Effect of long term Preservation on Dietary Fibre Components of Bamboo Shoots

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Abstract

Bamboo shoot, an emerging food is getting attention on world platform for its nutritional and functional benefits, is a dietary fibre rich vegetable which has numerous health aids like reducing obesity, low density lipoprotein (LDL) cholesterol, diabetes mellitus (type II), cardiovascular problems and improves gastrointestinal health, bowel movements and many others. Due to seasonal availability and short shelf-life, bamboo shoots areprocessed and preserved for long term usage. In this study, juvenile shoots of *Bambusa nutans* packaged in glass bottles and preserved in different solutions, were determined for dietary fibre components viz. nutrient detergent fibre (NDF), acid detergent fibre (ADF), lignin, hemicellulose and cellulose for six months of storage. Results showed an overall decrease of dietary fibre, ranges from minimum 3% to maximum 87% in different treatments at prolonged storage. Among different packages, the boiled shoots preserved in brine were least affected by storage with no significant changes in NDF, lignin and hemicellulose and 14% and 15% reduction of ADF and cellulose respectively after six months of storage. On the other hand, water preserved raw shoots weremost affected (48-87% reduction) upon storage. High availability of dietary fibre in fresh and stored shoots make bamboo shoots a preferred food in fitness promoting diet and can be used in food fortification in various ready to eat food regimes of modern time.

Keywords: Dietary fibre, Bamboo shoot, Storage, Boiling, Health promotion.

Introduction

Dietary fibres are amongst the most enduring dietetic interests worldwide and attracted considerable attention in area of remedial research and reflected as a significant constituent of diet for health promotion (Nirmala et al. 2011; Zhu et al. 2018). Variable foods contain different composition of dietary fibre with dissimilar biological properties that are basically carbohydrate-based polymers comprising majorly of cellulose, hemicellulose, lignin, gums, mucilage, oligosaccharides, pectin and minor constituents like cutin, suberin and waxes. They remain undigested by endogenous enzymes in the stomach and small intestine while some components get fermented partially or entirely and absorbed during passage through large intestine, while the remaining is excreted in stools (Bangoura et al. 2013; Zhu et al. 2018). Dietary fibres are recognized for deterrence and curing numberous sicknesses and its major functions include, addition of roughage to alimentary canal, regulation of bowel movement, lowering low-density lipoprotein (LDL) cholesterol resulting toreduction of cardiovascular diseases and insulin levels in blood (type 2 diabetes mellitus) (Gold et al. 1999; Anderson et al. 2009; Güroy et al. 2013). Moreover, bamboo shoots are also effective in remediying obesity, gall stone, colon carcinoma, haemorrhoids, hyperlipidaemia and irritable bowel syndrome (Cummings et al. 1997; Rodriguez et al. 2006). This polymer with such advantageous functional properties is mostly obtained from certain vegetables, fruits, pulses and cereals (Chen et al. 2014). Bamboo shoot is one such vegetable which has high dietary fibre composition, as they contain 2.23 to 4.49 g/100 g fresh weight (Nirmala et al. 2009).
Bamboo shoot, a well-known food article in South Asian countries is a freshly emerged culm of bamboo, present especially during rainy season. Currently, it is getting recognized worldwide due to its nutritional and functional properties and immense health benefits (Nirmala et al. 2014; Chen et al. 2018). Along with dietary fibres, bamboo shoots contain a huge array of nutrients and phytochemicals viz. carbohydrates, proteins, essential amino acids, phenols, phytosterols, minerals and vitamins while low in fats and calories (Nirmala et al. 2011, 2014). However, a drawback of bamboo shoot is its short shelf life (3–4 days after harvest) which is a deterrent in its distribution and marketing. Preservation of bamboo shoots is needed to prolong its usage that can result to enhance its market potential (Rawat et al. 2016; Saini et al. 2017). Negligible work is reported on determination of dietary fibres of bamboo shoots during long term storage. In this study, different dietary fibre components of shoots of Bambusa nutans in different treatments were evaluated up to six months of storage. B. nutans is an evergreen, medium sized and thick walled bamboo with sympodial habit, having a culm height of 6 – 15 meters, stem girth 5-10 cm and 25 – 45 cm long internodes. Its edible shoots are moderate sized with 20-25 cm height and 25-35 cm basal circumference which provide 50-55% consumable portion after removal of inedible culm sheath (Premlata et al. 2011; Saini et al. 2015). Fresh shoots of B. nutans contain carbohydrates (2.26 – 3.30 g/100g), proteins (3.25 g/100g), amino acids (2.21 g/100g), starch (1.37 g/100g), ash (0.82 – 90 g/100g), vitamin C (1.19 – 5.30 mg/100g) and high moisture content (91 – 94%) (Bhatt et al. 2005; Kumbhare and Bhargava 2007; Premlata et al. 2011; Saini et al. 2015).

Material and Method

Collection of Germplasm

Juvenile shoots of selected species viz. Bambusa nutans were collected from local cultivation as well as vegetable markets of Imphal district of North-eastern state of Manipur (24.66 °N, 93.90 °E), India. Collection of young shoots was done during the peak season of their availability i.e. between the months of July – August.

Preliminary Processing

Collected shoots were brought to laboratory and subjected to pre-processing which include washing and removing outer culm sheaths and discarding the inedible tip and hard basal portion to obtain edible part of shoot. The edible portion was chopped into cubes of 3 cm and divided in two parts; one half was left raw and the other one boiled for 20 minutes, cooled and then subjected to different packaging.

Packaging and storage

The boiled and raw cubes of shoot were immersed separately in autoclaved distilled water and brine (10%), it was then preserved in pre-sterilized glass bottles tightened with plastic lids. The containers were then stored in refrigerator at 4 °C until analysis during each month.

Method

Dietary fibres have five sub-components viz. NDF, ADF, Cellulose, Hemicellulose and Lignin. All these were estimated by using the method given by Goering and Van Soest (1970).

Neutral Detergent Fibre (NDF)

One gram of dried and crushed fresh shoot was gelatinized in distilled water with 0.01 g of α-amylase and kept at 60 °C for 2 hours. The nutrient detergent solution (10 ml), dekalin (0.2 ml), sodium sulphate (0.1 g) were then added to the mixture and heated for 20 minutes. The precipitates formed were filtered after washing with acetone through a sintered glass crucible and dried at 100 °C for 8 hours. The residue was allowed to cool to room temperature, weighed and ignited in the muffle.
The residue was again allowed to cool to room temperature, weighed and weight loss was calculated.

The amount of dietary fibre (NDF) was calculated using the equation:

\[
\text{Amount of NDF (g/100g)} = \frac{\text{loss in weight after ignition}}{\text{weight of sample in gram}} \times 100
\]

Acid Detergent Fibre (ADF)

One gram of dried and crushed fresh shoot was digested in 50 ml of the acid detergent reagent and 2 ml of dekalin for 30 minutes while adjusting the heat from time to time. The solution mixture was filtered and the precipitates were transferred to previously weighed clean Goach crucible. The residue was washed with hot water (90-100 °C) with a final wash of acetone. The crucible was dried in oven at 100°C for 8 hours, cooled to room temperature and reweighed. The weight loss of the residue after ignition was calculated.

The estimation of ADF was calculated using the equation:

\[
\text{Amount of ADF (g/100g)} = \frac{\text{loss in weight after ignition}}{\text{weight of sample in gram}} \times 100
\]

Lignin

The ignited residues of NDF and ADF were mixed in a crucible and immersed in 72 % H₂SO₄. After 3 hours the residue was filtered and rinsed repeatedly with boiling distilled water to attain pH 5 then finally washed with acetone. The dry weight was noted and the residue was then ignited at 100 °C and reweighed after cooling to room temperature.

The amount of lignin was calculated using the equation:

\[
\text{Amount of Lignin (g/100g)} = \frac{\text{loss in weight after ignition}}{\text{weight of sample in gram}} \times 100
\]

Hemicellulose:

It was determined by:

\[
\text{Hemicellulose (g/100g)} = \text{NDF} - \text{ADF}.
\]

Cellulose:

It was determined by:

\[
\text{Cellulose (g/100g)} = \text{ADF} - \text{lignin}.
\]

All the five components were calculated in g/100g fresh weight.

Statistics

Data were subjected to one way analysis of variance (ANOVA) using PASW statistics software version 18.0. Statistical difference was determined by using Duncan’s multiple range tests at significance level of \( p < 0.05 \).
Results

Dietary fibres in bamboo shoots can be categorized into (1) nutrient detergent fibre (NDF), which consist the indigestible constituents of the shoots viz. hemicelluloses, cellulose and lignin and (2) acid detergent fibre (ADF) which predominantly determines cellulose and lignin were evaluated in this study.

Table 1. Comparative account of dietary fibre (g/100g fresh weight) components in fresh and boiled shoots of *Bambusa nutans*

<table>
<thead>
<tr>
<th>Table 1.</th>
<th>Fresh</th>
<th>Boiled</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDF</td>
<td>5.34 ± 0.14&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.14 ± 0.10&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>ADF</td>
<td>1.17 ± 0.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.16 ± 0.08&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lignin</td>
<td>0.78 ± 0.10&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.33 ± 0.01&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>4.17 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.98 ± 0.02&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cellulose</td>
<td>0.40 ± 0.04&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.83 ± 0.09&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Data are presented in mean values ± Standard deviation (n=3). Values with different letters superscript in each row indicate significant differences (p<0.05) among treatments for individual components.

Neutral Detergent Fibre (NDF)

NDF was found highest in fresh shoots as 5.34 ± 0.14 g/100g which was reduced (p<0.05) upon boiling to 4.14 ± 0.10 g/100g which translates to 23% reduction in NDF (Table 2). Among raw shoots, NDF content decreased at a faster rate in water compared to brine preservation with a reduction of around 15% after one month followed by a consistent reduction rate (5-6% each month) going to five months of preservation. By the end of preservation 52% of NDF was reduced. On the other hand, brine storage showed a decrease of NDF by around 9% after first month and consistent gradual reduction by up to 37% by the end of six months. Both water and brine preserved boiled shoots showed insignificant change after four months of storage, but after five months NDF reduced slightly (7%) with a total reduction of 13% by the end of six months preservation in water stored shoots, while no significant changes were reported in brine preserved boiled shoots (Figure 1).

Table 2. NDF content in shoots of *B. nutans* in different storage conditions after each month up to six months of storage

<table>
<thead>
<tr>
<th>Bamboo shoot</th>
<th>Storage solution</th>
<th>0 month</th>
<th>1 month</th>
<th>2 month</th>
<th>3 month</th>
<th>4 month</th>
<th>5 month</th>
<th>6 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>Water</td>
<td>5.34±0.14</td>
<td>4.52±0.12</td>
<td>4.28±0.12</td>
<td>4.02±0.07</td>
<td>3.80±0.04</td>
<td>3.57±0.03</td>
<td>2.60±0.06</td>
</tr>
<tr>
<td></td>
<td>Brine</td>
<td>5.34±0.14</td>
<td>4.86±0.22</td>
<td>4.59±0.03</td>
<td>4.29±0.05</td>
<td>3.98±0.04</td>
<td>3.75±0.02</td>
<td>3.65±0.04</td>
</tr>
<tr>
<td>Boiled</td>
<td>Water</td>
<td>4.14±0.10</td>
<td>4.14±0.05</td>
<td>4.13±0.05</td>
<td>4.07±0.03</td>
<td>4.00±0.06</td>
<td>3.84±0.04</td>
<td>3.62±0.05</td>
</tr>
<tr>
<td></td>
<td>Brine</td>
<td>4.14±0.10</td>
<td>4.13±0.09</td>
<td>4.12±0.12</td>
<td>4.10±0.08</td>
<td>4.08±0.03</td>
<td>4.06±0.01</td>
<td>4.02±0.08</td>
</tr>
</tbody>
</table>

Data are presented in mean values ± Standard deviation (n=3).
Figure 1. Monthly % reduction in NDF content in different storage conditions upto six months of storage in shoots of *B. nutans*. RW= raw shoots preserved in water, RB= raw shoots preserved in brine, BW= boiled shoots preserved in water, BB= boiled shoots preserved in brine

Acid Detergent Fibre (ADF)

ADF content in raw and boiled shoots showed same values *viz.* 1.17 ± 0.10 g/100g and 1.16 ± 0.08 g/100g respectively (Table 3). Upon storage (Figure 2), raw shoots in both water and brine solution showed insignificant ADF content changes for three months. After six months storage, raw shoots’ ADF decreased largely in water solution (62%) compared to brine solution (28%). Like NDF, in the case of boiled shoots, no significant (*p > 0.05*) changes in ADF was seen for three months in both storages, beyond which water preserved showed slight reduction (14%) upto four months with an overall decline (50%) to 0.59 ± 0.03 g/100g at the end of six months of preservation. On the other hand, brined shoots showed insignificant changes with a mere reduction of 14 % with highest amount of ADF (1.01 ± 0.03 g/100g) after six months of storage.

Table 3. ADF content in shoots of *B. nutans* in different storage conditions after each month upto six months of storage

<table>
<thead>
<tr>
<th>Bamboo shoot</th>
<th>Storage solution</th>
<th>0 month</th>
<th>1 month</th>
<th>2 month</th>
<th>3 month</th>
<th>4 month</th>
<th>5 month</th>
<th>6 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>Water</td>
<td>1.17±0.06</td>
<td>1.02±0.07</td>
<td>1.01±0.03</td>
<td>1.01±0.02</td>
<td>0.82±0.03</td>
<td>0.68±0.04</td>
<td>0.44±0.03</td>
</tr>
<tr>
<td></td>
<td>Brine</td>
<td>1.17±0.06</td>
<td>1.09±0.10</td>
<td>1.00±0.02</td>
<td>1.00±0.03</td>
<td>0.95±0.02</td>
<td>0.90±0.02</td>
<td>0.84±0.05</td>
</tr>
<tr>
<td>Boiled</td>
<td>Water</td>
<td>1.16±0.08</td>
<td>1.16±0.01</td>
<td>1.16±0.04</td>
<td>1.14±0.01</td>
<td>1.02±0.05</td>
<td>0.81±0.03</td>
<td>0.59±0.03</td>
</tr>
<tr>
<td></td>
<td>Brine</td>
<td>1.16±0.08</td>
<td>1.17±0.04</td>
<td>1.14±0.08</td>
<td>1.13±0.01</td>
<td>1.10±0.03</td>
<td>1.06±0.04</td>
<td>1.01±0.03</td>
</tr>
</tbody>
</table>

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

Lignin content was 0.78 ± 0.10 g/100g in raw shoots which was reduced to a large extent (57%) in boiled shoots with retained amount of 0.33 ± 0.01 g/100g (Table 4). Upon storage (Figure 3), raw shoots showed a large decrease in lignin content after one month with 56-58% reduction. Raw shoots have insignificant lignin content changes from the second month up to the third month of preservation. After six months, raw shoots’ lignin content was reduced to 13% in water and 32% in brine preservation. There is no significant change in lignin content of brine preserved boiled shoots all throughout the duration of storage while water preserved boiled shoots showed reduction only after fifth and sixth months with 33% and 61% retention respectively.

Table 4. Lignin content in shoots of *B. nutans* in different storage conditions after each month up to six months of storage

<table>
<thead>
<tr>
<th>Bamboo shoot</th>
<th>Storage solution</th>
<th>0 month</th>
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<th>3 month</th>
<th>4 month</th>
<th>5 month</th>
<th>6 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>Water</td>
<td>0.78±0.10</td>
<td>0.32±0.02</td>
<td>0.32±0.01</td>
<td>0.32±0.03</td>
<td>0.23±0.02</td>
<td>0.16±0.01</td>
<td>0.10±0.01</td>
</tr>
<tr>
<td></td>
<td>Brine</td>
<td>0.78±0.10</td>
<td>0.34±0.09</td>
<td>0.30±0.03</td>
<td>0.30±0.02</td>
<td>0.29±0.00</td>
<td>0.27±0.03</td>
<td>0.25±0.02</td>
</tr>
<tr>
<td>Boiled</td>
<td>Water</td>
<td>0.33±0.01</td>
<td>0.38±0.01</td>
<td>0.38±0.04</td>
<td>0.37±0.05</td>
<td>0.32±0.03</td>
<td>0.22±0.02</td>
<td>0.13±0.00</td>
</tr>
<tr>
<td></td>
<td>Brine</td>
<td>0.33±0.01</td>
<td>0.36±0.05</td>
<td>0.34±0.02</td>
<td>0.34±0.03</td>
<td>0.33±0.01</td>
<td>0.32±0.03</td>
<td>0.30±0.02</td>
</tr>
</tbody>
</table>

Data are presented in mean values ± Standard deviation (n=3).
Figure 3. Monthly % reduction in lignin content in different storage conditions up to six months of storage in shoots of *B. nutans*. RW = raw shoots preserved in water, RB = raw shoots preserved in brine, BW = boiled shoots preserved in water, BB = boiled shoots preserved in brine.

**Hemicellulose**

A reduction (*p* < 0.05) of 28% in hemicellulose content was observed after boiling of shoots (Table 5). While storing, the reduction in raw shoots was more prominent in water preservation than in brine preservation which showed 48% and 33% reduction of hemicellulose content after six months respectively. On the other hand, boiled shoots displayed no significant (*p* > 0.05) changes in hemicellulose throughout the storage period (Figure 4).

Table 5. Hemicellulose content in shoots of *B. nutans* in different storage conditions after each month up to six months of storage

<table>
<thead>
<tr>
<th>Bamboo shoot</th>
<th>Storage solution</th>
<th>0 month</th>
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<th>2 month</th>
<th>3 month</th>
<th>4 month</th>
<th>5 month</th>
<th>6 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>Water</td>
<td>4.17±0.03</td>
<td>3.50±0.05</td>
<td>3.31±0.09</td>
<td>3.01±0.05</td>
<td>2.98±0.07</td>
<td>2.65±0.07</td>
<td>2.16±0.03</td>
</tr>
<tr>
<td></td>
<td>Brine</td>
<td>4.17±0.03</td>
<td>3.77±0.12</td>
<td>3.59±0.05</td>
<td>3.29±0.02</td>
<td>3.03±0.06</td>
<td>2.85±0.04</td>
<td>2.81±0.09</td>
</tr>
<tr>
<td>Boiled</td>
<td>Water</td>
<td>2.98±0.02</td>
<td>2.98±0.04</td>
<td>2.97±0.09</td>
<td>2.93±0.02</td>
<td>2.98±0.11</td>
<td>3.03±0.07</td>
<td>3.03±0.08</td>
</tr>
<tr>
<td></td>
<td>Brine</td>
<td>2.98±0.02</td>
<td>2.96±0.05</td>
<td>2.98±0.04</td>
<td>2.97±0.07</td>
<td>2.98±0.06</td>
<td>3.00±0.05</td>
<td>3.01±0.05</td>
</tr>
</tbody>
</table>

Data are presented in mean values ± Standard deviation (n=3).
Figure 4. Monthly % reduction in hemicellulose content in different storage conditions upto six months of storage in shoots of *B. nutans*. RW= raw shoots preserved in water, RB= raw shoots preserved in brine, BW= boiled shoots preserved in water, BB= boiled shoots preserved in brine

**Cellulose**

The values of cellulose in processed and preserved shoots showed a random pattern unlike other dietary fibre components. The cellulose content doubled its amount after boiling from 0.40 ± 0.04 g/100g in raw shoots to 0.83 ± 0.09 g/100g after boiling (Table 6). During preservation, the cellulose in raw shoots increased by 75-82% in water and brine after one month followed by a constant trend upto the third month. From the fourth month up to sixth month it showed a general decrease in cellulose content with lower retention in water (47%) compared to brine (84%). On other hand, boiled shoots showed no change in cellulose content for the duration of three months and later showed more retention (p<0.05) in water with 55% retention compared to 85% in brine from the initial value after six months of storage (Figure 5).

Table 6. Cellulose content in shoots of *B. nutans* in different storage conditions after each month upto six months of storage

<table>
<thead>
<tr>
<th>Bamboo shoot</th>
<th>Storage solution</th>
<th>0 month</th>
<th>1 month</th>
<th>2 month</th>
<th>3 month</th>
<th>4 month</th>
<th>5 month</th>
<th>6 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>Water</td>
<td>0.40±0.04</td>
<td>0.70±0.05</td>
<td>0.69±0.02</td>
<td>0.69±0.01</td>
<td>0.59±0.01</td>
<td>0.52±0.03</td>
<td>0.34±0.02</td>
</tr>
<tr>
<td></td>
<td>Brine</td>
<td>0.40±0.04</td>
<td>0.73±0.03</td>
<td>0.70±0.02</td>
<td>0.70±0.03</td>
<td>0.66±0.02</td>
<td>0.63±0.01</td>
<td>0.59±0.03</td>
</tr>
<tr>
<td>Boiled</td>
<td>Water</td>
<td>0.83±0.09</td>
<td>0.78±0.02</td>
<td>0.78±0.05</td>
<td>0.77±0.03</td>
<td>0.70±0.02</td>
<td>0.59±0.01</td>
<td>0.46±0.03</td>
</tr>
<tr>
<td></td>
<td>Brine</td>
<td>0.83±0.09</td>
<td>0.81±0.01</td>
<td>0.80±0.02</td>
<td>0.79±0.02</td>
<td>0.77±0.04</td>
<td>0.74±0.01</td>
<td>0.71±0.01</td>
</tr>
</tbody>
</table>

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

Figure 5. Monthly % retention in cellulose content in different storage conditions upto six months of storage in shoots of *B. nutans*. RW= raw shoots preserved in water, RB= raw shoots preserved in brine, BW= boiled shoots preserved in water, BB= boiled shoots preserved in brine

**Discussion**

Before consumption, vegetables are usually processed and sometimes preserved through various methods which may modify the dietary fibre components in one way or another. During application of wet heating methods, like boiling, blanching and storage in cans, the dry matter often leaches out into the hot water, which mainly includes molecules with low molar mass and certain dietary fibre which can lead to its reduction (Svanberget al. 1997; Wennberg et al. 2003). *Bambusa nutans* is one of the most...
popular bamboo species whose shoots are liked by consumers because of its smooth texture and sweet taste (Premlata et al. 2015). It has medium sized shoots and which need appropriate processing methods for further commercialization of this species. In this study, except ADF, all other dietary fibre components were affected by boiling. NDF, lignin and hemicellulose were lowered while cellulose showed elevation in content after boiling. During the period of storage, except for cellulose, all other four components showed decline in value when preserved in raw form in water and brine, while boiled shoots preserved in brine showed insignificant change in dietary fibre content. Cellulose content was enhanced in raw stored shoots during initial months of storage but later it decreased in both raw and boiled preservation. Bajwa et al. (2016) also showed increase in cellulose content in bamboo shoots of Dendrocalamus hamiltonii in 5% brine with 107% retention after one month of storage, whereas in our study B. mutans showed 183% retention in brine after one month, so its is advantageous over the former species. On the other hand, lignin, hemicellulose and NDF decreased in same treatment while, boiled shoots showed loss for all dietary fibre components. Increase in cellulose content by the onset of storage may be due to reduction in lignin, as plants with inhibited lignin biosynthetic pathway gene Pt4CL1 are reported to be compensated for by enhancement in cellulose content (Hu et al. 1999), which might be leached out later with further storage. Nyman et al. (1987) have also reported reduction in dietary fibre of swede (a hybrid of cabbage and turnip) after boiling and canning. Boiled peas, carrots, green beans and brussel sprouts canned in salt solution (2.2%) at 5 °C have shown no change in dietary fibre which was in line with our results. At high temperature during heat treatments, the weak linkages between polysaccharides and glycosidic bonds within the dietary fibre polysaccharides may be cleaved off which possibly lead to solubilization and loss of the polysaccharides of dietary fibres resulting to its reduction (Nyman et al. 1987b; Phillips and Palmer 1991; Selvendran and Robertson 1994; Svanberget et al. 1995; Jimnez et al. 2000). Upon brining, the salt content encourages cell distortion or rupture and acid hydrolysis which affect the fibre composition and ultimately firmness of shoot tissue (Vanburen et al. 1988; Zheng et al. 2013a; Zhang et al. 2016). Moreover the Na⁺ can replace the Ca²⁺ and cleave the hydrogen linkages between polysaccharide molecules of dietary fibre thus lead to their more intense dissolution in brine and eventual decrease in raw shoots (Sterling 1968; Jimnez et al. 2000; Cho and Buesher 2012). Luo et al. (2012) reported decrease of 15% in lignin content after 12 days of storage in heat-treated shoots compared to control shoots, which can be accounted to suppression in activity of phenylalanine ammonia-lyase (PAL), cinnamyl and peroxidase (POD) which are key enzymes in biosynthesis of lignin (Zheng et al. 2013b). Upon various treatments, hemicellulose could be hydrolysed into pentose and hexose monosaccharides through acid catalysed hydrolysis (Zhu et al. 2018).

Along with enormous health promotional effects, dietary fibre if incorporated in foodstuff, improves its quality by supplementing certain functional properties such as improving water and oil holding capacity, textural modification, stabilizing fatty and gel like food, escape syneresis and enhance shelf-life (Elleuch et al. 2011; Nirmala et al. 2014). It can be easily fortified into diet such as in dairy and bakery goods, soups, jams, beverages, sausages and meats to obtain fitness promoting foods with low calories and harmful lipids (Nirmala et al. 2014). Studies are conducted on fortification of bamboo shoots and its dietary fibre to improve quality of various food regimes. Zhang et al. (2017) revealed that the incorporation of bamboo shoot dietary fibre can enhance the viscoelasticity, extensibility, plasticity and improve the processing properties of off-frozen dough. Bamboo shoot dietary fibre can also improve the textural and rheological properties of milk pudding effectively by tightly aggregation the particles, and making the microstructure dense and more compact (Zheng et al. 2017). It was also recommended to fortify the flour with bamboo shoot powder to enhance the organoleptic and nutritional quality of cookies (Choudhary et al. 2015; Mustafa et al. 2016). Other food products like candies, nuggets and crackers were also prepared by supplementing bamboo shoots to its main ingredients (Sood et al. 2013; Nimisha et al. 2015). Phyllostachys pubescens culm was used to extract the hemicellulosic fractions and was considered to promote its potential uses in the food industry (Peng et al. 2012).

Envisaging current findings, the best preserved shoots with highest dietary fibre components i.e. brine preserved boiled shoots can be directly consumed as salad, in preparation of curries, stocks, soups, stir-fries and multifarious culinary items. Stored shoots can be used in paste and powdered form as a
fibre substitute for fortification of breakfast cereals, sauces, mustard, ketchup, pasta, noodles, shredded cheese, snacks, frozen desserts, and bakery products. In addition, the stored shoots can be available any time of the year for extraction of dietary fibres along with other phytochemicals for incorporation in pharmaceutical formulations.

**Conclusion**

Bamboo shoot, a dietary fibre concentrated herbage has attracted considerable attention in area of research and projected as a significant constituent of diet for remedial and health promoting properties. Dietary fibre in bamboo shoots mainly comprises NDF, ADF, lignin, hemicellulose and cellulose. Current findings demonstrated that fresh shoots contained highest amount of NDF, lignin and hemicellulose, boiling the shoots resulted to higher levels of cellulose while maintaining the level of ADF. There was an overall decrease of dietary fibres after six months of storage. Among different packages, the boiled shoots preserved in brine were least affected by storage with no significant changes in NDF, lignin and hemicellulose and 86% and 85% retention of ADF and cellulose respectively after six months of storage. Raw shoots in brine were second best for preserving dietary fibre, followed by water preserved boiled shoots and water preserved raw shoots which has the lowest retention after storage. While losing some of fibre content upon storage, bamboo shoots still retained high values than many fresh vegetables of commercial importance. These results suggest that bamboo shoots can be a preferable food additive in diet for health promotion and fortification industry to obtain a low calorie and low fat ready to eat food stuff for fitness conscious modern populaces.

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