Theme: 3.2. Food and Pharmaceuticals

Effect of long term Preservation on Dietary FibreComponents 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 problemsand improves gastrointestinal health, bowel movements and many other*s*. 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 fibres,ranges from minimum 3% to maximum 87% in different treatmentsat 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 dieteticinterests worldwide andattracted considerable attention in area of remedial research and reflected as a significantconstituent 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 comprisingmajorlyof cellulose, hemicellulose, lignin, gums, mucilage, oligosaccharides, pectinand minor constituents like cutin, suberin and waxes. They remainundigested by endogenous enzymes in thestomach and small intestine while some components get fermentedpartially or entirelyand absorbed during passage through large intestine, while theremaining is excreted instools (Bangoura et al. 2013; Zhu et al. 2018). Dietary fibres are recognized for deterrence and curing numeroussicknesses and its major functions include, addition of roughage to alimentary canal,regulation of bowel movement, lowering low-density lipoprotein (LDL) cholesterol resulting toreduction ofcardiovascular diseases and insulin levels inblood (type 2 diabetes mellitus)(Gold et al. 1999; Anderson et al. 2009; Güroy et al. 2013) . Moreover,bamboo shoots are also effective in remedying obesity, gall stone, colon carcinoma, haemorrhoids, hyperlipidaemia and irritable bowel syndrome (Cummings et al. 1997; Rodríguez 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 drawbackof 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 toprolong its usage that can resultto enhanceits market potential(Rawat et al.2016; Saini et al. 2017).Negligiblework 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 upto 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. Itsedible shoots are moderate sized with 20-25 cm height and 25-35 cm basal circumference which provide50-55% consumable portion after removal of inedible culm sheath (Premlata et al. 20115; 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. 20115; Saini et al. 2015).

Material and Method

Collection of Germplasm

Juvenile shoots of selected species *viz. Bambusa nutans* were collected fromlocal 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 washingand removing outer culmsheaths and discarding the inedible tip and hard basal portion to obtain edible part of shoot. The edible portion was chopped incubes of 3 $cm^3$and divided in two parts; one half was left raw and the other one boiled for 20 minutes, cooledand 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 with0.01 g of α-amylase and kept at60 °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 20minutes. 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 furnace at 500°C for 3 hours.The residue was again allowedto cool to room temperature, weighed and weight loss was calculated.

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

$$Amount\ of\ NDF\left(\frac{g}{100g}\right) = \frac{loss\ in\ weight\ after\ ignition}{weight\ of\ sample\ in\ gram} \times 100$$

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 weighedclean Goach crucible. The residuewas washed with hot water (90-100 °C) with a final washof acetone.The cruciblewas 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:

$$Amount\ of\ ADF\left(\frac{g}{100g}\right) = \frac{loss\ in\ weight\ after\ ignition}{weight\ of\ sample\ in\ gram} \times 100$$

Lignin

The ignited residues ofNDF and ADF were mixed in a crucible and immersed in 72 % H_2SO_4. After 3 hours the residuewas 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 theequation:

$$Amount\ of\ Lignin\left(\frac{g}{100g}\right) = \frac{loss\ in\ weight\ after\ ignition}{weight\ of\ sample\ in\ gram} \times 100$$

Hemicellulose:

It was determined by :

Hemicellulose (g/100g) = NDF - ADF.

Cellulose:

It was determined by:

Cellulose (g/100g) = ADF - 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 ligninand (2) acid detergent fibre (ADF)which predominantlydetermines 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*

	Fresh	Boiled
NDF	5.34 ± 0.14 [a]	4.14 ± 0.10 [b]
ADF	1.17 ± 0.06 [a]	1.16 ± 0.08 [a]
Lignin	0.78 ± 0.10 [a]	0.33 ± 0.01 [b]
Hemicellulose	4.17 ± 0.03 [a]	2.98 ± 0.02 [b]
Cellulose	0.40 ± 0.04 [b]	0.83 ± 0.09 [a]

Data are presented in mean values ± Standard deviation (n=3). Values with different letters superscript in each row indicates 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/100gwhich translates to 23% reduction in NDF (Table 2). Among raw shoots,NDF content decreased at a faster rate in water compared to brine preservationwith 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 preservedboiled 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 monthspreservation in water stored shoots, whileno 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 upto six months of storage

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

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

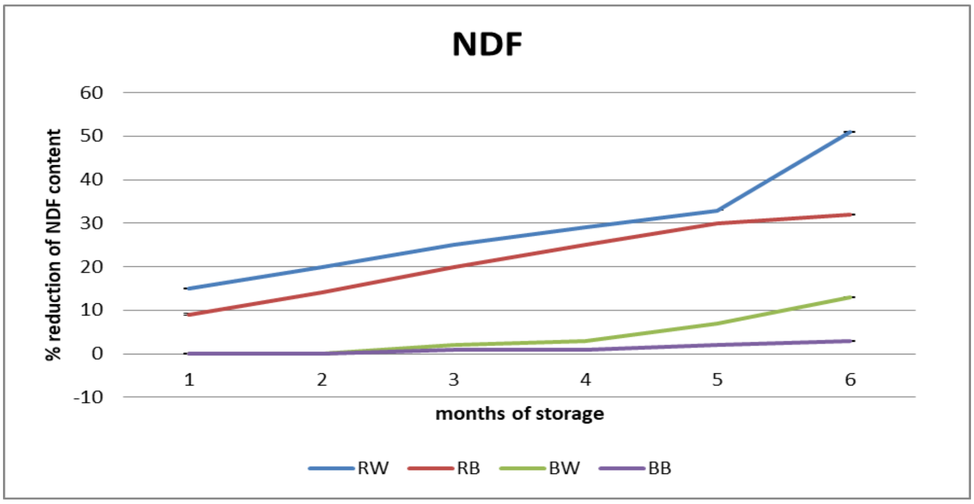

Figure1. Monthly % reduction in NDF content in different storage conditions upto six months of storage in shoots of *B. nutans*. RW= raw shoots preserved in water, RB= raw shoots preserved in brine, BW= boiled shoots preserved in water, BB= boiled shoots preserved in brine

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 contentchanges forthree months.Aftersix 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 changeswith a mere reduction of 14 % withhighest 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

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

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

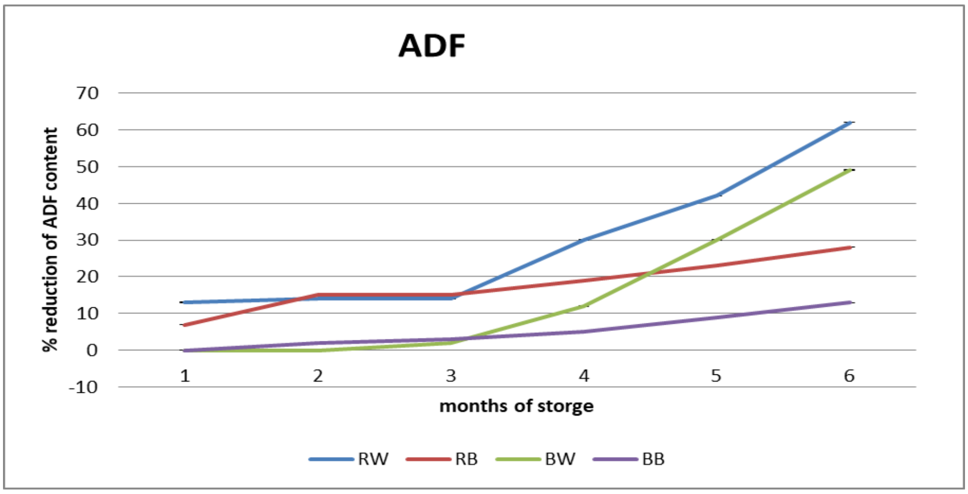

Figure2. Monthly % reductionin ADF content in different storage conditions upto six months of storage in shoots of *B. nutans*. RW= raw shoots preserved in water, RB= raw shoots preserved in brine, BW= boiled shoots preserved in water, BB= boiled shoots preserved in brine

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 decreasein 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 whilewater 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 upto six months of storage

Bamboo shoot	**Storage solution**	0 **month**	1 **month**	2 **month**	3 **month**	4 **month**	5 **month**	6 **month**
Raw	Water	0.78±0.10	0.32±0.02	0.32±0.01	0.32±0.03	0.23±0.02	0.16±0.01	0.10±0.01
	Brine	0.78±0.10	0.34±0.09	0.30±0.03	0.30±0.02	0.29±0.00	0.27±0.03	0.25±0.02
Boiled	Water	0.33±0.01	0.38±0.01	0.38±0.04	0.37±0.05	0.32±0.03	0.22±0.02	0.13±0.00
	Brine	0.33±0.01	0.36±0.05	0.34±0.02	0.34±0.03	0.33±0.01	0.32±0.03	0.30±0.02

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

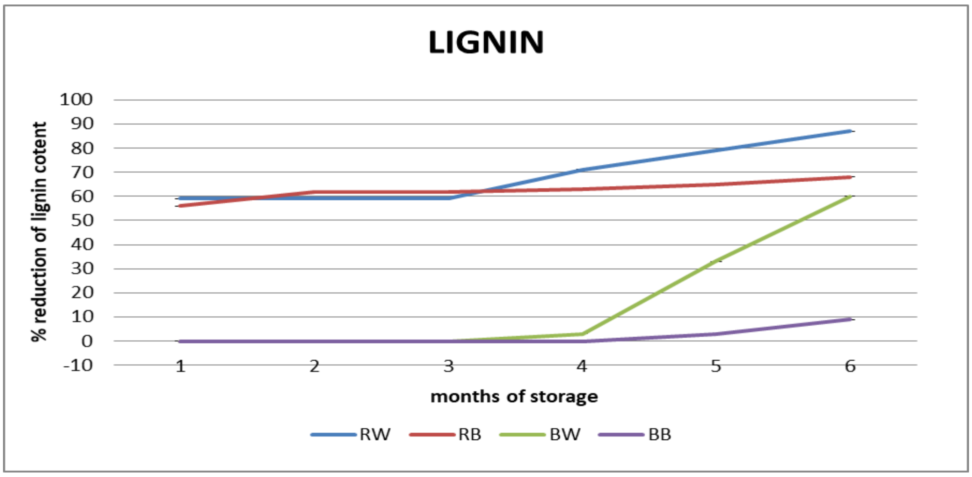

Figure3. Monthly % reduction in lignin content in different storage conditions upto six months of storage in shoots of *B. nutans*. RW= raw shoots preserved in water, RB= raw shoots preserved in brine, BW= boiled shoots preserved in water, BB= boiled shoots preserved in brine

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 preservationthan 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 upto six months of storage

Bamboo shoot	Storage solution	0 month	1 month	2 month	3 month	4 month	5 month	6 month
Raw	Water	4.17±0.03	3.50±0.05	3.31±0.09	3.01±0.05	2.98±0.07	2.65±0.07	2.16±0.03
	Brine	4.17±0.03	3.77±0.12	3.59±0.05	3.29±0.02	3.03±0.06	2.85±0.04	2.81±0.09
Boiled	Water	2.98±0.02	2.98±0.04	2.97±0.09	2.93±0.02	2.98±0.11	3.03±0.07	3.03±0.08
	Brine	2.98±0.02	2.96±0.05	2.98±0.04	2.97±0.07	2.98±0.06	3.00±0.05	3.01±0.05

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

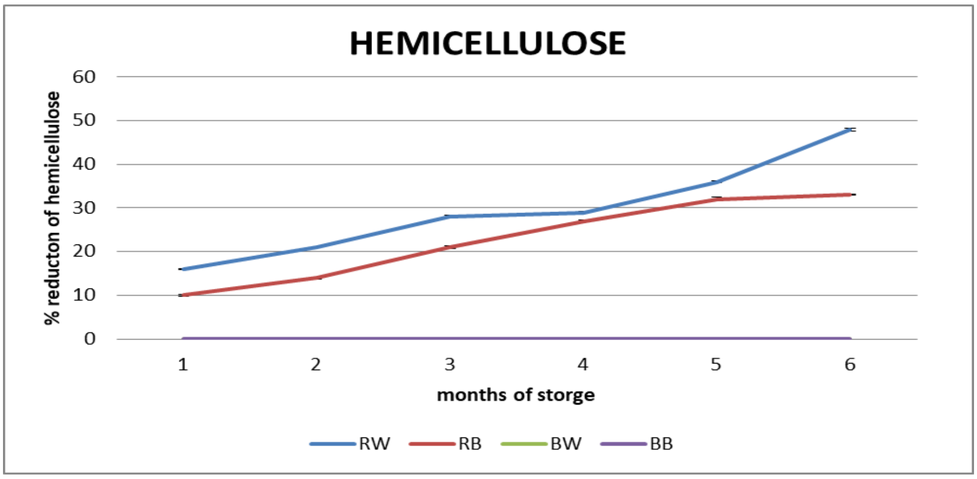

Figure 4. Monthly % reduction in hemicellulose content in different storage conditions upto six months of storage in shoots of *B. nutans*. RW= raw shoots preserved in water, RB= raw shoots preserved in brine, BW= boiled shoots preserved in water, BB= boiled shoots preserved in brine

Cellulose

The values of cellulose in processed and preserved shoots showed a random pattern unlike other dietary fibre components. Thecellulose 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 contentwith lower retention in water (47%) compared to brine (84%). On other hand, boiled shoots showed no changein cellulose contentfor 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

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

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

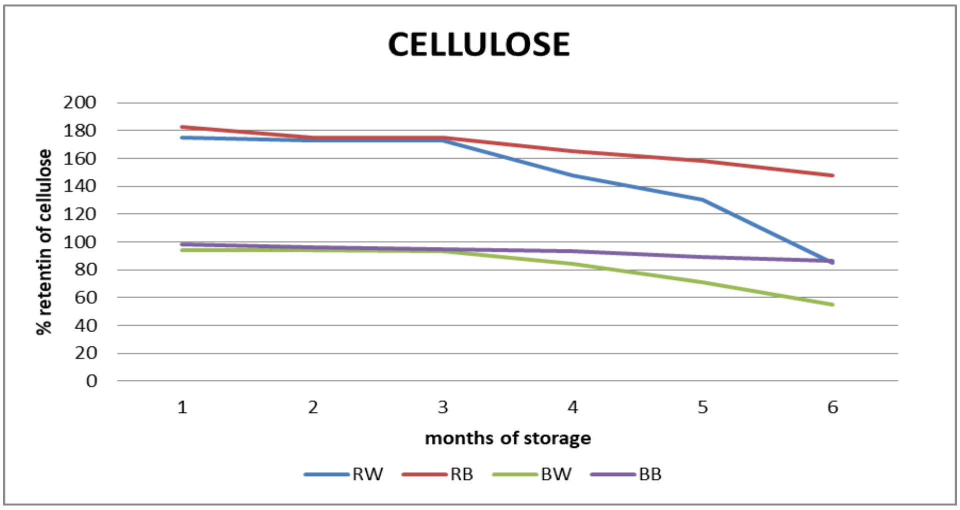

Figure 5. Monthly % retention in cellulose content in different storage conditions upto six months of storage in shoots of *B. nutans*. RW= raw shoots preserved in water, RB= raw shoots preserved in brine, BW= boiled shoots preserved in water, BB= boiled shoots preserved in brine

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 heatingmethods, likeboiling, blanchingand storage in cans, the drymatter oftenleaches out into the hot water, which mainly includes molecules with lowmolar mass and certain dietary fibrewhich 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 increasein cellulose content in bamboo shoots of *Dendrocalamus hamiltonii*in 5% brine with 107% retentionafter one month of storage,whereas in our study *B. nutans*showed 183% retention in brine after one month, so itis advantageous over the former species.On the other handlignin, 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 Pt4CL1are 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 dietaryfibre ofswede(a hybrid of cabbageand turnip) after boiling and canning.Boiled peas, carrots, green beans and brussel sprouts canned in salt solution (2.2%) at 5 °Chave shown no change in dietary fibre which was in line with our results. At hightemperature during heat treatments, theweak linkages between polysaccharides andglycosidicbonds within the dietary fibre polysaccharides may be cleavedoff which possibly lead to solubilization and loss ofthe polysaccharides of dietary fibres resulting to its reduction (Nymanet al. 1987b; Phillips and Palmer1991; Selvendran and Robertson 1994; Svanberget al. 1995; Jimnez et al. 2000).Upon brining, thesalt contentencourage 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 $Ca^{2+}$and cleave the hydrogen linkages between polysaccharide molecules of dietary fibre thus lead to their more intense dissolution in brine and eventual decreasein rawshoots (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 inheat-treatedshoots compared to control shoots, which can be accounted tosuppression 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 monosaccharidesthrough acid catalysed hydrolysis (Zhu et al. 2018).

Along with enormous health promotional effects, dietary fibre if incorporated in foodstuff,improves its quality by supplementing certainfunctional properties such as improving water and oil holding capacity, texture modification, stabilizing fatty and gel likefood, escape synaeresis and enhance shelf-life(Elleuch et al. 2011; Nirmala et al. 2014). It can be easilyfortifiedinto diet such as in dairy and bakery goods,soups, jams,beverages, sausages and meats to obtainfitness 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 offrozen dough. Bamboo shoot dietary fibre can also improve the textural and rheological properties of milk pudding effectively by tightly aggregatingthe particles, and making the microstructure dense and more compact (Zheng et al.2017).It was also recommended to fortify theflour 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 andwas considered to promote its potential uses in thefood 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 inpasteand powdered form as a fibre substitute forfortification of breakfast cereals, sauces, mustard, ketchup,pasta, noodles, shreddedcheese, 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 inpharmaceutical formulations.

Conclusion

Bamboo shoot, a dietary fibre concerted herbage has attracted considerable attention in area ofresearch 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 highervalues than many fresh vegetables of commercial importance. These results suggest thatbamboo shootscan be a preferable food additive in apt 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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References

Alfredo, V.O.; Gabriel, R.R.; Luis, C.G.; David, B.A. 2009.Physicochemical properties of a fibrous fraction from chia (*Salvia hispanica* L.).LWT - Food Science and Technology. 42, 168-173.

Anderson, J.W.; Baird, P.; Davis Jr., R.H.; Ferreri, S.; Knudtson, M.;Koraym, A.; Waters, V.; Williams, C.L. 2009. Health benefits of dietary fiber. Nutrition Reviews, 67,188-205.

Bajwa, H.K.; Nirmala, C.; Kaul, A.; Bisht, M.S. 2016.Changes in organoleptic, physicochemical and nutritional qualities of shoots of an edible bamboo *Dendrocalamus hamiltonii*Nees and Arn.Ex Munro during processing.Journal of Food Processing and Preservation,doi:10.1111/jfpp.12716.

Bangoura, M.L.; Nsor-Atindana, J.; Zhu, K.; Tolno, M.B.; Zhou, H.; Wei, P. 2013. Potential hypoglycaemic effects of insoluble fibres isolated from foxtail millets [*Setariaitalica* (L.) *P. Beauvois*]. International Journal of Food Science & Technology, 48, 496-502.

Bhatt, B.P.; Singh, K; Singh, A. 2005. Nutritional values of some commercial edible bamboo speciesof the North Eastern Himalayan region, India. Journal of Bamboo and Rattan, 4(2), 111-124.

Chen, G.; Chen , K.; Zhang, R.; Chen, X.; Hu, P.; Kan, J. 2018. Polysaccharides from bamboo shoots processing by-products: New insightinto extraction and characterization. Food Chemistry, 245, 1113-1123.

Chen, Y.; Ye, R.; Yin, L.; Zhang, N. 2014. Novel blasting extrusion processing improved the physicochemical properties of soluble dietary fiber from soybean residue and in vivo evaluation. Journal of Food Engineering, 120, 1-8.

Cho, M.J.;Buescher, R.W. 2012. Potential role of native pickling cucumber polygalacturonase in softening of fresh pack pickles. Journal of Food Science, 77, C443–C447.

Choudhury, M.; Badwaik, L.S.; Borah P.K.; Sit, N.; Deka, C. 2015. Influence of bamboo shoot powder fortification on physico-chemical, textural and organoleptic characteristics of biscuits. Journal of Food Science and Technologym,doi:10.1007/s13197-015-1709-3.

Cummings, J.H.; Roberfroid, M.B.; Anderson, H. 1997. A new look at dietary carbohydrates: Chemistry, physiology and health. European journal of clinical nutrition, 51, 417-423.

Devi, P.B.; Vijayabharathi, R.;Sathyabama, S.;Malleshi, N.G.; Priyadarisini, V.B. 2014. Health benefits of finger millet (L.) polyphenols and dietary fiber: a review. Journal of Food Science and Technology, 51, 1021-1040.

Dreher, M.L. 2017a. Fiber and Healthy Dietary Patterns in Weight Regulation.Dietary Fiber in Health and Disease.Nutrition Science Solution LLC, Wimberley, USA.Pp 163-200.

Dreher, M.L. 2017b. Fiber and Other Dietary Factors in Breast Cancer.Dietary Fiber in Health and Disease.Nutrition Science Solution LLC, Wimberley, USA.Pp 367-399.

Elleuch, M.; Bedigian, D.; Roiseux, O.;Besbes, S.; Blecker, C.; Attia, H. 2011. Dietary fibre and fibre-rich by-products of food processing: characterisation, technological functionality and commercial applications: a review. Food Chemistry, 124, 411-421.

Goering, H.K.; Van Soest, P.J. 1970. Forage Fiber Analyses (apparatus, reagents, procedures and some applications). Agriculture Handbook. USDA, Washington, DC, 379, 1-20.

Gold, S.P.; Man, I.L.; Kader, A.A.; Keintz, C. 1999. Influence of production handling and storage on polynutrient contents of foods. Nutrition reviews, 52 (9), S46-S52.

Güroy, B.; Ergün, S.; Merrifield, D.L.; Güroy, D. 2013.Effect of autoclaved Ulva meal on growth performance, nutrient utilization and fatty acid profile of rainbow trout, Oncorhynchusmykiss.Aquaculture International, 21, 605-615.

Hu, W.; Harding,S.A.; Lung, J.;Popko, J.L.; Ralph, J.;Stokke, D.D.; Tsai, C.; Chiang, V.L. 1999. Repression of lignin biosynthesis promotes cellulose accumulation and growth in transgenic trees. Nature Biotechnology volume 17, 808–812.

Izydorczyk, M.S.; Biliaderis, C.G. 1995. Cereal arabinoxylans: advances in structure and physicochemical properties. Carbohydrate Polymers, 28, 33-48.

Jime´nez, A.; Rodrı´guez, R.; Ferna´ndez-Caro, I.; Guille´n, R.; Ferna´ndez-Bolan˜os, J.; Heredia, A. 2000. Dietary fibre content of table olives processed under different European styles: study of physico-chemical characteristics. Journal of the Science of Food and Agriculture, 8, 1903-1908.

Kumbhare, V.; Bhargava, A. 2007.Effect of processing on nutritional value of central Indian bamboo shoots.Part-1. Journal ofFood Science and Technology, 44(1), 29-31.

Luo, Z.; Feng, S.; Pang, J.; Mao, L.; Shou, H.; Xie, J. 2012.Effect of heat treatment on lignification of postharvest bamboo shoots (*Phyllostachys praecox f. prevernalis.).* Food Chemistry, 135, 2182–2187

Mustafa, U.;Naeem, N.;Masood, S.;Farooq, Z. 2016.Effect of Bamboo Powder Supplementation on Physicochemical and Organoleptic Characteristics of Fortified Cookies.Food Science and Technology, 4(1), 7-13.

Nimisha, S.M.; Chauhan, A.S.; Rekha1, M.N.; Negi, P.S.; Nusrath, N.; Asha, M.R. 2015. Composition of Edible Portion of Tender Bamboo Shoot (TBS) and Development of Various Candies with and without Incorporation of Ginger and Pineapple Flavours. American Journal of Nutrition and Food Science, 2(1), 7-15.

Nirmala, C.;Bisht, M.S.;Laishram, M. 2014. Bioactive compounds in bamboo shoots: health benefits and prospects for developing functional foods. International Journal of Food Science and Technology, 49, 1425–1431.

Nirmala, C.;Bisht, M.S.; Sheena, H. 2011. Nutritional Properties of Bamboo Shoots: Potential and Prospects for Utilization as a Health Food. Comprehensive Reviews Food Science Food Safety, 10, 153-165.

Nirmala, C.; Sheena, H.; David, E. 2009. Bamboo shoots: a rich source of dietary fibres. In Klein,F.; Moller, G. ed., Dietary Fibres, Fruit and VegetableConsumption and Health, New York: Nova Science Publishers,pp 15–30.

Nyman, M.;Björck, I.;Håkansson, B.; Asp, N.G. 1987a. Popping of whole-grain wheat: effects on dietary fiber degradation in the rat intestinal tract. Journal of Cereal Science, 5(1), 67–72.

Nyman, M.;Pålsson, K.E.; Asp, N.G. 1987b. Effects of processing on dietary fiber in vegetables. LebensmWissTechnol, 20(1), 29–36.

Park, E.J.; Jhon, D.Y. 2009. Effects of bamboo shoot consumption on lipid profiles and bowel function in healthy young women. Nutrition, 25, 723–728.

Peng, H.; Wang, N.;Zhengrong, Y.; Liu, Y.; Zhang, J.; Ruan, R. 2012. Physiochemical characterization of hemicelluloses from bamboo (*Phyllostachys pubescens* Mazel) stem. Industrial Crops and Products, 37, 41–50.

Phillips, K.M.; Palmer, J.K. 1991. Effect of freeze-drying and heating during analysis on dietary fiber in cooked and raw carrots. Journal of Agriculture and Food Chemistry, 39(7),1216–1221.

Premlata, T.; Saini, N.; Nirmala, C.; Bisht, M.S. 2015.Nutrient Components in Young Shoots of Edible Bamboos ofManipur, India.In: Proceedings of 10th World Bamboo Congress, theme: Food and Pharmaceuticals, September 17-22, 2015, Damyang, Korea.

Rawat, K.; Sharma, V.; Saini, N.; Nirmala, C.;Bisht, M.S. 2016.Impact of Different Boiling and Soaking Treatments on the Release and Retention of Antinutrients and Nutrients from the Edible Shoots of Three Bamboo Species. American Journal of Food Science and Nutrition Research, 3(3), 31-41.

Rodríguez, R.; Jimenez, A.;Fernandez-Bola~nos, J.; Guillen, R.; Heredia, A. 2006.Dietary fibre from vegetable products as source of functional ingredients.Trends in Food Science & Technology, 17, 3-15.

Saini, N.; Nirmala, C.; Bisht, M.S. 2015.Bamboo Resource of Himachal Pradesh (India) and Potential of Shoots in Socio-economic Development of the State.In: Proceedings of 10th World Bamboo Congress, theme: Community and Economic Development, September 17-22, 2015, Damyang, Korea.

Saini, N.; Rawat, K.; Nirmala, C.; Bisht, M.S. 2017.Qualitative and Quantitative Mineral Element Variances in Shoots of two Edible Bamboo species after Processing and Storage Evaluated by Wavelength Dispersion X-ray Fluorescence Spectrometry. International Journal of Innovative Research in Science, Engineering and Technology, 6(5), 8262-8270.

Selvendran, R.R.; Robertson, J.A. 1994. Dietary fiber in foods: amount and type. InAmadò, R.; Barry, J.L.;Frølich, W. ed.,Physico-chemical properties of dietary fiber and effect of processing on micronutrients availability. Luxembourg: COST 92 Directorate- General XIII,pp 11–19.

Sood, S.; Walia, S.; Gupta, M.;Sood, A. 2013.Nutritional Characterization of Shoots and Other Edible Products of an Edible Bamboo - *Dendrocalamus hamiltonii.*Current Research in Nutrition and Food Science,1(2), 169-176.

Sterling, C. 1968. Effect of solutes and pH on the structure and firmness of cooked carrot. International Journal of Food Science and Technology, 3,367–371.

Story, J.A.; Kritchevsky, D.; 1976.Comparison of the binding of various bile acids and bile salts in vitro by several types of fiber.Journal of Nutrition, 106, 1292-1294.

Svanberg, S.J.M.;Gustafsson, K.B.H.;Suortti, T.; Nyman, E.M.G.L. 1995. Molecular weight distribution, measured by HPSEC, and viscosity of water-soluble dietary fiber in carrots following different types of processing. Journal of Agricultural and Food Chemistry,43(10), 2692–2697.

Svanberg, S.J.M.; Nyman, E.M.G.L.;Andersson, R.; Nilsson, T. 1997.Effects of boiling and storage on dietary fiber and digestible carbohydrates in various cultivars of carrots.Journal of the Science of Food and Agriculture,73(2), 245–254.

Vanburen, J.P.; Kean, W.P.;Wilkison, M. 1988. Influence of salt and pH on the firmness of cooked snap beans in relation to the properties of pectin. Journal of Texture Studies,19, 15–25.

Wennberg, M.S.;Engqvist, G.M.; Nyman, E.M.G.L. 2003.Effects of Boiling on Dietary Fiber Components in Fresh and Stored White Cabbage (*Brassica oleracea* var. *capitata*). Food Chemistry and Toxicology, 68(5), 1615-1621.

Zhang, H.; Zhang, Y.; Wang, X.; Xiang, Q.; Bai, Y.; Li, S.; Yang, L. 2017. Effects of Bamboo Shoot Dietary Fiber on Mechanical Properties, Moisture Distribution, and Microstructure of Frozen Dough.Hindawi Journal of Chemistry, Article ID: 4513410, pp7.

Zhang, F.; Zheng, J.; Zhong, J.; Chen, G.; Kan, J. 2016.Kinetics of texture change of bamboo shoots during Pickling process.Journal of Food Process Engineering, doi:10.1111/jfpe.12369.

Zheng, J.; Zhang, F.; Zhou, C.; Chen, G.; Lin, M.;Kan, J. 2013a.Changes in amino acid contents, texture and microstructure of bamboo shoots during pickling process. International Journal of Food Science and Technology, 48, 1847–1853.

Zheng, J.; Zhang, F.; Song, J.; Lin, .; Kan, J. 2013b. Effect of blanching and drying treatments on quality of bamboo shoot slices. International Journal of Food Science and Technology, 49, 531–540.

Zheng, J.; Wu, J.; Dai, Y.;Kan, J.; Zhang, F. 2017. Influence of bamboo shoot dietary fiber on the rheological and textural properties of milk pudding. LWT - Food Science and Technology, 84, 364-369.

Zhu, Y.; Chu, J.; Lu, Z.; Lv, F.; Bie, X.; Zhang, C.; Zhao, H. 2018; Physicochemical and functional properties of dietary fiber from foxtail millet (*Setariaitalic*) bran. Journal of Cereal Science, 79, 456-461.