Chapter 5

Influence of fermentation on bamboo shoot quality with and without addition of *Garcinia pedunculata* Roxb. fruit
5.1 Introduction

Bamboo shoots are young edible sprouts that come out from the ground. Tender young shoots are edible and are very popular in the traditional cuisines of various tribes and communities of South, South-East and East Asia. They are mainly used fresh, dried, shredded, canned, pickled or fermented.\(^1\) A total of 17 amino acids are present in bamboo shoots, out of which eight are essential for the human body.\(^2\) Minerals mainly consisting of chromium, copper, iron, potassium, calcium, manganese, zinc, less amounts of phosphorus, and selenium are found in bamboo shoots.\(^3\) The lipid content of shoot is very less and the main fatty acids present in lipid are palmitic, linoleic and linolenic acids.\(^4\) Both fresh and fermented bamboo shoots are rich in vitamins and phytosterols. Phytosterols act as nutraceuticals\(^5\) and are precursors of many pharmaceutically active steroids found in plants.\(^6\)

Fermented bamboo shoot is an important part of the traditional foods in the Northeastern state of India. Fermentation of bamboo shoots not only helps to extend storage life but also enhanced safety of foods using the natural microflora and their antibacterial compounds. Such traditional fermented food will be a potential source of lactic acid bacteria.\(^7\)-\(^8\) It also adds specific flavour, aroma and taste to the fermented product. Khorisa is a traditional fermented bamboo shoot product of Assam, India and it is important part of diet of both rural and urban people and is extensively used as a main ingredient in different food items like meat, fish preparations, preparing pickles etc. In the process of khorisa fermentation, small quantities of dried fruit of \textit{Garcinia pedunculata} Roxb. (Local name: Borathedkera) are added along with the shoot for fermentation, as a possible acidifier. The fruit of the garcinia tree is globose in shape and is 8-12 cm in diameter with fleshy aril. The fruit is used by the indigenous people as an antiscorbutic, astringent, cooling, cardiotonic and emollient.\(^9\) The fruit is rich in antioxidants, but has low phenolic compounds.\(^10\)

Effects of bamboo shoot fermentation and aging on nutritional and sensory qualities of Soibum, a traditional fermented bamboo shoot product of Manipur (India) were studied by Giri and Janmejay.\(^11\) The changes in nutrient contents and texture of bamboo shoots during pickling process were studied by Zheng et al.\(^12\) However, the studies on fermentation and microbiology of \textit{khorisa} is yet be made. Therefore the present investigation was undertaken to examine the physicochemical...
and microbial changes during the fermentation of young bamboo shoots in the process of making \textit{khorisa}. The study also makes a comparison between the two types of \textit{khorisa} viz. fermented with and without the use of \textit{Garcinia pedunculata} Roxb., with reference to its nutritional and safety point of view.

5.2 Materials and methods

5.2.1 Materials

Bamboo shoots (\textit{Bambusa balcooa}) were collected from Nagaon, Assam, India. The shoots were transported to the laboratory within 24 h of collection, and then shoots were defoliated and washed. The unwanted parts were removed and the soft edible portions were stored at 4\textdegree C for further analysis. The fresh shoot was subjected to chemical analysis, and then they were used to prepare \textit{khorisa}. Mature \textit{Garcinia pedunculata} Roxb. was harvested from local horticultural orchard of Nagaon, Assam (India), and transported to the laboratory within 24 h. They were washed, shredded uniformly and dried in a cross airflow tray drier (IKON, India) at 40 \textdegree C for 24 h (moisture content 12\%) and kept in sterile containers and stored at 4 \textdegree C till further use.

All microbiological growth media, supplements, anaerobic system (Mark II), anaerobic gas packs (3.5 litre) and anaerobic indicator tablets were obtained from HiMedia Laboratories (India). Acetonitrile (HPLC grade) and 2, 2-diphenyl-1-picrylhydrazyl (DPPH) were obtained from Merck (Darmstadt, Germany). Water used in all the experiments was double distilled and deionised (Elix Millipore Water Purification System, USA). The carbohydrate standards (raffinose, trehalose, maltose, sucrose, melibiose, lactose, glucose, xylose, galactose, rhamnose, inositol, arabinose and fructose) and organic acid standards (oxalic acid, tartaric acid, formic acid, pyruvic acid, lactic acid, acetic acid, citric acid, succinic acid, propionic acid) were of HPLC grade and obtained from Sigma (Sigma Aldrich, USA). All other chemicals used in the study were obtained from Merck (India).

5.2.2 Bamboo shoot fermentation and its kinetics

The fermentation of bamboo shoot was carried out in two batches in two replicates. In first batch bamboo shoots were grated and packed tightly in pre-sterile 500g capacity glass jars (Batch-1) and in the second batch pieces of \textit{Garcinia}
pedunculata Roxb. were mixed (1%) along with grated bamboo shoot and packed in pre-sterile 500g capacity glass jars (Batch-2). The glass jars were incubated at 32°C in an incubator (New Brunswick Scientific, USA) for a period of 12 days for natural anaerobic fermentation. Fermentation kinetics was studied for a period of 12 days at regular intervals of 48 hours (2 days) for both the batches. Each batch consists of 7 jars to avoid cross contamination. One jar was taken out at an interval of 2 days from each batch and analyzed variation in pH, acidity, total phenol, antioxidant activity, reducing sugar and microbial count. The methods are discussed below.

5.2.3 Proximate analysis

Fresh and fermented bamboo shoots were analyzed for moisture, ash, protein, carbohydrate and fat, according to the standard AOAC\textsuperscript{13} methods. The nitrogen content was converted to protein by multiplying with a factor of 6.25. Vitamin C was estimated on fresh shoot by titrating against 4% oxalic acid using 2, 6-dichlorophenolindophenols (DCPIP) as indicator.\textsuperscript{14}

5.2.4 Estimation of total phenolics and antioxidant activity

Sample (1 g) was extracted with 10 ml of 80% methanol and centrifuged at 10000g at room temperature. Residue was reextracted (five times) with of 80% methanol and centrifuged. Supernatant was collected and used for the analysis of total phenolics and antioxidant activity. The total phenolics in the sample were estimated using Folin-Ciocalteu reagent (FCR) as described by Bray and Thorpe.\textsuperscript{15} Supernatant was evaporated to dryness and residue was dissolved in 5 ml distilled water and aliquots (0.2-2 ml) were taken in different test tubes and final volume of 3 ml was made using distilled water. FCR (0.5 ml) was added and after 3 minutes 2 ml of 20% sodium carbonate was added to each test tube. The mixture was heated on a water bath at 100°C for 1 minute and then cooled. Absorbance was measured at 650 nm in spectrophotometer (Spectronic 20D\textsuperscript{+}, Thermo Scientific, USA). The results were expressed as mg phenol/ 100 g of sample as catechol equivalent.

Free radical scavenging activity was used to measure the total antioxidant activity by using 2, 2-diphenyl-1-picrylhydrazyl (DPPH) assay method. DPPH is a commercial oxidising radical used to be reduced by antioxidants. The disappearance of the DPPH radical absorption at a particular wavelength is monitored by the
reduction in optical density. Methanolic extract of bamboo shoot (20 µL) was mixed with 1.5 ml of DPPH solution (0.025 g DPPH in 1000 ml of methanol) and the tubes were vortexed (Vortex Shaker, LaboTech, India) immediately and allowed to react for 45 minutes in a dark environment at room temperature. The control was prepared without the addition of any sample for baseline correction. Absorbance was measured at 517 nm in a spectrophotometer (Spectronic 20D+, Thermo Scientific, USA). The free radical scavenging activity was expressed as inhibition percentage and calculated by using the following equation.16

\[
\text{% Free radical scavenger activity} = \left(\frac{\text{Control absorbance} - \text{Sample absorbance}}{\text{Control absorbance}}\right) \times 100
\]

5.2.5 Estimation of pH and acidity

Sample (10 g) was blended for 15 min with 100 ml double distilled water in a homogenizer (Remi, Mumbai, India). The pH of the slurry was determined using a pH meter (PH 510 Eutech Instruments, Cyberscan, Malaysia) calibrated with standard buffer solution (Merck, Mumbai, India). Titratable acidity was estimated by titrating the filtrate (10 ml) of the slurry with 0.1 N NaOH solution using phenolphthalein as indicator (0.1% w/v in 95% ethanol). Titratable acidity was expressed in mg lactic acid equivalent per gram of sample.13

5.2.6 HPLC analysis

Organic acids and carbohydrate profile of fresh and fermented bamboo shoot of both the batches were determined using HPLC system (Dionex Ultimate 3000, Germany). Organic acids were quantified using UV detection of 210 nm, on Hamilton OA C18-column and mobile phase was 0.2M sodium sulphate, adjusted with methanesulphonic acid to pH of 2.68. Standard organic acids used for analysis were oxalic acid, tartaric acid, formic acid, pyruvic acid, lactic acid, acetic acid, citric acid, succinic acid and propionic acid.17 Carbohydrates were analysed using RI detection on Hamilton Ca-column using water as a mobile phase. Flow rate and column temperature was 0.6 ml/min and 30°C respectively for both analyses. Standard sugars used for analysis were raffinose, trehalose, maltose, sucrose, melibiose, lactose, glucose, xylose, galactose, rhamnose, inositol, arabinose and fructose.18-19 Stock and standard solutions of organic acids were prepared in
acetonitrile:water (80:20), and those of carbohydrates were prepared in water. Calibration curve were prepared using two different concentrations of each standard. Thus, a calibration curve was prepared for each organic acid and carbohydrate.

5.2.7 FTIR spectroscopy

The infra-red spectra for all the samples were obtained with a FTIR spectrometer (PerkinElmer, USA). The equipment was operated with scanning range of 4000 –450 cm$^{-1}$ and spectrum of 100. Sample (clear glassy disk) for FTIR analysis were prepared by mixing powdered sample with IR grade KBr using suitable press at around 12,000 psi pressure.

5.2.8 Microbial analysis

Fermented sample weighing 11 g was blended in 99 ml double distilled sterile 0.89% (w/v) sodium chloride diluents by use of a Stomacher lab-blender 400 (Seward Medical, London, UK) for 3 minutes. Appropriate serial dilutions were made and plated on plate count agar (PCA) for total plate count, the plates were incubated at 36°C for 36-48 h. Potato dextrose agar (PDA) supplemented with 10% sterile tartaric acid solution was used for yeast and mould count, the plates were incubated at 27°C in a dark environment for 36-48 h. Lactobacillus MRS agar supplemented with 3% CaCO$_3$ and 0.1% bromocresol purple indicator solution was used for estimation and enumeration of lactic acid producing bacteria. The plates were incubated at 36°C for 48-72 hours inside an Anaerobic System (Mark II) with anaerobic gas packs and anaerobic indicator tablets. The colonies that appeared were counted as colony forming units (CFU) per gram wet weight of sample.

5.2.9 Statistical analysis

All analyses were performed in triplicate and data were reported as mean ± SD. The data was assessed by analysis of variance (ANOVA) and Duncan’s multiple range test. Statistical significance was defined at $p \leq 0.05$. 

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5.3 Results and discussion

5.3.1 Influence of fermentation on nutrients

Fresh and fermented shoot were analysed for various biochemical parameters, and the results are shown in Table 5.1. Fat content of fresh shoot was very low (0.67%), thus very less changes were observed in fermented shoot. The protein content decreased from 3.78% to 2.40% after fermentation, this may be due to denaturation of protein. Carbohydrate which is an ideal source of energy content decreased in shoots after fermentation; it may be due to use of available carbohydrate by the microorganisms. The content of carbohydrate in fresh shoot was 4.50% which decreased to 1.45% and 1.39% in batch-1 and batch-2 respectively. Ash content was 0.86% and no significant change was observed during fermentation.

Vitamin C content was found less in the fermented shoots than the fresh shoots, but the reduction is more in batch-1 than batch-2. Total phenolics content were found to be increased 2-3 fold after fermentation. Fresh shoot having phenolics content of 97.5 mg increased to 255 mg and 239 mg/100g in batch-1 and batch-2 respectively. However, antioxidant activity was recorded to be higher in fermented shoots (49.20 and 55.35% DPPH RSA for batch-1 and batch-2), as antioxidant capacity of bamboo shoot is closely related to L-ascorbic acid and total phenolic compounds. The drop in pH and increase in acidity were also recorded in both the batches.

5.3.2 Fermentation kinetics of Khorisa

Fermentation kinetics for both the batches was studied for a period of 12 days at regular intervals of 48 hours (2 days). Each sample was analyzed for variation in pH, acidity, total phenol, antioxidant activity, reducing sugar and microbial count as discussed below.

5.3.2.1 Change in pH

The decrease in pH was directly proportional to the increase in fermentation time (Fig.5.1). The pH of khorisa decreased during fermentation, from initial values of 6.40 to 4.52 and 4.09 for batch-1 and batch-2 respectively. Decrease in pH is mainly because of lactic acid fermentation of bamboo shoot. Drop in pH was more
**Table 5.1.** Chemical composition of fresh and fermented shoot

<table>
<thead>
<tr>
<th></th>
<th>Fat (%a)</th>
<th>Protein (%)</th>
<th>Carbohydrate (%)</th>
<th>Ash (%)</th>
<th>Vitamin C (mg/100g)</th>
<th>Total phenolics (mg/100g)</th>
<th>Antioxidant activity (%DPPH)</th>
<th>pH</th>
<th>Acidity (% LA)</th>
<th>Reducing sugars (g/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh Shoot</td>
<td>0.67±0.8b</td>
<td>3.78±1.4a</td>
<td>4.50±1.0a</td>
<td>0.86±0.05a</td>
<td>2.45±0.5a</td>
<td>97.5±4.2a</td>
<td>26.67±1.6a</td>
<td>6.40±0.15a</td>
<td>0.89±0.25a</td>
<td>1.37±0.05a</td>
</tr>
<tr>
<td>Khorisa (Batch-1)</td>
<td>0.44±0.1b</td>
<td>2.56±0.8b</td>
<td>1.45±1.2b</td>
<td>0.83±0.01b</td>
<td>1.09±0.2b</td>
<td>255±4.4b</td>
<td>49.20±1.5b</td>
<td>4.52±0.19b</td>
<td>2.82±0.16b</td>
<td>0.32±0.06a</td>
</tr>
<tr>
<td>Khorisa (Batch-2)</td>
<td>0.41±0.2b</td>
<td>2.40±0.5b</td>
<td>1.39±0.9b</td>
<td>0.81±0.02b</td>
<td>1.37±0.3b</td>
<td>239±5.2b</td>
<td>55.35±1.2b</td>
<td>4.09±0.23b</td>
<td>3.75±0.19c</td>
<td>0.26±0.09a</td>
</tr>
</tbody>
</table>

All data are the mean ± SD of three replicates. Mean followed by different letters in the same column differs significantly (P ≤ 0.05). n=3
Influence of fermentation on bamboo shoot quality with and without addition of Garcinia pedunculata Roxb. It acts as an acidulant and enhances the fermentation. The end product khorisa was sour in taste with a typical fermented flavour. Above results are comparable with pH of some fermented bamboo shoot products of North East India like mesu, soidon, soibum, soijim, ekung, eup and hirring having average pH of 3.9, 4.2, 4.2, 4.1, 3.9, 4.1 and 4.0 respectively.\textsuperscript{22-23} During the manufacturing of jiang-sun (fermented bamboo shoots product of Taiwan), a pH of 4.2 was also observed in the day-1 fermented sample, and a pH of 3.5 was observed in the 30-day sample.\textsuperscript{24} Medoua et al.\textsuperscript{25} reported that, during first two days of natural fermentation of yam (\textit{Dioscorea dumetorum}) hardened tubers, pH decreased from 5.5 to 4.8 and then to 3.9 after 14 days of fermentation.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Fig5.1.pdf}
\caption{Change in pH and acidity of bamboo shoot during fermentation.}
\end{figure}

\subsection*{5.3.2.2 Change in acidity}

Acidity was measured on the basis of \% lactic acid. Increase in the acidity was found in both batches. However, distinct differences were observed in their changes over time. In batch-1 acidity changed from 0.89\% to 2.82\% whereas, it was slightly higher for batch-2, and values changed from 0.89\% to 3.75\% (Fig.5.1). The relative increase in high acidity could be due to the lactic acid production during fermentation of
bamboo shoot. Analysis of variance showed a significant effect (p≤0.05) of fermentation time on titratable acidity. Similar trend was reported for *Dioscorea dumetorum* hardened tubers.\(^{25}\)

### 5.3.2.3 Change in total phenol content

Change in total phenol content was observed from 97.5 to 255.0 and 239.0 mg catechol equivalent/100g for batch-1 and batch-2 respectively. Analysis of variance showed a significant effect of the fermentation time. There was an exponential increase in total phenols level with fermentation time (Fig.5.2). Phenolics are usually found in conjugated forms through hydroxyl groups with sugar and glycosides in plant materials and these may catalyze during fermentation and thus lead to an increase in the content of total phenolics.\(^{26}\) However, Luo et al.\(^ {27}\) reported that, total phenolic content of control and salicylic acid treated bamboo shoot increased progressively during storage at 1°C.

![Fig. 5.2. Change in total phenol of bamboo shoot during fermentation. Vertical bars represent standard errors of means, n = 3.](image)

### 5.3.2.4 Change in antioxidant activity (% DPPH RSA)

Antioxidant activity increased with time of fermentation. Values were observed to increase from 26.67 to 49.20 % for batch-1 and 55.30 % batch-2. However, after 8 days there was very less change observed in both the batches but DPPH radical scavenging activity increased more for batch-2 (Fig.5.3). The results were inclining
with the antioxidant activity of lactic-fermented *Anoectochilus formosanus* (traditional Asian herb) ranged from 61% to 78%\(^{28}\).

**Figure 5.3.** Change in antioxidant activity of bamboo shoot during fermentation. Vertical bars represent standard errors of means, n = 3.

### 5.3.2.5 Change in reducing sugars content

Reducing sugars like glucose is the most important substrate for microbes to undergo fermentation. Understanding the dynamics of reducing sugars will also enable to understand the fermentation mechanism. There was a sharp decrease in the reducing sugars content recorded during initial 8 days fermentation and after that it became slow. Reduction was noted from 1.37 to 0.32 g/100g for batch-1 and 1.37 to 0.26 g/100g for batch-2 (Fig. 5.4). Pérez-Gregorio et al.\(^{29}\) also reported similar observation in reducing sugar, during mulberries fermentation.
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Fig. 5.4. Change in reducing sugars of bamboo shoot during fermentation. Vertical bars represent standard errors of means, n = 3.

5.3.2.6 Microbial analysis

Microbial kinetics of both the batches for total plate count (TPC), yeast and mould and lactic acid bacteria (LAB) are given in Fig. 5.5. At the onset of fermentation TPC increased manifolds and it was maximum at 6th day (6.95 log cfu/g) for batch-1 and at 4th day (7.20 log cfu/g) for batch-2, but afterward TPC decreased or almost stable in both the cases. Yeast and mould count increased from 5.18 to 6.00 log cfu/g for batch-1 and 5.18 to 6.18 log cfu/g for batch-2 upto 6th day, and afterwards it declined. At the end of 12th day, count was 4.46 and 4.51 log cfu/g for batch-1 and batch-2. LAB is mainly responsible for fermentation and imparts sour test development because of lactic acid production. LAB count was observed high during onset of fermentation and it increased till 6th day of fermentation. The values changed from 5.24 to 6.93 and 7.04 log cfu/g for batch-1 and batch-2 respectively. Growth of LAB decreased from 6th day onwards for both the batches. Similar LAB growth was also observed in other studies on lactic acid fermentation on different products.24, 30-31 The decreased in microbial count attributed to both drop in pH of the fermented product and production of antimicrobial biometabolites by the dominant lactic acid bacteria.
5.3.3 HPLC analysis of organic acids and carbohydrates

HPLC results evinced the presence of oxalic acid, tartaric acid, formic acid, pyruvic acid and lactic acid in fresh bamboo shoot. However, in fermented shoots, oxalic acid and pyruvic acid were found absent in batch-1 as well as oxalic acid and formic acid was found absent in batch-2 (Table 5.2). But the concentration of acids present in fermented shoots was found to increase. Lactic acid concentration in fresh shoot is 2.824 mg/g, which increased to 37.030 mg/g for batch-1 whereas it increased to 39.492 mg/g for batch-2. This is mainly because of lactic acid fermentation of shoot by lactic acid bacteria. Concentration of tartaric acid also found to increase from 1.733 mg/g to 32.041 mg/g and 51.021 mg/g for batch-1 and batch-2 respectively. However, other acids like acetic acid, citric acid, succinic acid and propionic acid were found absent in all the samples.

HPLC analysis of carbohydrates showed the presence of raffinose, sucrose, glucose, galactose and inositol in fresh bamboo shoot. Although raffinose, sucrose and glucose were not found in fermented shoot (batch-1), however, trehalose was recorded...
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during fermentation (Table 5.2). Concentration of galactose was recorded high in fermented shoot. Fresh shoot showed galactose concentration of 2.296 mg/g which increased to 31.277 mg/g and 23.480 mg/g for batch-1 and batch-2 respectively. Raffinose and glucose were retained in batch-2. Concentration of raffinose was quite high in batch-2 compared to fresh shoot, but glucose concentration gets diminished. The change in the concentration of different carbohydrates might be due to their utilization by the group of lactic acid bacteria during their cellular metabolism. However, other sugars like maltose, melibiose, lactose, xylose, rhamnose, arabinose and fructose were found absent in all the samples. Kozukue et. al.\textsuperscript{32} reported the presence of major organic acids viz., oxalic, citric and malic acid as well as sugars viz., fructose, glucose and sucrose in raw bamboo shoots (\textit{Phyllostachys pubescens}). However, during this study citric acid, malic acid and fructose were not detected.

\textbf{Table 5.2} Characteristics of organic acids and carbohydrates present in fresh and fermented bamboo shoots.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Ret. time (Min)</th>
<th>Peak name</th>
<th>Amount (mg/g)</th>
<th>Fresh shoot</th>
<th>Khorisa (Batch-1)</th>
<th>Khorisa (Batch-2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Acids</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3.89</td>
<td>Oxalic Acid</td>
<td>0.001</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>2</td>
<td>4.29, 4.23</td>
<td>Tartaric Acid</td>
<td>1.733</td>
<td>32.041</td>
<td>51.021</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4.53, 4.57</td>
<td>Formic Acid</td>
<td>0.012</td>
<td>2.965</td>
<td>ND</td>
<td>0.452</td>
</tr>
<tr>
<td>4</td>
<td>4.63</td>
<td>Pyruvic Acid</td>
<td>0.037</td>
<td>ND</td>
<td>16.741</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>4.93, 4.89</td>
<td>Lactic Acid</td>
<td>2.824</td>
<td>37.030</td>
<td>39.492</td>
<td></td>
</tr>
<tr>
<td>Carbohydrates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>8.42, 8.70</td>
<td>Raffinose</td>
<td>0.092</td>
<td>ND</td>
<td>11.022</td>
<td>ND</td>
</tr>
<tr>
<td>2</td>
<td>8.80</td>
<td>Trehalose</td>
<td>ND</td>
<td>11.022</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>9.16</td>
<td>Sucrose</td>
<td>0.514</td>
<td>ND</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>10.35, 10.37</td>
<td>Glucose</td>
<td>23.801</td>
<td>ND</td>
<td>13.119</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>11.80, 11.82, 11.73</td>
<td>Galactose</td>
<td>2.296</td>
<td>31.277</td>
<td>23.480</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>14.22, 14.12, 14.02</td>
<td>Inositol</td>
<td>0.131</td>
<td>0.201</td>
<td>0.223</td>
<td></td>
</tr>
</tbody>
</table>

ND – Not Detected
5.3.4 FTIR analysis

The FTIR spectrum pattern of shoot revealed six different peaks between 4000 and 800 cm\(^{-1}\) (Fig. 5.6). All characteristic peaks were observed in fresh and fermented samples. However, slight changes in peak intensities were observed in the fermented shoot. Gradual changes in the positions of the peak from 1650.63 (fresh shoot) to 1627.75 (batch-1) and 1626.72 (batch-2) was observed, corresponding to the stretching vibration of C=C bond. The changes were affected significantly by the fermentation of shoot. The peak assignment for identified peak and their related compounds present in fresh and fermented bamboo shoots are shown in Table 5.3.

![Figure 5.6](image)

**Fig. 5.6.** FTIR spectrum pattern for fresh and fermented shoots of Batch-1 and Batch-2.

**Table 5.3.** Peak assignment and their related compounds present in fresh and fermented bamboo shoots.

<table>
<thead>
<tr>
<th>Peak value</th>
<th>Fresh</th>
<th>Fermented (Batch-1)</th>
<th>Fermented (Batch-2)</th>
<th>Peak assignments</th>
<th>Compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>3410.61</td>
<td>3401</td>
<td>3401</td>
<td>O-H Stretching</td>
<td>Alcohols/ Phenols</td>
<td></td>
</tr>
<tr>
<td>2925.91</td>
<td>2925.43</td>
<td>2925</td>
<td>C-H Stretching</td>
<td>Alkanes (methylene)</td>
<td></td>
</tr>
<tr>
<td>1650.63</td>
<td>1627.75</td>
<td>1626.72</td>
<td>C=C Stretching</td>
<td>Aromatic</td>
<td></td>
</tr>
<tr>
<td>1400.82</td>
<td>1408.62</td>
<td>1405.70</td>
<td>C-H bending</td>
<td>Alkanes</td>
<td></td>
</tr>
<tr>
<td>1072.30</td>
<td>1040.05</td>
<td>1074.70</td>
<td>C-O Stretching</td>
<td>Carboxylic acid</td>
<td></td>
</tr>
</tbody>
</table>
5.4 Conclusion

Fermentation of bamboo shoots evinced various changes in physicochemical compositions. Minor changes in fat, protein, crude fibre, ash and vitamin C were recorded but carbohydrates concentration dropped markedly during fermentation. Increase in acidity and drop in pH up to 4.09 reveal the stability of fermented bamboo shoot products against contaminating microorganisms. Significant increase in total phenolics and antioxidant activity during fermentation highlighted its nutritional status and importance. Addition of *Garcinia pedunculata* Roxb. in bamboo shoot not only enhances the fermentation process but also imparts significant desirable changes in the product.
References


