tender bamboo shoots were used as daily food by Thai people because of its good taste and low cost (Visuphakha, 1985). Fresh, fermented and roasted bamboo shoots were considered culinary treats and were consumed as vegetables, pickles, salads and in various other forms in several countries (Christine and Wetterwald, 1992).

In Thailand, the young and tender shoots of most of the edible bamboo species were consumed fresh or made into pickles, vegetables and dried forms that were considered as delicacies (Visuphaka, 1985). Joshi *et al.* (1994) indicated the usefulness of bamboo shoots in the preparation of chutney, curry and pickle. The author also indicated that bamboo shoots were preserved by steaming, pickling and drying for future consumption which added a distinct flavour to many dishes. Tender shoots of *B. balcooa* were consumed after cooking and also preserved after fermenting and drying (Bhargava and Kumbhare, 1996)

The succulent shoots of bamboo species were found to be edible and were also used for making pickles (Tewari, 1993). Qilong and Hongxing (2000) also indicated the usefulness of edible bamboo shoots like *Phyllostachys praecox* and *Phyllostachys prominens* in the preparation of pickles which remained fresh and sweet in taste for more than 6 months

In Thailand and Vietnam shoots are finely grated and used in salads, while in Japan shoots are boiled whole for more than two hours and used to prepare soups and in assorted dishes (Food standards Australia New Zealand, 2004)

Bhatt *et al.* (2005) indicated the usefulness of young succulent bamboo shoots as vegetables, pickles, salads etc. by the tribal communities of North Eastern Himalayan region of India. Fitzgerald (2008) indicated the usefulness of bamboo shoots in different recipes like bamboo chutney, beer, candy, vinegar and soup.

Tender bamboo shoots after processing can be used to prepare candies, chutneys and canned products (CFTRI, 1999).

Mgeni (1983) indicated that *Oxytenanthera braunii* the bamboo species cultivated in Tanzania is used for bamboo wine production during rainy season. Bamboo beer rich in bioflavanoids, was reported to be a refreshing healthy beverage, which helped to decrease blood lipid levels when consumed frequently (Zhang *et al*., 2000).

An indigenous fermented food namely *soibum* exclusively produced from succulent bamboo shoots was consumed as an indispensable constituent of diets of Manipur from time immemorial (Kumar, 1997., Srivastava, 1999 and Giri and Janmejay, 2000).

In Orissa, the new sprouts of bamboo culms were converted to small pieces like noodles called Hendua and dried and stored for future use (Nirmala *et al.,* 2007).

Giri and Janmejay (2000) indicated that the bamboo shoots were consumed after cooking with colocasia corms, green peas, pumpkins, potatoes and used in different recipes, especially chutney and consumed as supplementary ingredient by frying with fishes.

Singh *et al.* (2003) indicated that the ethnic foods made from bamboo shoots were consumed by tribal communities of Andhra Pradesh, Mizoram, Nagaland, Tripura, Sikkim, Meghalaya and Manipur.

Han and Koo (1993) reported that bamboo shoot could be used as a flavour material because they contain plenty of free sugars and amino acids which are sweet in taste.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The materials used and the methods followed in the present study are given under the following headings.

3.1 Collection of bamboo shoots
3.2 Processing of bamboo shoots
3.3 Analysis of chemical constituents of fresh and processed bamboo shoots
3.4 Selection of bamboo shoot for product development
3.5 Product development with processed bamboo shoots
3.6 Quality evaluation of products during storage
3.7 Analysis of data

3.1 Collection of bamboo shoots

Four species of edible bamboo shoots namely *Bambusa bambos, Bambusa tulda, Dendrocalamus hamiltonii, Dendrocalamus strictus* were collected with the help from Kerala Forest Research Institute, Peechi, Trichur, Kerala. The shoots were collected at an approximate height less than eighteen inches at its tender stage when it emerges from the soil.

The bamboo shoots collected are shown in plates 1 to 8

3.2 Processing of bamboo shoots

The collected bamboo shoots after cleaning and slicing were dipped in boiling water and cooked for 40 minutes uncovered as recommended by Kumar (2005).

Processing of bamboo shoots is given in plates 9 and 10.

Plate 1. ***Bambusa bambos*** **shoot**

Plate 2. Cleaned shoot of *Bambusa bambos*

Plate 3. ***Bambusa tulda*** **shoot**

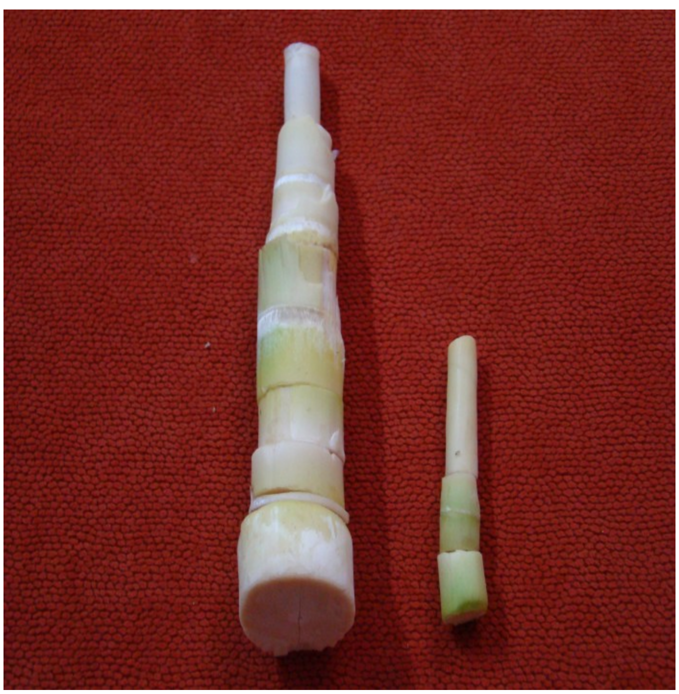

Plate 4. Cleaned shoots of *Bambusa tulda*

Plate 5. ***Dendrocalamus hamiltonii*** **shoot**

Plate 6. Cleaned shoots of ***Dendrocalamus hamiltonii***

Plate 7. ***Dendrocalamus strictus*** **shoot**

Plate 8. Cleaned shoots of Dendrocalamus *strictus*

Plate 9. Bamboo shoot after cleaning and slicing

Plate 10. Processing of bamboo shoot

3.3 Analysis of chemical constituents of fresh and processed bamboo shoots

Fresh and processed bamboo shoots were analysed for the following chemical constituents. Following analyses were carried out in triplicate samples.

3.3.1 Moisture
3.3.2 Total carbohydrates
3.3.3 Crude fibre
3.3.4 Soluble fibre
3.3.5 Protein
3.3.6 Reducing sugar
3.3.7 Vitamin C
3.3.8 Total free amino acids
3.3.9 Calcium
3.3.10 Iron
3.3.11 Potassium
3.3.12 Sodium
3.3.13 Nitrates
3.3.14 Oxalates

3.3.1 Moisture

Moisture content of bamboo shoot was estimated using the method of A.O.A.C (1980). To determine the moisture content 5 g of edible bamboo shoots was taken in a petridish and was dried in a hot air oven at 60° - 70° C, cooled in a dessicator and weighed . The process of heating and cooling was repeated until a constant weight was achieved .The moisture content was calculated from the loss in weight during drying and expressed in percentage.

3.3.2 Total carbohydrates

The total carbohydrate content was analysed colourimetrically using anthrone reagent as suggested by Sadasivam and Manickam (1992). The dried and powdered sample was hydrolysed by keeping in a boiling water bath with 5 ml of 2.5 N HCl, cooled and neutralized with sodium carbonate until the effervescence ceases. The volume was made up to 100 ml with distilled water and centrifuged. 0.5 ml of supernatant was taken and made up to 1 ml with distilled water and 4 ml of anthrone reagent was added and heated for eight minutes, cooled rapidly and the intensity of green to dark green colour was read at 630 nm. A standard graph was prepared using serial dilution of standard glucose solution. From the standard graph the amount of total carbohydrate present in the sample was estimated and expressed in percentage of fresh sample.

3.3.3 Crude fibre

The fibre content was estimated by acid alkali method as suggested by Chopra and Kanwar (1978). One gram of dried and powdered sample was boiled with 200 ml of 1.25 per cent sulfuric acid for thirty minutes. It was filtered through a muslin cloth and washed with boiling water. The residue was again boiled with 200 ml of 1.25 per cent sodium hydroxide for thirty minutes. Repeated the filtration through the muslin cloth and washed with 1.25 per cent sulphuric acid, water and alcohol. The residue was transferred to a preweighed ashing dish, dried, cooled and weighed. The residue was then ignited in a muffle furnace at 600°c for 30 minutes, cooled in a dessicator and weighed. The crude fibre content of the sample was calculated from the loss in weight on ignition and expressed in percentage on fresh weight basis.

3.3.4 Soluble fibre

The soluble fibre content in the sample was estimated by the method suggested by Raghuramulu *et al*. (2003). To one gram of the sample, 50 ml of phosphate buffer and 0.1 ml heat stable α- amylase solution were added and boiled in a water bath at 100° C for 15 minutes. The pH was adjusted to 7.5 and 0.1 ml protease solution was added, and incubated for 30 minutes at 60°C. The digestion was carried out by adding 0.3 ml amyloglucosidase, and incubated for 30 min at 60° C with continuous agitation. The filtrate was collected and 4 volumes of pre-heated 95 per cent ethanol was added and kept for 60 minutes for complete precipitation. The precipitate was transferred into a pre weighed crucible, dried and weighed. Percentage of soluble fibre was found out and was converted to fresh weight basis.

3.3.5 Protein

The protein content was estimated using the method of A.O.A.C (1980).The sample (0.3 g) was digested by adding 0.4g of $CuSo_4$, 3.5g K_2So_4 and 6 ml Con. H_2SO_4 until the colour of the sample was changed to green. After digestion, it was diluted with water and 25 ml of 40 per cent NaOH was pumped. The distillate was collected in 2 per cent boric acid containing mixed indicators and then titrated with 0.2 N HCl. The nitrogen content obtained was multiplied with a factor of 6.25 to get the crude protein content and expressed in percentage of fresh sample.

3.3.6 Reducing Sugar

The content of reducing sugar was estimated by the method given by Lane and Eynon. (Ranganna, 1986). To one gram of sample, an amount of distilled water was added and clarified with neutral lead acetate. The excess lead acetate was removed by adding potassium oxalate. The volume was then made up to 250 ml. An aliquot of this solution was titrated against a mixture of 10 ml Fehling's A and B using methylene blue indicator. The reducing sugar content was expressed in percentage on fresh weight basis.

3.3.7 Vitamin C

The Vitamin C content of the sample was estimated by the method of A.O.A.C (1955). One gram of the sample was extracted in 4 per cent oxalic acid using a mortar and pestle and made up to 100 ml. The supernatant was titrated against 2, 6 dichlorophenol indophenol dye solution until the appearance of a pink colour which persists for a few seconds. Ascorbic acid content of the sample was calculated from the titre value and expressed in mg100 g^{-1} of sample.

3.3.8 Total free amino acids

Presence of total free amino acid was estimated colourimetrically as suggested by Sadasivam and Manickam (1992). The dried sample (0.5 g) was ground with a small quantity of acid-washed sand and 10 ml of boiling 80 per cent ethanol was added, filtered and centrifuged. The filtrate of the repeated extraction was pooled and evaporated. To 0.1 ml of this filtrate, 1 ml of ninhydrin solution was added and made up to 2 ml with distilled water. The tube was heated in boiling water bath for 20 minutes and 5 ml of the diluent was added. After 15 minutes the purple colour developed was read at 570 nm. A standard graph was prepared using serial dilution of leucine and the total amino acid content in the sample was estimated from the standard graph and expressed in percentage of fresh sample.

3.3.9 Calcium

The calcium content was estimated using titration method with EDTA as suggested by Page (1982). One gram of dried and powdered sample was predigested with 10 ml of 9:4 mixtures of nitric acid and perchloric acid and volume was made up to 100 ml. To five ml of diacid extract, 10 ml water, 10 drops of hydroxylamine hydrochloride, 10 ml triethanolamine, 2.5 ml sodium hydroxide and 10 drops of calcone were added. Then, it was titrated with 0.02 N EDTA until the appearance of permanent blue colour .Calcium content was expressed in mg $100g^{-1}$ of fresh sample.

3.3.10 Iron

The iron content was analysed colourimetrically by Wong's method as suggested by Raghuramulu *et al.* (1983). To an aliquot of 6.5 ml diacid digested sample solution, one ml of 30 per cent sulphuric acid, one ml of 7 per cent potassium persulphate solution and 1.5 ml of 40 per cent potassium thiocyanate solution were added. The intensity of the red colour was measured within twenty minutes at 540 nm. The content of iron present in the sample was estimated from standard graph prepared using serial dilution and expressed in mg $100g^{-1}$ on fresh weight basis.

3.3.11 Potassium

The potassium content was estimated using flame photometer as suggested by Jackson (1973). One ml of the digested solution was made up to 25 ml and the intensity was read directly in flame photometer and potassium content was expressed in mg $100g^{-1}$ on fresh weight basis.

3.3.12 Sodium

The sodium content was estimated using flame photometer as suggested by Jackson (1973). The digested solution was directly fed into flame photometer and sodium content was expressed in mg $100g^{-1}$ on fresh weight basis.

3.3.13 Nitrates

Nitrate content was estimated by method suggested by Marderosian *et al.* (1979). One gram of dried and powdered sample was extracted in 100 ml of distilled water for 30 minutes by shaking and filtered. To 5 ml of filtrate, 0.1 g of 3, 4 dimethyl phenol was added, followed by 10 ml of Con. H_2So_4 and allowed to stand for 10 minutes. To this 30 ml of distilled water was added, kept the flask in running water for 30 minutes. Later the contents were steam distilled and 25 ml of distillate was collected in a volumetric flask containing 3 ml of 5 per cent NaOH .The colour intensity of the samples was measured in a spectrophotometer at 430nm.

A standard graph was prepared using serial dilution of standard sodium nitrate solution and the content of nitrate in the sample was estimated from the standard graph and expressed in mg $100g^{-1}$ of fresh sample.

3.3.14 Oxalates

The oxalate content in the sample was analysed colourimetrically as suggested by Marderosian *et al.* (1979). To 0.5 g of dried and powdered sample 10 ml of distilled water and 10 ml of citric acid reagent were added. The sample was extracted by shaking for 10 minutes at room temperature and filtered. The precipitate was dissolved in 50 ml of 0.4 N HCl by shaking for 10 minutes and filtered again. Two ml of filtrate was taken and added 2 ml of diluted iron ferron reagent and the absorbance was read at 540 nm in a spectrophotometer. The oxalate content of dried sample was calculated from the standard graph and converted to fresh weight basis.

3.4 Selection of bamboo shoot for product development

To select the ideal species for product development the four bamboo shoot species were ranked on the basis of major nutrients namely protein, total carbohydrate, crude fibre, calcium , iron, potassium and sodium and two anti nutritional factors namely oxalates and nitrates. From the four species evaluated one of the species which had maximum nutritional qualities and minimum antinutritional factors was selected for product development. The availability of the shoot was also taken into consideration while selecting the species for product development.

3.5 Product development with processed bamboo shoots

Two products namely pickle and vattal (dehydrated product) were prepared using processed bamboo shoots of *Bambusa bambos*. The pickle was prepared using the standard recipe suggested by Cane and Bamboo Technology Center (2007) and vattal was prepared using the standard procedure of Pavunny (1996) for the preparation of banana pseudostem pickle, with necessary modifications. The procedures for the preparation of pickle and vattal is described in Appendix I and Appendix Π respectively. The pickle and vattal developed are given in plates 11 to 14.

3.6. Quality evaluation of products during storage

The pickles and vattals were stored at ambient storage conditions for a period of three months and following quality characteristics were evaluated during storage.

3.6.1 Organoleptic evaluation of edible bamboo shoot products

3.6.1.1 Selection of judges

A series of organoleptic trials were carried out using simple triangle test at laboratory level to select a panel of ten judges between the age group of 18 to 35 years as suggested by Jellanick (1985).

3.6.1.2 Preparation of score card

Score card containing the five qualities attributes like appearance, colour, flavour, texture and taste were prepared for the assessment of bamboo shoot products. Each of the above mentioned qualities were assessed by a nine point hedonic scale. Overall acceptability was calculated separately using the average of above mentioned quality attributes. The score card used for the evaluation of bamboo shoot products is given in the Appendix III and Appendix IV.

Plate 11. Bamboo shoot pickle

Plate 12. Bamboo shoot pickle stored in glass bottle

Plate 13. Bamboo shoot vattal packed in polythene bags

Plate 14. Bamboo shoot vattal after frying

3.6.1.3 Organoleptic evaluation

Organoleptic evaluation of bamboo shoot pickle and vattal after frying were carried out in the morning time using the score card by a panel of ten selected judges, at monthly intervals for a period of three months.

3.6.2 Peroxide value

Peroxide value of the pickle was estimated to find the rate of rancidity during storage. It was estimated by the method suggested by Sadasivam and Manickam (1992) initially and at the end of three months of storage.

To one gram of sample taken in a boiling tube one gram of potassium iodide and 20 ml solvent mixture (glacial acetic acid and chloroform) were added. The tubes were placed in boiling water for 30 seconds and transferred the contents to a conical flask containing 20 ml of 5 per cent potassium iodide solution. The tubes were washed twice with 25 ml water each time and collected into the conical flask. This was then titrated against sodium thiosulphate solution until the disappearance of yellow colour. Then 0.5 ml of starch was added and titrated till the appearance of blue colour. A blank solution was also prepared and peroxide value was computed and expressed in milliequivalent per kg of the sample

3.6.3 Microbial enumeration and insect infestation of product

The total microbial count of pickle and vattal was enumerated using serial dilution and plate count method as described by Agarwal and Hasija (1986) initially and at the end of three months of storage. One gram of sample was added to 9 ml sterile water and agitated for 20 minutes. One ml of this solution was transferred to a test tube containing 9 ml of sterile water to get 10^{-2} dilution and similarly 10^{-3}, 10^{-4} and 10^{-5} dilutions were also prepared.

Enumeration of total microbial count was carried out using nutrient agar media for bacteria, potato dextrose agar media for fungus and sabouraud's dextrose agar media for yeast , which was obtained from Himedia Lab , Mumbai .The dilution used for bacteria was 10^{-5} and for fungi and yeast 10^{-3} dilution was used.

By examining the bamboo shoot vattals under the microscope, the presence of storage insects was assessed at the end of three months of storage.

3.7 Analysis of data

The observations recorded were tabulated and the data was analysed statistically as Completely Randomised Design (CRD). Varieties were compared by Duncan's Multiple Range Test (DMRT). For organoleptic studies Kendall's coefficient of concordance was used to assess the degree of agreement among the judges. The microbial count was analysed using paired't' test method

RESULT

4. RESULT

The result pertaining to the study entitled “Quality evaluation and value addition of edible bamboo shoots” are presented under the following heads:

4.1 Chemical composition of fresh and processed bamboo shoots

4.2 Selection of bamboo shoots for product development

4.3 Quality evaluation of bamboo shoot products

- 4.3.1 Organoleptic evaluation of bamboo shoot products
- 4.3.2 Peroxide value of pickle during storage
- 4.3.3 Enumeration of microbial population of pickle and vattal during storage
- 4.3.4 Evaluation of insect infestation in vattal during storage

4.1 Chemical composition of fresh and processed bamboo shoots

Fresh and processed bamboo shoots from four different species namely *Bambusa bambos*, *Bambusa tulda, Dendrocalamus hamiltonii* and *Dendrocalamus strictus* were analysed for different chemical constituents like moisture, total carbohydrate, crude fibre, soluble fibre, protein, reducing sugar, vitamin C, total free amino acids, calcium, iron, potassium and sodium. The anti nutritional factors namely nitrate and oxalates were also analysed in fresh and processed bamboo shoots. The result pertaining to the chemical constituents in fresh and processed bamboo shoots are presented in this section.

4.1.1 Moisture

The moisture content of four species of fresh and processed bamboo shoots is given in the Table 1. The mean moisture content in the fresh shoots varied from 90.53 per cent to 92.27 per cent. The highest moisture content was found in *D. strictus* and lowest in *B. bambos*.

On the basis of DMRT, the species were categorised into two groups according to moisture content *B. bambos*, *B. tulda* and *D. hamiltonii* were included in the same group (b) which indicated that these three species had no significant difference between themselves with respect to moisture content but the moisture content of *D. strictus* was significantly high than the moisture content observed in other three species.

Table 1. Moisture content (%) of fresh and processed bamboo shoots

Species	Fresh		Processed	
	Mean	**±SE**	**Mean**	**+-SE**
Bambusa bambos	$90.53^{B}{}_{b}$	.07	$93.27^{A}{}_{c}$	.18
Bambusa tulda	$90.67^{B}{}_{b}$	.33	$95.33^{A}{}_{a}$	.33
Dendrocalamus hamiltonii	$90.60^{B}{}_{b}$	0	$95.20^{A}{}_{a}$	.10
Dendrocalamus strictus	$92.27^{B}{}_{a}$	.07	$94.20^{A}{}_{b}$	.00

All lower case alphabets are to be read row wise and all upper case alphabets as column wise to form homogenous groups

In processed shoots, the moisture contents varied from 93.27 to 95.33 per cent with the highest and lowest contents in *B. tulda* and *B. bambos* respectively. Statistically, it was found that there was no significant difference in moisture content between *B. tulda* and *D. hamiltonii* while the moisture content differed significantly from the other two species namely *B. bambos* and *D. strictus.*

The moisture content of processed bamboo shoots was found to be higher when compared to the fresh shoots in all species and the increase in moisture content was found to be statistically significant in all the four species.

4.1.2 Crude fibre

Crude fibre content of fresh and processed bamboo shoots are furnished in Table 2. In fresh bamboo shoots the mean crude fibre content varied from 0.53 per cent to 0.62 per cent. High crude fibre content was found in *B. tulda* and lowest in *B. bambos* and *D. hamiltonii.*

Table 2. Crude fibre content (%) of fresh and processed bamboo shoots

Species	Fresh		Processed	
	Mean	±SE	Mean	±SE
Bambusa bambos	0. $53^{A}{}_{a}$	.03	$0.29^{B}{}_{a}$	.02
Bambusa tulda	$0.62^{A}{}_{a}$	.03	$0.12^{B}{}_{b}$	.02
Dendrocalamus hamiltonii	$0.53^{A}{}_{a}$	.03	$0.14^{B}{}_{b}$	0
Dendrocalamus strictus	$0.54^{A}{}_{a}$	.08	$0.14^{B}{}_{b}$	.02

All lower case alphabets are to be read row wise and all upper case alphabets as column wise to form homogenous groups

All the four species were grouped under the same category (a) on the basis of DMRT, indicating that there was no significant difference in crude fibre content among fresh bamboo shoots.

The mean crude fibre content in processed shoots was found to be 0.29 per cent (*B.bambos*), 0.12 per cent (*B. tulda*) and 0.14 per cent (*D. hamiltonii* and *D. strictus*). The highest and the lowest crude fibre content were found to be in *B. bambos* and *B. tulda* respectively. Statistically, it was seen that the bamboo shoot species namely *B. tulda, D. hamiltonii* and *D. strictus* had no significant difference between each other while the crude fibre content of *B. bambos* differed significantly from these three species.

A decrease in crude fibre content was noticed in all the four species of bamboo shoots after processing and the decrease in crude fibre content during processing was found to be statistically significant.

4.1.3 Total carbohydrates

Total carbohydrate content of the four species is furnished in the Table 3. In fresh bamboo shoots the mean total carbohydrate content varied from 1.26 to 2.21 per cent and in processed shoots it varied from 1.34 to 4.49 per cent. Among the four species higher total carbohydrate of (2.21) was found in fresh shoots of *D. hamiltonii* and lowest in *B. tulda* and *D. strictus*.

Statistically, the fresh bamboo shoots were differentiated into two categories on the basis of total carbohydrate content namely ‘a’ and ‘b’ with two species in each category, and the total carbohydrate content in *D. strictus* and *B. tulda* differed significantly from the content observed in *B. bambos* and *D. hamiltonii*.

The total carbohydrate content of bamboo shoots after processing was found to be *B.bambos* (2.42%), *B. tulda* (4.49%), *D. hamiltonii* (3.23%) and *D. strictus* (1.34%) with the highest and lowest content in *B. tulda* and *D. strictus respectively*. Total carbohydrate content of each species differed significantly from each other after processing. An increase in the total carbohydrate content was observed after processing of the bamboo shoots. The increase observed in the total carbohydrate content after processing was found to be statistically significant in all the four species.

Table 3. Total carbohydrate content (%) of fresh and processed Bamboo shoot

Species	Fresh		Processed	
	Mean	±SE	Mean	±SE
Bambusa bambos	$2.19^{B}{}_{a}$	.01	$2.42^{A}{}_{c}$	.01
Bambusa tulda	$1.26^{B}{}_{b}$	.00	$4.49^{A}{}_{a}$	.00
Dendrocalamus hamiltonii	$2.21^{B}{}_{a}$	.00	$3.23^{A}{}_{b}$	.00
Dendrocalamus strictus	$1.26^{B}{}_{b}$	.00	$1.34^{A}{}_{d}$	.00

All lower case alphabets are to be read row wise and all upper case alphabets as column wise to form homogenous groups

4.1.4 Soluble fibre

Soluble fibre content of four species of bamboo shoots in the fresh and processed state is furnished in Table 4. In fresh shoots the mean soluble fibre content varied from 0.02 to 0.03 per cent. The highest content was observed in *B. tulda* and *D. strictus*, while the lowest content in B. *bambos* and *D. hamiltonii.*

On the basis of DMRT, fresh bamboo shoots from the four different species were grouped under the same category ‘a’ and hence it is inferred that the variation observed in soluble fibre content among fresh shoots was statistically insignificant.

The amount of soluble fibre in all the four processed bamboo shoot species was found to be zero per cent.

Table 4. Soluble fibre content (%) of fresh and processed Bamboo shoots

Species	Fresh		Processed	
	Mean	**±SE**	**Mean**	**± SE**
Bambusa bambos	0.02 a	0	0	0
Bambusa tulda	0.03 a	0	0	0
Dendrocalamus hamiltonii	0.02 a	0	0	0
Dendrocalamus strictus	0.03 a	0	0	0

All lower case alphabets are to be read row wise and all upper case alphabets as column wise to form homogenous groups.

4.1.5 Protein

The mean protein content of fresh bamboo shoots varied from 0.81 to 1.09 per cent (Table 5) with the highest content in *D. strictus* and the lowest in *B. tulda.*

According to DMRT classification the fresh shoots from four species were grouped under a single category ‘a’ and thus the variation in the protein content among different varieties was found to be statistically insignificant.

The protein content of processed bamboo shoots varied from 0.24 per cent (*B. tulda*) to 0.54 per cent (*B. bambos*). Statistically, the species namely *B. bambos* differed significantly from the remaining three species in protein content.

Table 5. Protein content (%) of fresh and processed bamboo shoots

Species	Fresh		Processed	
	Mean	±SE	Mean	±SE
Bambusa bambos	$1.01^{A}{}_{a}$	.04	$0.54^{B}{}_{a}$	.08
Bambusa tulda	$0.81^{A}{}_{a}$	.00	$0.24^{B}{}_{b}$	.03
Dendrocalamus hamiltonii	$0.86^{A}{}_{a}$	.12	$0.38^{B}{}_{b}$	.02
Dendrocalamus strictus	$1.09^{A}{}_{a}$	.24	$0.25^{B}{}_{b}$	.03

All lower case alphabets are to be read row wise and all upper case alphabets as column wise to form homogenous groups

The table clearly showed a reduction in protein content during processing of bamboo shoots and the decrease was found to be statistically significant.

4.1.6 Reducing sugar

Reducing sugar content of fresh and processed bamboo shoots is given in Table 6. The reducing sugar content in fresh shoots varied between 0.30 to 0.82 per cent. The species *D. strictus* had the lowest and *B. tulda* had the highest reducing sugar content. In processed shoots, the mean reducing sugar content varied from 0.21 to 0.36 per cent. *D. strictus* contained the lowest and *B. tulda* the highest.

On the basis of DMRT, in fresh and processed shoots, the species were categorized into four groups, indicating that there is significant difference in the reducing sugar content between the species.

Table 6. Reducing sugar content (%) of fresh and processed bamboo shoots

Species	Fresh		Processed	
	Mean	±SE	Mean	±SE
Bambusa bambos	$0.34^{A}{}_{c}$	0	$0.23^{B}{}_{c}$	0
Bambusa tulda	0.82^{A} a	0	$0.36^{B}{}_{a}$	0
Dendrocalamus hamiltonii	$0.52^{A}{}_{b}$	.01	$0.31^{B}{}_{b}$	0
Dendrocalamus strictus	$0.30^{A}{}_{d}$	0	$0.21^{B}{}_{d}$	0

All lower case alphabets are to be read row wise and all upper case alphabets as column wise to form homogenous groups

As observed in Table 6, the reducing sugar content decreased significantly after processing in all the four bamboo shoot species.

4.1.7 Calcium

The mean calcium content of four species of bamboo shoot in the fresh and processed forms are given in the Table 7. The mean calcium content ranged from 10.00 to 32.67 mg 100g^{-1}in fresh shoots and from 4.00 to 8.33 mg 100g^{-1} in processed shoots. The highest and lowest calcium content were observed in *B. bambos* and *B. tulda* both in fresh and processed shoots.

The fresh shoots were grouped under three categories on the basis of DMRT. The species namely *B. tulda* and *D. strictus* were included in the same category 'c', while *B. bambos* and *D. hamiltonii* were grouped under two separate categories namely 'a' and 'b' respectively and the calcium content of bamboo shoot species grouped in each category differed significantly..

In the processed shoots significant variation was observed in the calcium content of *B. bambos* and *B. tulda* and the variation observed in the calcium content of *B. tulda*, *D. strictus* and *D. hamiltonii* was found to be statistically insignificant.

Table 7. Calcium content (mg 100g^{-1}) of fresh and processed bamboo shoots

Species	Fresh		Processed	
	Mean	±SE	Mean	± SE
Bambusa bambos	32.67^{A}_{a}	1.7	8.33^{B}_{a}	1.3
Bambusa tulda	10.00^{A}_{c}	0	4.00^{B}_{b}	1.0
Dendrocalamus hamiltonii	15.00^{A}_{b}	0	5.67^{B}_{ab}	.67
Dendrocalamus strictus	10.67^{A}_{c}	1.3	7.00^{B}_{ab}	1.0

All lower case alphabets are to be read row wise and all upper case alphabets as column wise to form homogenous group

A decrease in the calcium bamboo shoots was observed during processing and the decrease was found to statistically significant.

4.1.8 Iron

The iron content of four species of bamboo shoots is shown in the Table 8. In case of fresh bamboo shoots the mean iron content varied from 0.22 to 0.79 mg $100g^{-1}$ with the highest content in *D. tulda* and the lowest in *D. strictus*.

On the basis of DMRT, the fresh bamboo shoot species were classified into two categories based on iron content. *B. tulda* and *D. hamiltonii* were included in group ‘a’, while *B. bambos* and *D. strictus* in group ‘b’. Both these categories differed significantly from each other with respect to iron content.

The iron content varied from 0.12 to 0.43 mg $100g^{-1}$ in processed shoots. The lowest content was observed in *D. strictus* and the highest in *B.tulda.* The four species of processed shoots were categorized into two groups ‘a’ and ‘b’ with two species in each category and the species included in each category differed significantly with respect to iron content.

Table 8. Iron content (mg $100g^{-1}$) of fresh and processed bamboo shoots

Species	Fresh		Processed	
	Mean	±SE	Mean	±SE
Bambusa bambos	$0.24^{A}{}_{b}$	0	$0.14^{B}{}_{b}$	0
Bambusa tulda	$0.79^{A}{}_{a}$	.02	$0.43^{B}{}_{a}$	.04
Dendrocalamus hamiltonii	$0.72^{A}{}_{a}$	.11	$0.37^{B}{}_{a}$	.06
Dendrocalamus strictus	$0.22^{A}{}_{b}$	0	$0.12^{B}{}_{b}$	0

All lower case alphabets are to be read row wise and all upper case alphabets as column wise to form homogenous groups

From Table 8, it is obvious that the iron content of the bamboo shoot species decreased during processing and this decrease was found to be statistically significant.

4.1.9 Potassium

Potassium content of fresh and processed bamboo shoot species are presented in Table 9. The mean potassium content in four species of fresh shoots varied from 21.67 mg $100g^{-1}$ in *B. bambos* to 42.33 mg $100g^{-1}$ in *D. hamiltonii*.

On the basis of DMRT, the four species of fresh bamboo shoots were classified into four different groups and they differed significantly from each other with respect to potassium content.

In processed shoots the mean potassium content ranged from 3.0 to 13.00 mg $100g^{-1}$, with the highest content in *B. bambos* and the lowest in *B. tulda*. The potassium content in processed shoots of *D. hamiltonii* and *D.strictus* was found to be 10.67 mg $100g^{-1}$ and they were included in category 'a' and differed significantly from *B. bambos* (13.00 mg $100g^{-1}$) and *B. tulda* (3.00 mg $100g^{-1}$) in potassium content.

The potassium content of the bamboo shoots decreased after processing and the decrease was found to be statistically significant in all the four species.

Table 9. Potassium content (mg 100 g^{-1}) of fresh and processed bamboo shoots

Species	**Fresh**		**Processed**	
	Mean	**± SE**	**Mean**	**±SE**
Bambusa bambos	$21.67^{A}{}_{d}$	.89	$13.00^{B}{}_{a}$	.00
Bambusa tulda	$33.00^{A}{}_{b}$	.58	$3.00^{B}{}_{c}$	.00
Dendrocalamus hamiltonii	$42.33^{A}{}_{a}$	.33	$10.67^{B}{}_{b}$	.33
Dendrocalamus strictus	$24.00^{A}{}_{c}$	.00	$10.67^{B}{}_{b}$	0

All lower case alphabets are to be read row wise and all upper case alphabets as column wise to form homogenous groups.

4.1.10 Sodium

The sodium content of fresh and processed bamboo shoot species are furnished in the Table 10. In the four species of fresh shoots the mean sodium content varied from 28.00 mg $100g^{-1}$ to 37.67 mg $100g^{-1}$. The highest content was found in *B. tulda* and the lowest in *D. strictus*. Statistically, the four species of fresh bamboo shoots were included in four different groups indicating significant variation among species in sodium content.

In processed shoots the sodium content ranged between 15.00 mg $100g^{-1}$ and 19.00 mg $100g^{-1}$ with lowest content in *D.hamiltonii* and the highest in *B. bambos.*

On the basis of DMRT, the processed shoots were grouped into three categories. The sodium content of *B. bambos* differed significantly from the other three species. The variation noticed in the sodium content of *B. tulda* and *D. strictus* as well as *B. tulda* and *D. hamiltonii* were found to be statistically insignificant.

Table 10. Sodium content (mg 100 g^{-1}) of fresh and processed bamboo shoots

Species	Fresh		Processed	
	Mean	±SE	Mean	±SE
Bambusa bambos	$32.00^{A}{}_{c}$	.57	$19.00^{B}{}_{a}$	.57
Bambusa tulda	$37.67^{A}{}_{a}$	.33	$16.00^{B}{}_{bc}$	0
Dendrocalamus hamiltonii	$35.67^{A}{}_{b}$	.33	$15.00^{B}{}_{c}$	0
Dendrocalamus strictus	$28.00^{A}{}_{d}$	0	$16.33^{B}{}_{b}$	.33

All lower case alphabets are to be read row wise and all upper case alphabets as column wise to form homogenous groups

A significant decrease in the sodium content was observed in four species of processed bamboo shoots.

4.1.11 Vitamin C

The Vitamin C content of fresh and processed bamboo shoots are presented in the Table 11.The mean values of vitamin C content in fresh shoots varied from 2.82 to 3.45 mg $100g^{-1}$. The highest vitamin C content was found in *B. bambos* and *D. hamiltonii* and lowest in *D. strictus.*

Table 11. Vitamin C content (mg $100g^{-1}$) of fresh and processed bamboo shoots

Species	Fresh		Processed	
	Mean	±SE	Mean	±SE
Bambusa bambos	3.45^{A}_{a}	.69	1.5^{B}	0
Bambusa tulda	3.41^{A}_{a}	.69	1.0^{B}	0
Dendrocalamus hamiltonii	3.45^{A}_{a}	.69	1.1^{B}	0
Dendrocalamus strictus	2.82^{A}_{a}	.56	1.3^{B}	0

All lower case alphabets are to be read row wise and all upper case alphabets as column wise to form homogenous groups

There was no significant difference among the four species of fresh bamboo shoots in vitamin C content.

In processed shoots the vitamin C content varied from 1 to 1.5 mg $100g^{-1}$ with the highest content in *B. bambos* and the lowest in *B. tulda*.

Significant decrease in vitamin C content was observed in all the four species on processing of shoots.

4.1.12 Total free amino acids

The total free amino acid content in four species of bamboo shoots is furnished in Table 12. In fresh bamboo shoots the mean total free amino acid content was found to be in the range of 0.061 and 0.112 per cent. The highest amino acid content was found in *B. tulda* and the lowest in *D. strictus.*

Statistically, the four species were grouped into two categories namely 'a' and 'b' and *B. bambos, B. tulda* and *D. hamiltonii* categorized together in group (a). It was seen that the on the basis of amino acid content *D. strictus* varied significantly from the other three species grouped under (a) .

Table 12. Total free amino acid content (%) of fresh and processed bamboo shoots

Species	Fresh		Processed	
	Mean	±SE	Mean	±SE
Bambusa bambos	$0.110^{A}{}_{a}$	0	$0.02^{B}{}_{a}$	.01
Bambusa tulda	$0.112^{A}{}_{a}$	0	$0.01^{B}{}_{a}$	0
Dendrocalamus hamiltonii	$0.110^{A}{}_{a}$	0	$0.01^{B}{}_{a}$	0
Dendrocalamus strictus	$0.061^{A}{}_{b}$	.01	$0.02^{B}{}_{a}$	0

All lower case alphabets are to be read row wise and all upper case alphabets as column wise to form homogenous groups

In processed shoots the mean amino acid content was found to be in the range of 0.01 and 0.02 per cent, with the highest content in *B. bambos* and *D. strictus* and the lowest in *B. tulda* and *D. hamiltonii.* The variation observed in the amino acid content of bamboo shoot species after processing was found to be statistically insignificant.

The total free amino acid content of processed shoots was found to be lower when compared to fresh ones. This decrease in total free amino acid content was found to be statistically significant in all the four species.

4.1.13 Nitrates

The nitrate content in the shoots is given in the Table 13. The nitrate content in different species of fresh shoots ranged between 15.65 and 57.97 mg $100g^{-1}$. The lowest content was found in *B. tulda* and the highest in *B. bambos.*

On the basis of DMRT, the fresh bamboo shoot species were classified into three categories. *B. tulda* and *D. strictus* were categorized in group c and *B. bambos* and *D. hamiltonii* were categorized in group a and b respectively indicating that the variations observed in the nitrate content of *B. tulda* and *D. strictus* were statistically insignificant while it varied significantly from *B. bambos* and *D. hamiltonii.*

Table 13. Nitrate content (mg 100 g^{-1}) of fresh and processed bamboo shoots

Species	Fresh		Processed	
	Mean	±SE	Mean	±SE
Bambusa bambos	$57.97^{A}{}_{a}$	.83	$15.74^{B}{}_{a}$	.89
Bambusa tulda	$15.65^{A}{}_{c}$	.62	$6.90^{B}{}_{b}$	0
Dendrocalamus hamiltonii	$23.19^{A}{}_{b}$	1.1	$8.16^{B}{}_{b}$	0
Dendrocalamus strictus	$16.94^{A}{}_{c}$	.38	$9.47^{B}{}_{b}$	1.5

All lower case alphabets are to be read row wise and all upper case alphabets as column wise to form homogenous groups

The nitrate content in the processed shoots ranged from 6.90 to 15.74 mg 100g^{-1}. The lowest was found in *B. tulda* and the highest in *B. bambos.* The nitrate content of B. *bambos* in processed state varied significantly from the other species namely *B. tulda, B. hamiltonii* and *D. strictus.*

From the Table 13, it is obvious that the nitrate content reduced in processed shoots and the decrease was found to be statistically significant in all four species.

4.1.14 Oxalates

The oxalate content of four bamboo shoots species is given in the Table 14. In fresh shoots the oxalate content varied from 49.60 to 101.4 mg 100g^{-1} with the highest oxalate content in *B. bambos* and lowest in *D. hamiltonii*.

In the processed shoots the amount of oxalates was found to be in between 11.87 mg $100g^{-1}$ and 50.13 mg $100g^{-1}$. The highest amount was in *D. strictus* and the lowest in *D. hamiltonii.* On the basis of DMRT, all the four species were categorized in four different groups in fresh and processed state based on oxalate content indicating that the oxalate content of four species varied significantly from each other.

Table 14. Oxalate content (mg 100 g^{-1}) of fresh and processed bamboo shoots

Species	Fresh		Processed	
	Mean	±SE	Mean	±SE
Bambusa bambos	$101.4^{A}{}_{a}$	4.0	$38.27^{B}{}_{b}$	.27
Bambusa tulda	$78.32^{A}{}_{c}$	1.4	$23.57^{B}{}_{c}$	.32
Dendrocalamus hamiltonii	$49.60^{A}{}_{d}$	.40	$11.87^{B}{}_{d}$	.07
Dendrocalamus strictus	$85.30^{A}{}_{b}$	.23	$50.13^{B}{}_{a}$	.12

All lower case alphabets are to be read row wise and all upper case alphabets as column wise to form homogenous groups

From the Table 14, it is clear that the oxalate content reduced after processing and the decrease was found to be statistically significant.

4.2 Selection of bamboo shoots for product development

To select the suitable species for product development the relative presence of anti nutrients in comparison with the presence of nutrients was assessed. The ideotype bamboo shoot after processing for product development shall have maximum content of nutrients with minimum content of anti nutrients. To select the ideal species for product development the four bamboo shoot species were ranked on the basis of major nutritents namely protein, total carbohydrate, crude fibre, calcium, iron, potassium and sodium and two anti nutritional factors namely oxalates and nitrates. The details pertaining to the content of nutrients and the relative ranking is given in Table 15. The details pertaining to the anti nutritional factors and the relative ranking is given in Table 16.

If the content of all the seven nutrients were highest in a species and the corresponding two anti nutrient contents under consideration the lowest, the ideotype species for product development will have a score of 7/2=3.5. In an experiment with these nutrients and anti nutrients under consideration, if the species did not posses all the desirable properties but possessed some, the species with a value as near to 3.5 shall be adjudged as the most suitable for product development

In such a way, when the four species of bamboo shoots were assessed for nutrient and anti nutrients, the scores for different species were found to be 2.86 (20/7) for *D. strictus*, 1.57 (11/7) for *B. bambos* and 5.33 (16/3) for *D. hamiltonii* and 6.33 (19/3) for *B. tulda*. Hence *D. strictus* was found to be in close proximity with the ideotype value of 3.5 followed by *B. bambos*, *D. hamiltonii* and *B. tulda*. Though, the anti nutritional content of *B. bambos* and *D. strictus* were high, the nutrient content of *B. bambos* with respect to protein, crude fibre, calcium, potassium and sodium were found to be maximum when compared to other three species. Hence, *B. bambos* was selected for product development taking into consideration its nutritional qualities and availability.

Table 15. Ranking on the basis of higher order nutritive value

Species	**Crude fibre**	**Total carbohydrates**	**Protein**	**Calcium**	**Iron**	**Potassium**	**Sodium**	**Total rank**
B. bambos	0.294 (1)	2.42 (3)	0.54 (1)	8.33 (1)	0.14 (3)	0.013 (1)	0.019 (1)	11
B. tulda	0.122 (4)	4.49 (1)	0.24 (4)	4.00 (4)	0.43 (1)	0.003 (3)	0.016 (2)	19
D. hamiltonii	0.144 (2)	3.23 (2)	0.38 (2)	5.67 (3)	0.37 (2)	0.01 (2)	0.015 (3)	16
D. strictus	0.135 (3)	1.34 (4)	0.25 (3)	7.00 (2)	0.12 (4)	0.01 (2)	0.016 (2)	20

Table 16. Ranking on the basis of anti nutrients

Species	Nitrates	Oxalates	Total rank
B. bambos	15.74 (4)	38.26 (3)	7
B. tulda	6.9 (1)	23.56 (2)	3
D. hamiltonii	8.16 (2)	11.8 (1)	3
D. strictus	10.92 (3)	50.12 (4)	7

4.3 Quality evaluation of bamboo shoot products

4.3.1 Organoleptic evaluation of bamboo shoot products

The two products namely pickle and vattal were prepared using *B. bambos.* The pickle was packed in glass bottles and vattal in polythene bags of 250 gauge thickness and stored in ambient storage conditions for a period of three months. The organoleptic evaluation was carried out at monthly intervals. The pickle was evaluated as such and vattal was evaluated after frying in coconut oil. The organoleptic evaluation was carried out using score card for different quality attributes like appearance, colour, flavour, texture, taste and overall acceptability initially and at monthly intervals for a period of three months. Both the products were ranked for different quality attributes based on their mean rank scores using Kendall's (W) test. The results of the organoleptic evaluation of the products are presented in this section.

4.3.1.1 Bamboo shoot Pickle

As revealed in table 17. the appearance of pickle was initially with a maximum score of 8.23. At the end of first month of storage the mean score reduced to 7.82. In the second month of storage slight increase in mean score was observed as 7.97, which further reduced to 7.86 at the end of third month of storage.

The means score for taste of pickle was found to be high at the end of second month of storage. Initially the mean score was found to be 7.76 and it decreased slightly during first month of storage (7.63). The mean score for taste at the end of third month was 7.70.

The mean score for flavour of pickle was 7.67 initially which increased to 7.70 and 7.89 at the end of first and second month of storage respectively. At the end of third month of storage a reduction in mean score was observed (7.74).

Table 17. Mean scores for different quality attributes of pickle during storage

Months	**Character**					
	Appearance	**Taste**	**Flavour**	**Texture**	**colour**	**Overall acceptability**
Initial	8.23 (2.90)	7.76 (2.20)	7.67 (2.05)	7.71 (2.30)	8.01 (2.80)	7.89 (2.70)
1st month	7.82 (2.15)	7.63 (2.25)	7.70 (2.55)	7.61 (1.95)	7.45 (1.75)	7.64 (2.10)
2nd month	7.97 (2.65)	7.90 (2.85)	7.89 (2.85)	8.30 (3.55)	8.04 (2.95)	8.0 (3.10)
3rd month	7.86 (2.30)	7.70 (2.70)	7.74 (2.55)	7.81 (2.20)	7.81 (2.50)	7.8 (2.10)
Kendall's (W) value	0.076	0.072	0.074	0.349	0.178	0 .147
Probability level of significance (%)	51.7	54.2	52.7	1.50	14.8	22.1

Figures in parenthesis are mean rank score

Maximum score of 8.30 was observed for texture of pickle at the end of second month of storage followed by 7.81 at the end of third month of storage. Initially the mean score for texture was 7.71 which decreased to 7.61 at the end of first month of storage.

The highest score for colour of pickle was recorded at the end of second month of storage (8.04). Initially the mean score for colour was 8.01 which decreased to 7.45 at the end of first month of storage. A mean score of 7.81 noticed at the end of third month of storage.

The mean score for overall acceptability of pickle stored for three months was found to be high at the end of second month of storage (8.0). Initially the overall acceptability score for pickle was 7.89 and it decreased to 7.64 at the end of first month. A mean score of 7.80 was recorded at the end of third month of storage.

Statistically, the different quality attributes namely taste, flavour, texture, colour and overall acceptability had highest mean rank scores at the end of second month of storage. For appearance the highest mean rank score of 2.90 was observed during initial evaluation.

From the results it is clear that the judges had significant agreement in differentiation of parameters namely, texture and colour over the months of storage. As regard to other parameters namely, appearance, taste, flavour and overall acceptability lesser order of agreement was observed

4.3.1.2 Bamboo shoot Vattal

The mean scores obtained for the organoleptic evaluation of bamboo shoot vattal during storage is given in Table 18. The mean rank scores obtained on the basis of Kendall's coefficient of concordance are also given in the table 18.

The mean score for appearance of vattal was found to be 7.5 initially, which increased to 7.77 at the end of first month of storage. Slight reduction in the mean scores for appearance of vattal was observed at the end of second month of storage (7.72). The highest score of 8.07 was recorded for appearance of vattal at the end of third month of storage.

For the quality attribute taste, gradual increase in mean scores was observed with advancement of storage period. Initially the mean score was 7.50. At the end of first and second month of storage the mean score was 7.56 and 7.66 respectively. A maximum score of 8.05 was recorded for taste of vattal at the end of third month of storage.

The mean score for flavour of vattal increased gradually on storage and recorded highest mean score of 8.05 at the end of third month of storage.

Table 18. Mean scores for different quality attributes of vattal during storage

Months	**Character**					
	Appearance	**Taste**	**Flavour**	**Texture**	**colour**	**Overall acceptability**
Initial	7.50 (2.10)	7.50 (2.30)	7.18 (1.80)	7.67 (1.85)	7.37 (1.60)	7.56 (1.70)
1st month	7.77 (2.60)	7.56 (2.40)	7.53 (2.55)	7.66 (2.05)	7.97 (2.65)	7.74 (2.60)
2nd month	7.72 (2.25)	7.66 (2.45)	7.54 (2.40)	8.02 (2.75)	7.96 (2.80)	7.77 (2.55)
3rd month	8.07 (3.05)	8.05 (2.85)	8.02 (3.25)	8.39 (3.35)	8.07 (2.95)	8.16 (3.15)
Kendall's (W) value	0.119	0.040	0.224	0.366	0.268	0.224
Probability level of significance (%)	31.2	75.5	8.1	1.2	4.5	8.1

Figures in parenthesis are mean rank scores

The mean score for flavour of vattal was found to be 7.18 (initially), 7.53 (first month) and 7.54 (second month) of storage.

For the texture of vattal the highest mean score of 8.39 was recorded at the end of third month of storage. Initially the mean score for texture was 7.76 which showed slight decrease in first month (7.66). At the end of second month of storage the mean score for texture of vattal was 8.02.

The highest score for colour of vattal was recorded at the end of third month of storage. Initially the mean score for colour was 7.37. At the end of first month of storage slight increase in mean score was observed as 7.97. In the second month the mean score for colour of vattal was 7.96.

The mean scores for overall acceptability of bamboo shoot vattal showed an increasing trend with advancement of storage period and recorded a maximum score of 8.10 at the end of third month of storage. Initially the mean score was 7.56. In the first and second month the mean score for overall acceptability was 7.74 and 7.77 respectively.

For different quality attributes namely appearance, colour, flavour, texture, taste and overall acceptability, the highest mean rank score were observed at the end of third month of storage From the results it is clear that the judges had significant agreement in differentiation of the parameters namely, flavour, texture, colour and overall acceptability over the months of storage. As regard to the other parameters namely, appearance and taste lesser order of agreement was observed.

4.3.2 Peroxide value of bamboo shoot pickle during storage

The peroxide values of pickle during the initial and third month of storage are given in Table 19.

Initially the peroxide value of pickle was found to be 0.4 meq kg^{-1} which increased to 4 meq kg^{-1} at the end of storage.

Table 19. Peroxide value of pickle during storage

Product	Peroxide value (meq kg^{-1})	
	Initial	**Final**
Pickle	0.4	4

4.3.3 Enumeration of microbial population of Pickle and Vattal during storage

4.3.3.1 Bamboo shoot Pickle

The bamboo shoot pickle was evaluated for bacteria, fungi and yeasts initially and at the end of third month of storage and results pertaining to microbial enumeration are presented in Table 20.

Initially, the bacterial count of bamboo shoot pickle was found to be 1.88×10^5 cfu g^{-1}, which increased to 3.66×10^5 cfu g^{-1} at the end of third month storage. On the basis of statistical analysis the variation in the bacterial count was found to be significant at 1% level. (Table 20)

Fungal growth was not detected in pickle at the initial month of storage while at the end of third month of storage the fungal count was found to be 0.66×10^3cfu g^{-1}.

Yeast growth was not detected in the pickle initially and at the end of storage.

4.3.3.2 Bamboo shoot Vattal

The results pertaining to the study of microbial growth in bamboo shoot vattal during three months of storage are furnished under the Table 21.

In vattal, the initial bacterial count was found to be 1.44×10^5 cfu g^{-1} which increased to 4.77×10^5 cfu g^{-1} at the end of third months of storage. The increase in the bacterial count noticed at the end of storage was found to be statistically significant at 1% level. (Table 21)

Fungal growth was not observed in vattal initially. At the end of storage the fungal count was found to be 1.96×10^3 cfu g^{-1}.

Growth of yeast was not detected in vattal during storage.

Table 20. Mean microbial count of pickle during storage

Periods of storage	Microbial population (cfu g^{-1})	
	Bacteria($x10^5$)	Fungi($x10^3$)
Initial	1.88	ND
Final	3.66	0.66
t- value	0.443**	-

ND- not detected Significant at 1% level

Table 21. Mean microbial count of Vattal during storage

Periods of storage	Microbial population (cfu g^{-1})	
	Bacteria($x10^5$)	Fungi($x10^3$)
Initial	1.44	ND
Final	4.77	1.96
t-value	8.94***	-

ND- not detected Significant at 1% level

3.4 Evaluation of insect infestation in bamboo shoot vattal during storage

Insect infestation in vattal was also evaluated initially and at the end of storage and insect infestation was not noticed.

DISCUSSION

5. DISCUSSION

The discussion pertaining to the study is presented under the following headings.

5.1 Chemical constituents of fresh and processed bamboo shoots

5.2 Quality evaluation of bamboo shoot products

- 5.2.1 Organoleptic evaluation of products during storage
  - 5.5.1.1 Bamboo shoot pickle
  - 5.5.1.2 Bamboo shoot vattal
- 5.2.2 Peroxide value of pickle during storage
- 5.3.3 Enumeration of microbial population of Pickle and Vattal during storage
- 5.3.4 Evaluation of insect infestation in vattal during storage

5.1 Chemical constituents of fresh and processed bamboo shoots

The moisture content of fresh bamboo shoot from four species varied from 90.53 to 92.27 per cent. *Bambusa bambos* had a moisture content of 90.53 per cent and was found to be nearer to the values suggested by Young (1954). *Dendrocalamus hamiltonii* contained a moisture content of 90.60 per cent, which was slightly higher than the value of 88.8 per cent suggested by Gopalan *et al*. (1994) in fresh bamboo shoots. The moisture content of *Bambusa tulda* was found to be 90.67 per cent which was in line with the moisture content of bamboo shoots reported by Das and Puzari (2007). Highest moisture content of 92.27 per cent was observed in *Dendrocalamus strictus*. This is found to be almost similar to the moisture content of bamboo shoots reported by Das and Puzari (2007) and within the moisture content of 85.98 to 93.37 per cent suggested by NMBA (2009).

Processed *B. tulda* shoots had the highest moisture content of 95.33 per cent followed by *D. hamiltonii, D. strictus* and *B. bambos.* The moisture content of *D. strictus* varied significantly from the moisture content of other three species before and after processing. The moisture content of the processed bamboo shoots varied significantly from the fresh shoots. The significant increase in the moisture content during processing may be because of the absorption of moisture during processing. The moisture content of fresh and processed shoots is illustrated in Fig 1.

The crude fibre content of fresh shoots varied from 0.53 per cent to 0.62 per cent with the highest content in *B. tulda*. Duke and Atchley (1986), Dransfield and Widjaja (1995) indicated a high fibre content in the range of 0.7 to 1.9 per cent in bamboo shoots. The crude fibre content of the four bamboo shoot species in the present study was found to be lower than the crude fibre content noticed by Kumbhare and Bhargava (2007) in four species of raw bamboo shoots, which varied from 0.71 - 0.98 per cent. The authors indicated a high fibre content of 0.98 per cent in *D. strictus.* However the crude fibre content of *D. strictus* in the present study was found to be only 0.54 per cent.

The crude fibre content of processed shoots varied from 0.12 to 0.29 per cent with *B. bambos* and *B. tulda* having the highest and lowest content. However, Kumbhare and Bhargava (2007) observed similar crude fibre content in boiled bamboo shoots as that of the raw shoots and indicated that processing of shoots did not affect the crude fibre content of bamboo shoots. The significant decrease in the crude fibre content from the fresh shoots may be due to the processing method employed and leaching of the soluble fibres. FAO (1990) also indicated a loss in crude fibre content in boiled peeled potatoes as compared to uncooked potato. The crude fibre content of fresh and processed shoots are illustrated in Fig 2.

The total carbohydrate content of fresh shoots varied from 1.26 to 2.21 per cent with the highest content in *D. hamiltonii* followed by *B. bambos* (2.19 per cent). Contrary to the present finding Duke and Atchley (1986), Tewari (1992), Dransfield and Widjaja (1995), Bhargava and Kumbhare (1996) reported a wide range of total carbohydrate content in between 2.0 to 6.4 per cent in different bamboo shoots species. *B. tulda* and *D. strictus* had total carbohydrate content of 1.26 per cent; the value was lower than the values suggested by Kumbhare and Bhargava (2007) who reported higher carbohydrate content in the range of 2.6 to 3.4 per cent in four different species of bamboo shoots.

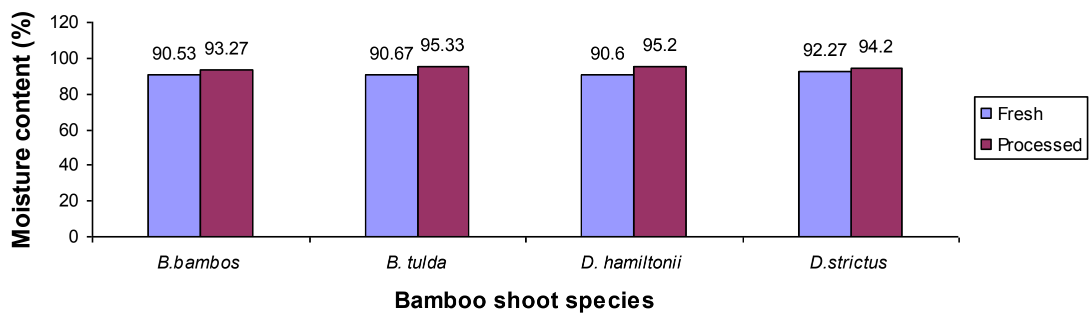

Fig 1.Moisture content of fresh and processed bamboo shoots

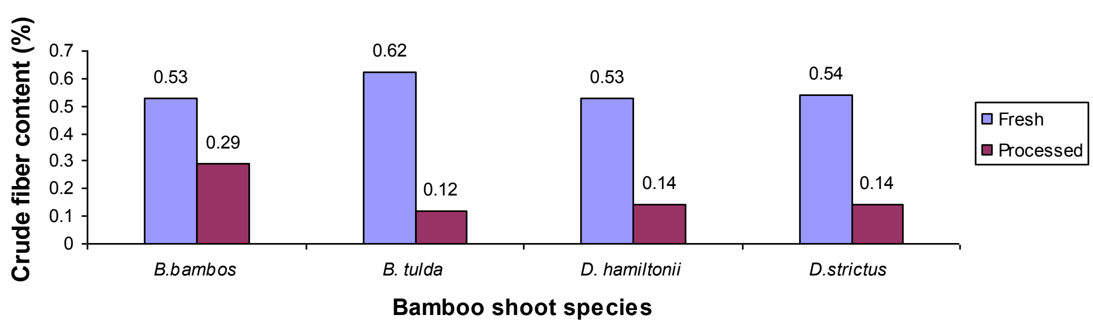

Fig 2. Crufe fibre content of fresh and processed bamboo shoots

The carbohydrate content of processed shoots varied from 1.34 to 4.49 per cent. The increase in the carbohydrate content of processed bamboo shoots was found to be statistically significant. The increase in the carbohydrate content of bamboo shoots after processing may be due to the fibrous nature of bamboo. During processing the polysaccharides may get hydrolysed into simple sugars and the resultant monosaccharides might have contributed to the increase. Kumbhare and Bhargava (2007) also reported an increase in total carbohydrate content in bamboo shoots after boiling. The total carbohydrate content of the shoots is illustrated in Fig 3.

The soluble fibre content of four bamboo shoot species was found to be almost similar. In the present study out of the total fibre content nearly 4 to 6 per cent of the fibre was found to be soluble fibres. Park and Jhon (2009) indicated a soluble fibre content of about 8 per cent in bamboo shoots. The soluble fibre content noticed in the present study was lower than the values reported by the authors. In the processed bamboo shoots the soluble fibre content was found to be zero and this might be due to the leaching of the soluble fibres in the water used for processing. Fig 4 illustrates the soluble fibre content present in fresh shoots.

The protein content in fresh bamboo shoots from four species varied from 0.81 to 1.09 per cent with the highest content in *D. strictus* and lowest in *B. tulda*. Young (1954) indicated a slightly higher protein content of 2.6 per cent in bamboo shoots. The protein content of fresh bamboo shoots was found to be lower than the values suggested by Duke and Atchley (1986), Anon (1988), Tewari (1993), Dransfield and Widjaja (1995) who reported a protein content of 2.0 to 4.4 g $100g^{-1}$ in different bamboo shoot species. Ferreira *et al.* (1992) indicated a high protein content of 46.1 per cent and 40.4 per cent in the apical and basal portions of *D. giganteus* shoots which were much higher than the values obtained in the present investigation. Han and Koo (1993) also observed a protein content of 3.05 per cent in bamboo shoots. As per the report published by NMBA (2009) the protein content of bamboo shoots varied from 1.98 to 3.29 per cent. Wide variation in the protein content of bamboo shoots in different studies may be attributed to the

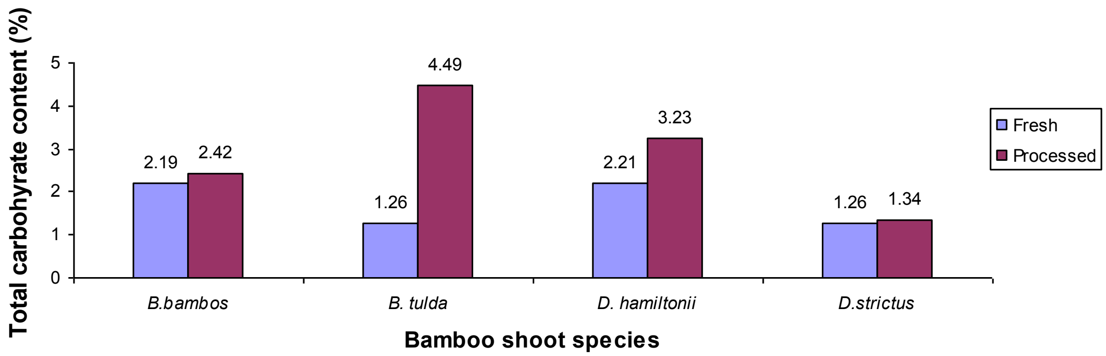

Fig 3. Total carbohydrate content of fresh and processed bamboo shoots

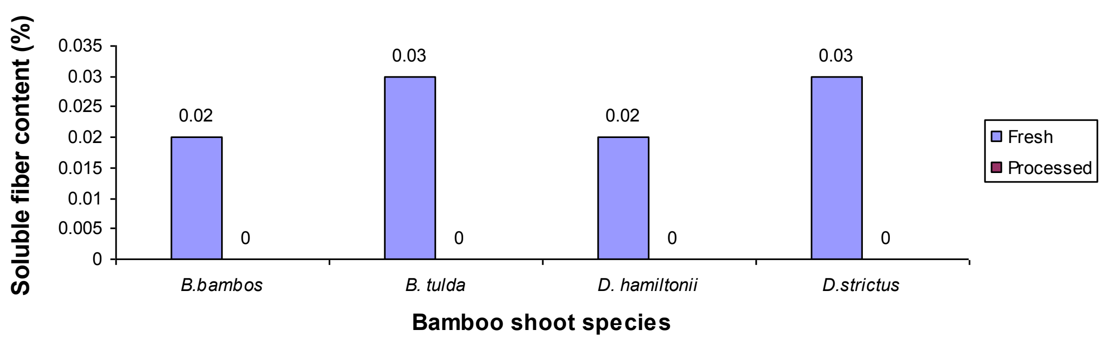

Fig 4. Soluble fibre content of fresh and processed bamboo shoots

differences in species, growing site, climatic factors and the part of shoots taken for analysis.

Significant decrease in the protein content was noticed in bamboo shoots during processing. The protein content in processed bamboo shoots from four species varied from 0.24 to 0.54 per cent. Kumbhare and Bhargava (2007) also indicated a decrease in crude protein content in the processed shoots. High temperature during the processing might have destroyed the essential amino acids and there by decreasing the protein content. The protein contained in the fresh and processed bamboo shoots are illustrated in the Fig 5.

Fresh shoots of *B. tulda* had the highest reducing sugar content of 0.82 per cent while the reducing sugar content of other three species varied from 0.30 to 0.52 per cent. Ferreira *et al.* (1992) reported higher reducing sugar content in the range of 1.1 to 1.2 per cent in the basal and apical portion of *D. gigantis* shoots. Kumbhare and Bhargava (2007) also indicated a reducing sugar content of 0.81 per cent in the raw shoots of *B. vulgaris*. The authors reported reducing sugar content in the range of 0.72 to 1.14 per cent in different species of bamboo shoots. The reducing sugar content observed in the present study was lower than the values reported by these authors. This may be due to the variation in the species of bamboo shoots selected for the study. A significant decrease in the reducing sugar content of all the four species of bamboo shoots was also noticed during processing.

Results revealed that processed *B. tulda* shoots had the highest reducing sugar content (0.36 per cent) and lowest was in D. *strictus* (0.21 per cent). *B. bambos* and *D. hamiltonii* was found to have reducing sugar content of 0.23 per cent and 0.31 per cent respectively. This is in line with the findings of Kumbhare and Bhargava (2007).They also indicated a decrease in the reducing sugar content of bamboo shoot species during boiling and indicated that the content varied from 0.10 to 0.59 per cent in boiled shoots. The decrease observed in the reducing sugar content of bamboo shoots during processing may be due to degradation of sugars by boiling. The decrease may also be due to the browning reactions of reducing sugars occurred during heating under moist conditions. Swiderski *et al*. (1989) reported a loss of above 60 per cent of soluble sugars during cooking. From the nutritional point of view this is thought to be an advantage since a high proportion of inassimilable raffinose and related sugars are also included under reducing sugars. Fig 6 illustrates the reducing sugar content in bamboo shoots.

The calcium content of fresh shoots varied from 10.00 mg $100g^{-1}$ to 32.67 mg $100g^{-1}$ with the highest and lowest values in *B. bambos* and *B. tulda* respectively. The values obtained are in close agreement with the values reported by Young (1954), Gopalan *et al.* (1994) and NMBA (2009). NMBA (2009) also indicated a calcium content of 14.38 mg $100g^{-1}$ in *D. hamiltonii*, which is almost similar to the value of 15 mg $100g^{-1}$ observed in the present study for *D. hamiltonii*.

The calcium content of all the four species of bamboo shoots decreased significantly during processing. The decrease may be due to the leaching of calcium in water as reported by Gopalan *et al.* (1994). A decrease in the ash content during boiling of bamboo shoots was reported by Kumbhare and Bhargava (2007). The calcium content in fresh and processed shoots are illustrated in Fig 7.

Highest and lowest iron content in fresh shoots was observed in *B. tulda* (0.79 mg $100g^{-1}$) and *D. strictus* (0.22 mg $100g^{-1}$) respectively. *D. hamiltonii* and *B. bambos* had an iron content of 0.72 mg $100g^{-1}$ and 0.24mg $100g^{-1}$ respectively. The iron content of the bamboo shoots observed in the present study was found to be higher than the iron content (0.1 mg $100g^{-1}$) reported by Young (1954) and Gopalan *et al.* (1994) The iron content of the bamboo shoot species in the present study was found to be lower than the value of 0.958 mg $100g^{-1}$ indicated by NMBA (2009). The iron content of 0.72 mg$100g^{-1}$ observed for *D. hamiltonii* in the present study was found to be almost similar to the iron content of 0.958mg $100g^{-1}$ reported by NMBA (2009).

During processing the iron content of bamboo shoots decreased significantly which may be due to the leaching of mineral in the water used for processing. The iron

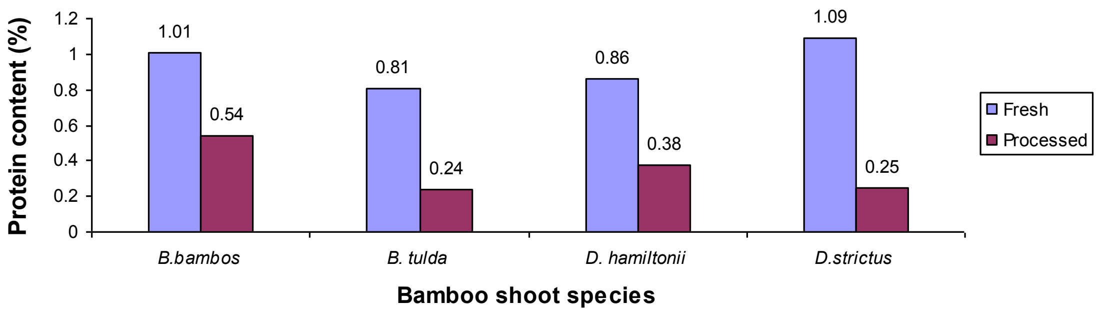

Fig 5. Protein content of fresh and processed bamboo shoots

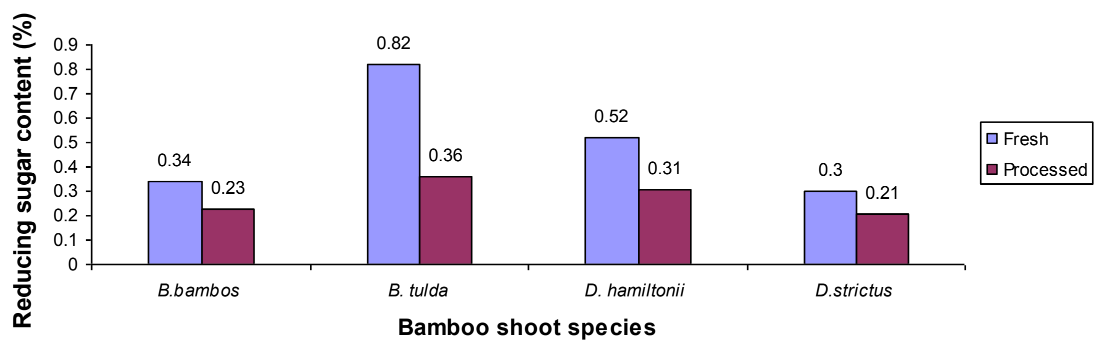

Fig 6. Reducing sugar content of fresh and processed bamboo shoots

content in four species of processed bamboo shoots varied from 0.12 to 0.43 mg $100g^{-1}$ with the highest in *B. tulda* and lowest in *D. strictus*. Fig 8 illustrates the iron content in fresh and processed shoots.

In fresh shoots, the highest potassium content was observed in *D. hamiltonii* (42.33 mg $100g^{-1}$) and lowest content (21.67 mg $100g^{-1}$) in *B. bambos*. *B. tulda* and *D. strictus* had a potassium content of 33.00 mg $100g^{-1}$ and 24.00 mg $100g^{-1}$ respectively. The potassium content of bamboo shoot species in the present study were higher than the potassium content reported by Bhatt *et al.* (2005).

As revealed from Fig 9 decrease in the potassium content was observed in all the four species during processing. Processed shoots of *B. bambos and B. tulda* had the highest (13.00 mg $100g^{-1}$) and lowest (3.00 mg $100g^{-1}$) potassium content respectively. *D. hamiltonii* and *D. strictus* had a potassium content of 10.67 mg 100 g^{-1}.The values obtained for processed shoots showed significant variation from the fresh ones, and the loss in potassium content in processed shoots might be because of the leaching of minerals in water as reported by Gopalan *et al.* (1994).

Fresh shoots of *B. tulda* had the highest sodium content of 37.67 mg $100g^{-1}$ and *D. hamiltonii* had a sodium content of 35.67 mg $100g^{-1}$ (Fig 10). While *B. bambos* and *D. strictus* contained sodium of about 32.00 mg $100g^{-1}$ and 28 mg $100g^{-1}$ respectively .The results of present study were lower than the values observed by Young (1954) who reported a sodium content of 91mg in the tender shoots of *B. bambos.* A significant decrease in the sodium content of bamboo shoots was observed in the present study in all the four species which may be due to the leaching action.

Vitamin C content of bamboo shoots in the range of 2.82 to 3.45 mg $100g^{-1}$ was observed in fresh bamboo shoots which decreased to 1.0 to1.5 mg $100g^{-1}$ on processing. The vitamin C content observed in fresh shoots was found to be lower than the values suggested by Young (1954), Visuphaka (1985), Bhargava and Kumbhare (1996), Gopalan (2004) and Bhatt *et al.* (2005) and higher than the values suggested by NMBA

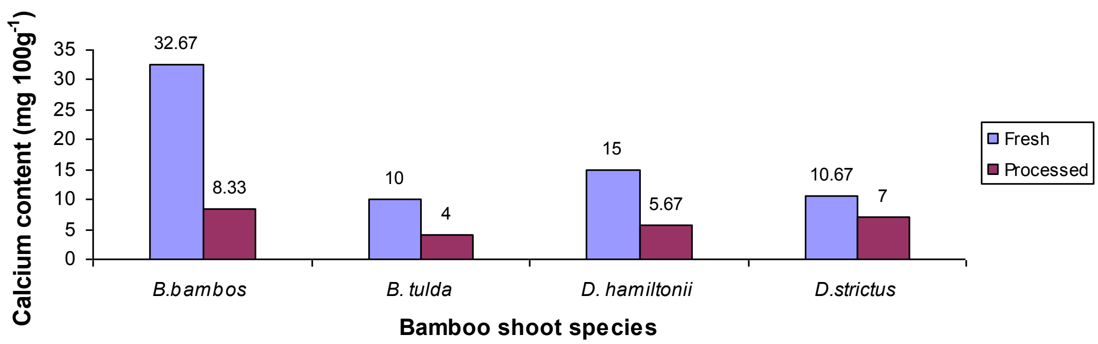

Fig 7. Calcium content of fresh and processed bamboo shoots

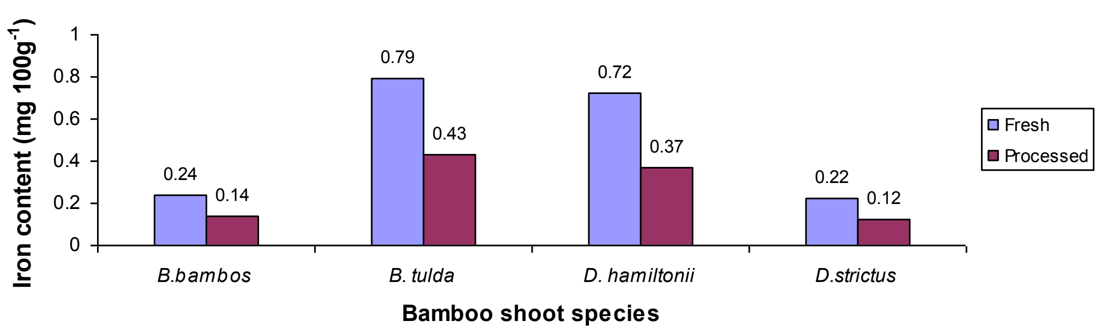

Fig 8. Iron content of fresh and processed bamboo shoots

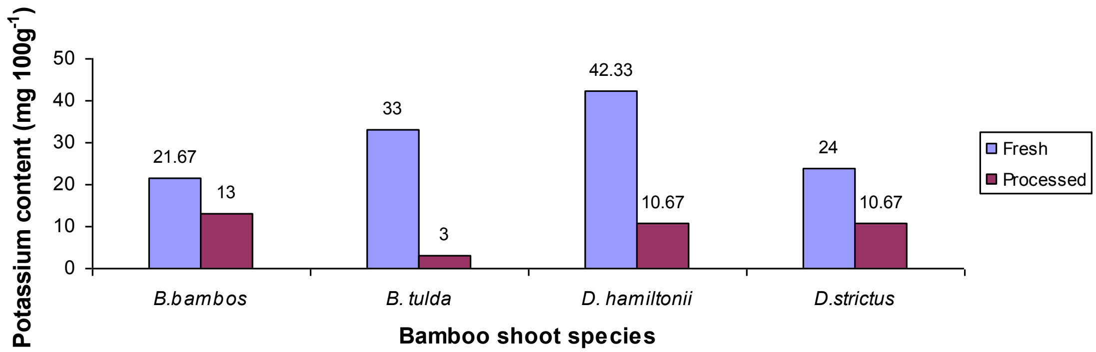

Fig 9. Potassium content of fresh and processed bamboo shoots

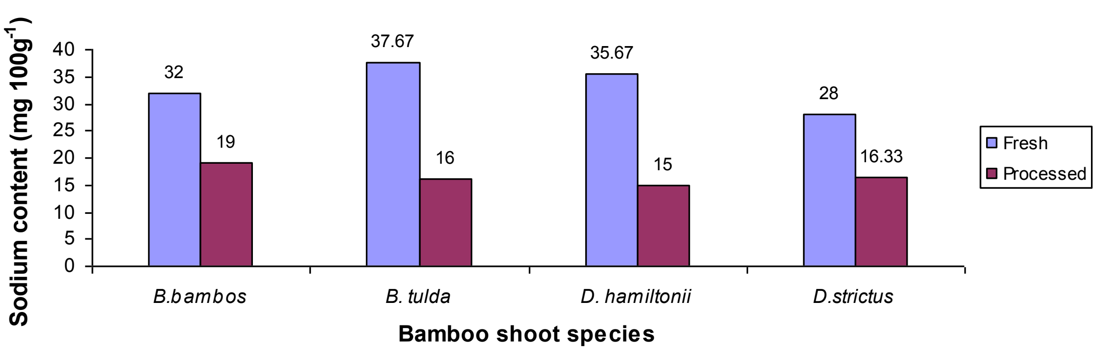

Fig 10. Sodium content of fresh and processed bamboo shoots

(2009). The decrease in vitamin C during processing might be due to their solubility in water and its heat labile nature. The vitamin C content of the shoots is illustrated in Fig 11.

Highest total free amino acid content (0.112 g $100g^{-1}$) was observed in *B. tulda* followed by *B. bambos* and *D. hamiltonii* (0.110 g $100g^{-1}$). As per the findings of Chaozong (1985) the total free amino acids in bamboo shoots reduces with age. The values obtained were similar to the findings of Kumbhare and Bhargava (2007) in *B. nutans* and *D. asper*. However the authors indicated a higher content of 0.70 per cent total free amino acid equivalent of leucine in *D. strictus* which was found to be much higher than the content noticed in *D. strictus* in the present study.

The total free amino acids decreased during processing in all four species of bamboo shoots as indicated in the Fig12. The content varied from 0.01 to 0.02 per cent. Kumbhare and Bhargava (2007) noticed slightly higher total free amino acids in the range of 0.06 to 0.22 per cent in boiled bamboo shoots. The reduction in total free amino acid during processing may be due to the degradation of amino acids due to prolonged heating at high temperature or browning reaction of amino acids. The major change in amino acids that occurs on cooking is due to maillard reaction. Loss of amino acids also takes place through leaching or may react with sugars to form complexes (Meredith and Dull, 1979).

The highest and lowest nitrate content in fresh shoots was found in *B. bambos* (57.97 mg $100g^{-1}$) and *B. tulda* (15.65 mg $100g^{-1}$) respectively. *D. hamiltonii* and *D. strictus* had a nitrate content of 23.19 mg $100g^{-1}$ and 16. 94 mg $100g^{-1}$ respectively.

As revealed from Fig 13 the nitrate content reduced after processing and in different species of processed shoots it varied from 6.90 to 15.74 mg $100g^{-1}$. The reduction in the nitrate content of bamboo shoots during processing may be leaching of nitrates through drained water.

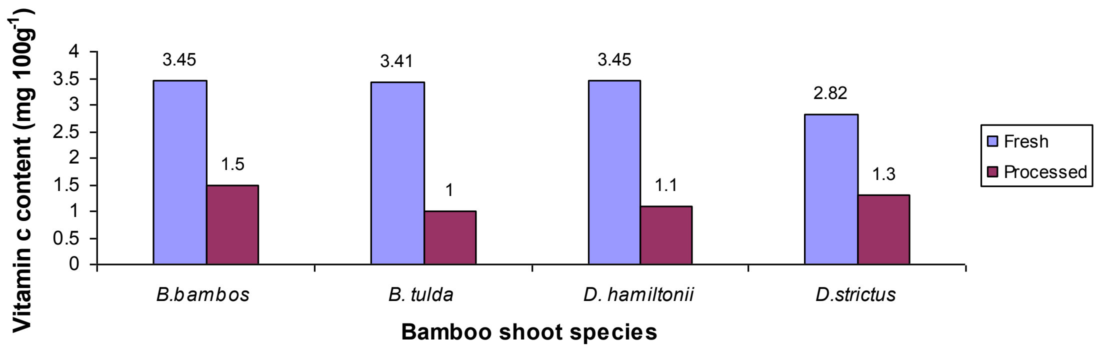

Fig 11. Vitamin C content of fresh and processed bamboo shoots

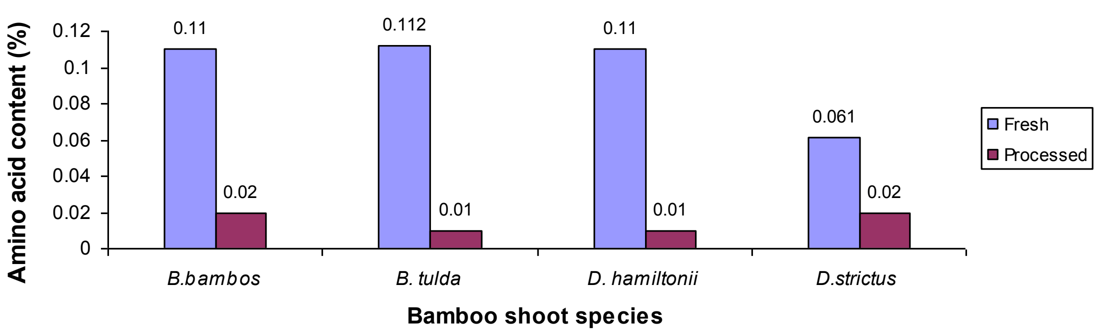

Fig 12. Total free amino acid content of fresh and processed bamboo shoots

The oxalate content in fresh bamboo shoots varied from 49.60 mg $100g^{-1}$ to 101.4 mg $100g^{-1}$ with the highest and lowest value in *B. bambos* and *D. hamiltonii* respectively. *B. tulda* and *D. strictus* had an oxalate content of 78.32 and 85.30 mg $100g^{-1}$ respectively. As illustrated in Fig 14 the oxalate content observed in fresh bamboo shoots was lower than the values reported by Judprasong *et al*. (2006) who indicated above 150 mg $100g^{-1}$ oxalates in *Bambusa spp*.

During processing the oxalate content decreased significantly and the content in different species of processed shoots varied from 11.87 mg to 50.13 mg $100g^{-1}$. Judprasong *et al*. (2006) also indicated a significant decrease in bamboo shoots after boiling.

5.2 Quality evaluation of bamboo shoot products

5.2.1 Organoleptic evaluation of products during storage

The organoleptic evaluation of pickle and vattal prepared with the processed bamboo shoots of *B. bambos* was conducted initially and at monthly intervals for a period of three months. Different quality attributes like appearance, taste, flavour, texture, colour and overall acceptability were evaluated. Changes in the organoleptic qualities of pickle and vattal were observed with the advancement of storage period.

5.2.1.1. Bamboo shoot pickle

Pickle made from bamboo shoot of *B. bamboos* had highest mean score for taste, flavour, texture, colour and overall acceptability at the end of second month of storage. For appearance the highest mean score was recorded initially. Although there was fluctuation in mean score for different quality attributed during storage, mean score above 7.5 was recorded for different quality attributes initially and throughout the storage period. The pickle was found to be highly acceptable at the end of second month of

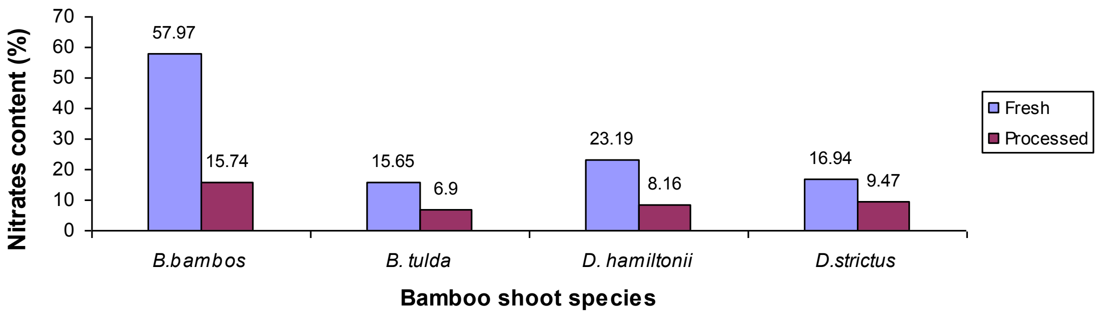

Fig 13. Nitrate content of fresh and processed bamboo shoots

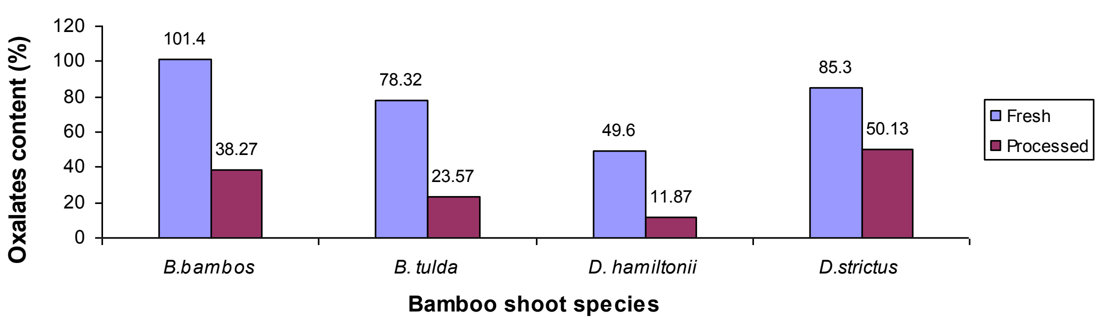

Fig 14. Oxalate content of fresh and processed bamboo shoots

storage. But a mean score above 7.70 was also recorded for different quality attributes at the end of third month of storage.

From this it can be inferred that the bamboo shoot pickle was acceptable even at the end of third month of storage and had good shelf life. NMBA (2009) also reported high acceptability for bamboo shoot pickle among judges. Effect of storage on the quality attributes of pickle stored in glass bottles is illustrated in Fig 15.

5.2.1.2 Bamboo shoot vattal

The vattal prepared by incorporating processed bamboo shoots was found to be highly acceptable initially and during storage. Initially the vattal obtained a mean score of above 7 for different quality attributes with an overall acceptability score of 7.56. During storage a gradual increase in the mean score for different quality attributes were observed with the highest score at the end of third month of storage. John (2001) also reported similar finding in vattal prepared out of banana flowerbud and pseudostem in which the mean scores for different attributes increased upto three months of storage and further decreased towards the end of sixth month of storage. NMBA (2009) indicated that incorporation of bamboo shoot in different recipes were highly acceptable in terms of flavour, appearance, odour, mouth feel and taste. Effect of storage on the quality attributes of vattal stored in polythene bags is illustrated in Fig 15.

5.2.2 Peroxide value of pickle during storage

With respect to the peroxide value of the pickle, an increase was noticed during storage. Increase in peroxide value may be attributed to the oxidation of fatty acids in bamboo shoot pickle by the catalytic activity of common salt, iron impurities that are probably present in the crude salt, proxidant action of moisture and also auto oxidation by atmospheric oxygen (Amano, 1962 and Wheaton and Lawson, 1985). Jishy (2004) also noticed an increase in the peroxide value of fish pickle during storage though there is an increase in the peroxide value during storage it was found to be with in the limit as

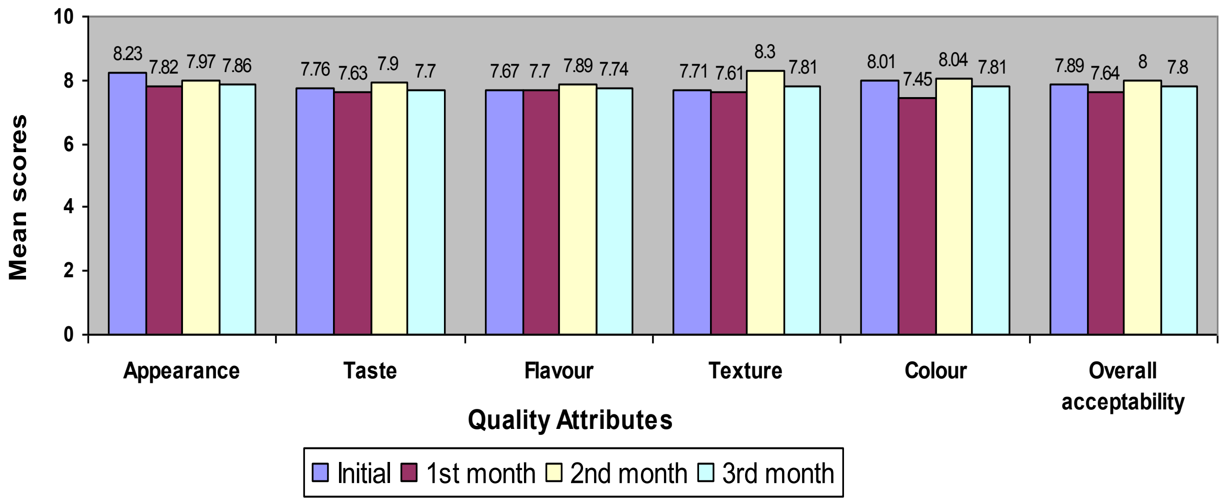

Fig 15. Mean scores for different quality attributes of pickle during storage

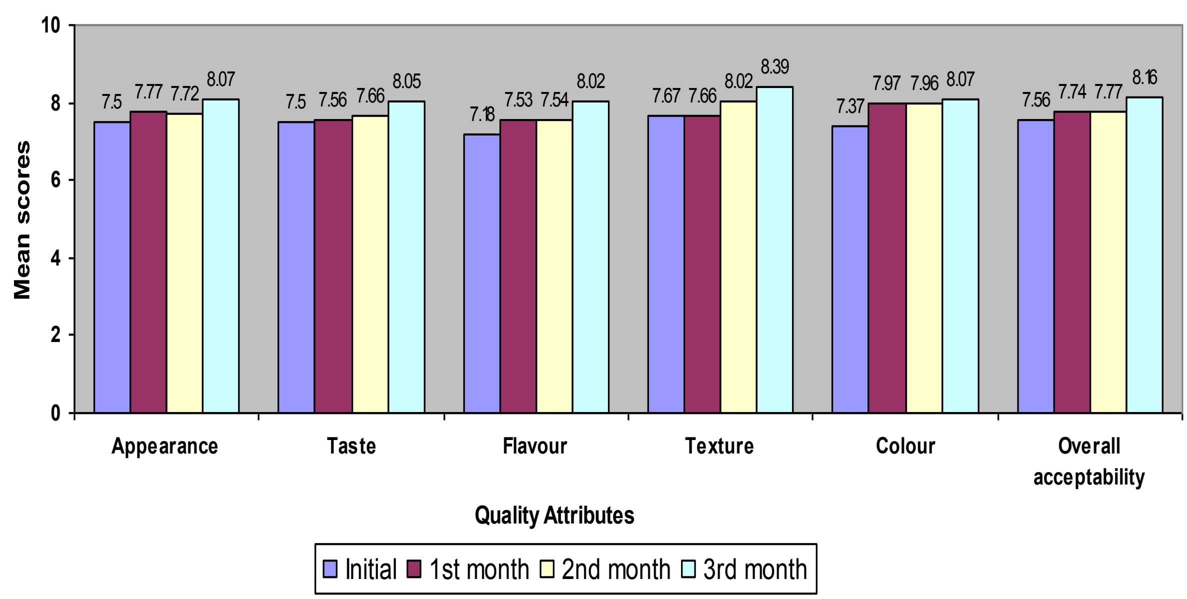

Fig 16. Mean scores for different quality attributes of vattal during storage

described by Mathews *et al.* (1998), who reported that oils having peroxide values less than 10 meq kg^{-1} are free from rancidity and suitable for consumption. This may be the reason for the acceptability of bamboo shoot pickle till the end of storage. The lower peroxide value noticed in the pickle at the end of storage may also be due to the excellent barrier of glass bottles used for packing the pickle as suggested by Gopal (1986).

5.2.3 Enumeration of microbial population of Pickle and Vattal during storage

The quality of the food product depends on the total micro flora present in them. Many organisms causing food borne illness may grow in foods under favourable conditions. According to Bera *et al.* (2001) the growth of fungi and bacteria in the food sample are influenced by moisture content, high or low relative humidity, temperature of storage and type of sample.

In bamboo shoot pickle from the initial bacterial count of 1.88×10^5 cfu g^{-1} the bacterial count increased significantly to 3.66×10^5 cfu g^{-1} at the end of storage. In vattal also the bacterial count increased to 4.77 cfu g^{-1} at the end of storage from the initial count of 1.44 cfu g^{-1} . Though fungal count was not detected in pickle and vattal initially, at the end of storage a fungal count of 0.66 in pickle and 1.96 in vattal was observed. Yeast growth was not detected in both products till the end of storage.

When compared to pickle the bacterial population in vattal was comparatively low initially. However the count increased to 4.77 cfu g^{-1} in vattal at the end of storage which was found to be higher than the count of 3.66 cfu g^{-1} observed in pickle at the end of storage. Low microbial population observed in pickle may be due to low acidity, high salt content and presence of spices which have bactericidal action and the use of gingelly oil. The protective effect of gingelly oil was reported by Davidar (2003). The absence of yeast may be because of the low sugar content in bamboo shoot products. Jishy (2004) also observed low bacterial count in fish pickle initially and during storage. The author also observed fungal growth in fish pickle at third month of storage only. The increase in fungal count during storage may be due to the increase in moisture content of the product as reported by Kapoor and Kapoor (1990).

5.2.4 Evaluation of insect infestation in vattal during storage

Insect infestation was not detected initially and at the end of three month storage which may be due to the appropriate storage conditions used for the study.

SUMMARY

6. SUMMARY

The present study entitled "Quality evaluation and value addition of edible bamboo shoots" was attempted to evaluate the biochemical constituents of both fresh and processed bamboo shoots from four species namely *Bambusa bambos, Bambusa tulda, Dendrocalamus hamiltonii* and *Dendrocalamus strictus.* The study also aimed to evaluate the quality of bamboo shoot pickle and vattal prepared from processed bamboo shoots.

The moisture content in fresh shoots from four species selected for the study varied from 90.53 to 92.27 per cent. In processed shoots the highest and the lowest moisture content was observed in *B. tulda* (95.33 %) and *B. Bambos* (93.27 %) respectively. The moisture content of the processed bamboo shoots varied significantly from the fresh shoots.

Significant increase in the total carbohydrate content of processed bamboo shoots was observed when compared to fresh shoots. In fresh shoots the total carbohydrate content ranged from 1.26 to 2.21 per cent with the highest in *D. hamiltonii* and lowest in *B. tulda* and *D. strictus* respectively. In processed shoots *B. tulda* contained the highest total carbohydrate content (4.49 %) and *D. strictus* the lowest (1.34 %).

The highest crude fibre content in fresh shoots was found in *B. tulda* and *B. bambos* (0.62%) and *D. hamiltonii* had the lowest crude fibre content (0.53 %). In processed shoots the crude fibre content ranged from 0.14 to 0.29 per cent with the highest in *B. bambos* and lowest in *B. tulda* respectively.

In fresh shoots the soluble fibre content varied from 0.02 to 0.03 per cent and in processed shoots soluble fibre content was found to be zero. Fresh shoots from *B. tulda* and *D. strictus* was found to have the highest soluble fibre content and the other two species contained the lowest.

The protein content in fresh shoots varied from 0.81 per cent in *B. tulda* to 1.09 per cent in *D. strictus*. The highest (0.54%) and the lowest (0.24%) protein content in processed shoots were found in *B. bambos* and *B. tulda* respectively. A reduction in the protein content was observed in bamboo shoots after processing.

With regard to the reducing sugar content the highest was observed in fresh shoots from *B. tulda* (0.82%) and lowest in *D. strictus* (0.30 %). A significant decrease in the reducing sugar content was observed after processing and it ranged form 0.21 to 0.36 per cent in processed shoots with lowest in *D. strictus* and highest in *B. tulda.*

Vitamin C content in the fresh shoots ranged between 2.82 and 3.45 mg $100g^{-1}$. The highest content was found in *B. bambos* and *D. hamiltonii* and the lowest in *D. strictus.* In processed shoots the highest (1.5 mg $100g^{-1}$) and the lowest content (1.0 mg 100 g^{-1}) was observed in *B. bambos* and *B. tulda* respectively.

Total free amino acid was found to be high in fresh shoots from *B. tulda* (0.112%) and low in *D. strictus* (0.061%). In processed shoots a decrease in the total free amino acids content was observed and in four species it ranged from 0.01 to 0.02 per cent. Statistically it was found that there was significant difference in the mean amino acid content between fresh and processed bamboo shoots.

The mean calcium content in the fresh shoots from four different species ranged from 10.00 to 32.67 per cent with the highest and lowest in *B. bambos* and *B. tulda* respectively. Lower calcium content was observed in processed shoots with the highest in *B. bambos* (8.33 %) and lowest in *B. tulda* (4.00%).

Fresh shoots of *B. tulda* contained the highest (0.79 mg $100g^{-1}$) and *D. strictus* had the lowest (0.22 mg $100g^{-1}$) iron content. In processed shoots the iron content ranged from 0.12 to 0.43 mg $100g^{-1}$. The iron content of processed shoots differed significantly from fresh ones.

The potassium content in fresh shoots ranged between 21.67 and 42.33 mg $100g^{-1}$ with the highest and the lowest in *D. hamiltonii* and *B. bambos* respectively. Significant decrease in the potassium content was observed in processed shoots with highest in *B. tulda* ($3.00mg100g^{-1}$) and lowest in *D. hamiltonii* and *D. strictus* ($10.67mg100g^{-1}$) respectively.

The sodium content was found to be high in fresh shoots of *B. tulda* ($37.6mg100g^{1}$) and low in *D. strictus* (28.00 mg $100g^{-1}$). A significant reduction in the sodium content of processed shoots was observed and in four species it ranged from 15.00 mg $100g^{-1}$ and 19.00mg $100g^{-1}$ with lowest in *D. hamiltonii* and highest in *B. bambos* respectively.

In terms of nitrates, the highest content of 57.97 mg $100g^{-1}$ and the lowest content of 15.65 mg 100^{-1} was found in *B. bambos* and *B. tulda* respectively. During processing the nitrate content reduced considerably and in different species it ranged from 6.90 mg $100g^{-1}$ to 15.74 mg $100g^{-1}$.

The highest and lowest oxalate content in the fresh shoots was found in *B. bambos* (101.4 mg $100g^{-1}$) and *D. hamiltonii* (49.60 mg $100g^{-1}$) respectively. During processing the oxalate content decreased and in processed shoots it ranged between 11.87 to 50.13 mg $100g^{-1}$.

Selection of suitable species for the product development was carried by ranking the four species based on their nutritional and anti nutritional constituents. *B. bambos* was selected as the most suitable species for product preparation taking into consideration its nutritional qualities and availability. Two products namely pickle and vattal were prepared from processed shoots of *B. bambos.*

In bamboo shoot pickle, the highest mean score for different quality attributes was observed at the end of second month of storage expect for appearance. The mean score for different quality attributes decreased towards the end of third month of storage and varied from 7.70 to 7.80 among different attributes. Judges had significant agreement in differentiation of texture and colour of pickle and lesser order of agreement was observed in case of appearance, taste, flavour and overall acceptability of pickle The pickle was found to be highly acceptable at the end of second month of storage..

In bamboo shoot vattal , the highest mean score for different quality attributes was observed at the end of third month of storage and they had good shelf life. The judges had significant agreement in differentiation of parameter namely flavour, texture, colour and overall acceptability over the months of storage.

The peroxide value of pickle increased during storage. The increase in peroxide value may be attributed to the oxidation of fatty acids present in bamboo shoot pickle.

The microbial enumeration of pickle stored in glass bottles and vattal in polythene bags revealed that the bacterial population increased significantly during storage. The fungal population was detected only from third month of storage both in pickle and vattal. Growth of yeast was not detected in both products.

In vattal, insect infestation was not observed during the period of storage.

Fresh bamboo shoots were found to be a good source of nutrients especially minerals. Primary processing considerably reduced the nutritional qualities of bamboo shoot. Processing of shoot is an inevitable step before consumption because it helps to reduce the anti nutrients in shoots. In the present study, the bamboo shoot products showed fluctuation in acceptability score during the entire period of storage. So storage studies for longer duration are required before recommendation. Bamboo shoots are gaining popularity in Indian cuisines as a delicacy and it is mainly due to the acceptable taste and health benefits associated with its consumption. Being a lesser known food product, bamboo shoot processing has potential to be developed as an innovative and promising enterprise.

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APPENDIX

APPENDIX – I

Recipe for the preparation of bamboo shoot pickle

Ingredients:

Bamboo shoots	- 500g
Gingelly oil	- 150 ml
Kala jeera	- 5g
Jeera powder	- 10g
Methi	- 10g
Garam masala	- 5g
Powdered mustard seed	- 15g
Vinegar	- 50ml
Red chilly powder	- 25g
Salt	- 50g
Turmeric powder	- 10g
Sauf	- 10g
Sodium benzoate	- 0.5g

Procedure:

After heating oil, spices, salt and sugar were added followed by processed bamboo shoots and stirred. While stirring continuously vinegar was added and mixed well. After cooling, sodium benzoate was added and mixed thoroughly and packed in air tight glass bottles (Cane and bamboo technology center, 2007)

Amount of final product – 820g

APPENDIX – II

Recipe for the preparation of bamboo shoot vattal

Ingredients:

Bamboo shoot	- 200g
Raw rice	- 100g
Pepper powder	- 2g
Salt	- to taste

Procedure:

Rice was soaked in water for one hour. After draining the water rice was a ground to a smooth paste. The batter was cooked to form a smooth paste. The sliced and processed bamboo shoots were added and cooked for 2 minutes with sufficient salt. Finally, pepper powder was added and stirred well. A spoon full of batter was flattened on a tray and dried in an electric oven at 70° C. After drying, the vattals were packed in polythene bags of 250 gauge thickness (Pavunny, 1996).

Amount of final product -112g

APPENDIX – III

Score card for organoleptic evaluation of bamboo shoot pickle

Name of the judge:
Date :

Characteristics	Score		
	1	**2**	**3**
Appearance			
Taste			
Flavour			
Colour			
Texture			
Over all acceptability			

9 point Hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Signature:

APPENDIX – IV

Score card for organoleptic evaluation of bamboo shoot vattal

Name of the judge:
Date :

Characteristics	Score		
	1	**2**	**3**
Appearance			
Taste			
Flavour			
Colour			
Texture			
Over all acceptability			

9 point Hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Signature:

ABSTRACT

Abstract

The study on "Quality evaluation and value addition of edible bamboo shoots" was undertaken to evaluate the bio chemical constituents of fresh and processed bamboo shoots from four species namely *Bambusa bambos, Bambusa tulda, Dendrocalamus hamiltonii* and *Dendrocalamus strictus.* Two products were prepared from processed bamboo shoots and storage studies were carried out to find out changes in organoleptic and shelf life qualities.

Among the four species evaluated, fresh shoots of *B. tulda* had the highest content of crude fibre, soluble fibre, reducing sugar, iron, sodium and total free amino acids. Highest content of nitrates and oxalates were recorded in fresh shoots of *B. bambos*.

In processed shoots, the highest content of fibre, protein, calcium, potassium, sodium and nitrates were observed in *B. bambos*. Processed shoots of *D. strictus* had the highest oxalate content.

In fresh shoots, significant variation among the four species was observed in reducing sugar, potassium, sodium and oxalate content, where as in processed shoots significant variation among species was noted only in total carbohydrates, reducing sugar and oxalate content. Fresh and processed shoots from four species were found to be a poor source of vitamin C.

A significant decrease in biochemical constituents was observed in the four species of bamboo shoots after processing except for moisture and total carbohydrates, which increased significantly on processing. The anti nutritional factor viz., nitrates and oxalates were also reduced significantly in the four species of bamboo shoots on processing.

B. Bambos was selected as the ideal species for product development taking into consideration its nutritional qualities and availability. Two products namely pickle and

vattal were prepared from processed shoots of *B. Bambos* and the quality attributes were studied for a period of three months.

Pickle made from bamboo shoot of *B. bamoos* had the highest mean score for taste, flavour, texture, colour and overall acceptability at the end of second month of storage. Although there was fluctuation in mean score for different quality attributes during storage, mean score above 7.5 was recorded for different attributes initially and throughout the storage period. The pickle was found to be highly acceptable at the end of second month of storage.

The vattals prepared by incorporating processed bamboo shoots were found to be highly acceptable initially and during storage. Initially the vattals obtained a mean score of above 7 for different quality attributes with an overall acceptability score of 7.56. During storage a gradual increase in the mean score for different quality attributes were observed with the highest score at the end of third month of storage.

The peroxide value of pickle increased during storage. The increase in peroxide value may be attributed to the oxidation of fatty acids present in bamboo shoot pickle.

The microbial enumeration of pickle stored in glass bottles and vattal in polythene bags revealed that the bacterial population increased significantly during storage. The fungal population was detected only at the end of third month of storage both in pickle and vattal. Growth of yeast was not detected in both products throughout the storage peroid.

In vattal, insect infestation was not observed during the period of storage.