EFFECT OF PROCESSING TECHNIQUES ON HOLISTIC QUALITY OF BAMBOO SHOOT (*Bambusa vulgaris*)

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by

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DEDICATED TO….

MY BELOVED PARENTS, LOVING HUSBAND &

LATE GRANDFATHER

CERTIFICATE

This is to certify that the thesis entitled "**Effect of Processing Techniques on Holistic Quality of Bamboo Shoot (*Bambusa vulgaris*)**" being submitted by **Mrs. Poonam Singhal** to the **Indian Institute of Technology Delhi** for the award of **Doctor of Philosophy** is a record of bonafide research work carried out by her under our guidance and supervision in conformity with the rules and regulations of Indian Institute of Technology Delhi. The research report and results presented in this thesis have not been submitted, in part or in full, to any other university or institute for the award of any degree or diploma.

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ABSTRACT

In recent years there has been a marked interest in health related issues due to increasing trend of lifestyle diseases amongst the urban population. Researchers are trying to explore the potential of lesser known traditional plant products having abundant bioactive constituents. Therefore, present research work was undertaken to study a non-conventional vegetable i.e. bamboo shoot species (Bambusa vulgaris) owing to its special nutritional characteristics. Since edible bamboo species has cyanogenic toxicity, hence it is important to develop a system of processing and preservation for keeping nutritive quality and antioxidant activity intact along with minimizing toxic content.

The effect of different domestic cooking processes i.e. Ordinary cooking (OC), Pressure cooking (PC) and Microwave cooking (MW) was investigated on the proximate composition, minerals, cyanogen content and antioxidant capacity using standard methods. Major nutrients like ash content (i.e. minerals), crude protein, carbohydrate, crude fiber and crude fat were found to decrease with all the three cooking treatments, but maximum reduction took place in the PC method. MW cooking showed maximum nutrient retention and the reason for this could be short time exposure to food matrix. Both macro elements like Ca, Mg, P, Na, K and the micro elements like Fe, Cu, Mn, Se and Zn were reduced to significant levels in the cooked samples but with a less percent decrease in the MW cooked sample. The cyanogen content also showed maximum reduction (90.22%) in MW cooked sample. The total phenol and flavonoid content in the fresh shoots was found to be 29.0 mg GAE/100g and 49.7 mg CE/100g respectively but the content decreased with cooking treatments. Antioxidant capacities determined by ABTS, DPPH, FRAP assays was also found to decrease in the cooked sample due to degradation of the antioxidant compounds and its leaching in the cooking medium.

Drying of bamboo shoot is attempted by different methods viz. Tray drying (TD), Sun drying (SD), Oven drying (OD), and Microwave drying (MWD). The effect of drying was studied on the physico-chemical characteristics of bamboo shoots. The dried samples were analyzed for change in nutritional composition, cyanogenic toxicity, antioxidant capacity, color, texture and rehydration potential. Amongst all the drying methods, MWD led to a faster drying whereas SD took the maximum time. The rehydration ratio of FD sample both at 25˚C and 100˚C was found to be highest in the beginning. After 60 min the rehydration ratio of FD and SD samples was found to be comparable. Fresh shoots have hard casing requiring a puncture force of 10.08 N but drying results in softening of the tissues. Amongst all the drying methods, FD required the least puncture force indicating its porous structure. As for the color of the dried shoot sample, FD sample exhibited the highest L value, lowest a and b values indicating lightness and giving an appearance close to the natural product. Dark color was induced in other treatments due to non-enzymatic browning.

The proximate composition of the bamboo shoot sample dried by different techniques was also estimated and compared with the fresh sample on dw basis. It was found that there was a reduction in all the major nutrients like protein (ranging from 3.51-33.38%), fat (ranging from 47.59-70.56%), fiber (ranging from 1.32-6.76%) and vitamin C (ranging from 6.34-

29.76%) during drying. All the major and micronutrients were reduced to considerable amounts during different drying methods. Highest reduction in the cyanogenic content was observed in the MWD sample due to high heat as compared to FD i.e at very low temperature.

Bamboo shoot fermentation is a traditional process carried out in different communities of the North-Eastern region. Therefore, to understand the mechanism involved in the traditional process and further improvement, its scientific validation was done. The shoots were fermented for a period of 30 days with the addition of inoculum (2 year previously fermented shoot) and see the effect of fermentation on the cyanogens content and acidity Initial investigation showed that the acidity increased and cyanogenic toxicity decreased (14.7 ppm dw basis) at the end of fermentation period (30 days) with a level reaching close to the permissible limit (< 10 ppm dw basis) as prescribed by WHO standards. The final fermented bamboo shoot product was further analyzed for the proximate composition, minerals and antioxidant capacity. An increase in the protein content (+17.28%) was found in the fermented sample while other nutrients like fat and vitamin C were found to decrease i.e. 90.2% and 35.77% respectively as these were used up by the growing micro-organisms. Fermentation leads to reduction in the mineral content but Fe content did not change significantly. A significant increase in the phenol (29.0 to 42.06 mg GAE/100g) and flavonoid content (49.7 to 59.44 mg CE/100g) was observed. Antioxidant capacity was also found to increase in fermented shoots indicating their potential for scavenging free radicals to protect human health.

Further, for in-depth understanding of microbial aspect of traditional knowledge, using certain additives like salt, sugar, mustard seeds, acetic acid and above inoculum, a 10 days experiment was set up. Microbial activity (TVC and LAB) was found to be at the initial stage and increased upto 6^{th} day of fermentation, after which it decreased and became stable as the nutrients for the metabolic activity of the micro-organism were depleted. Genus Lactobacillus was found to be involved in the fermentation process. It was also found that additives like salt, mustard seeds and inoculum can help in fastening the fermentation process and can also enhance the taste of the product.

Overall, the research findings would help in developing an integrated system for processing and preservation of bamboo shoots. Microwave cooking can be explored as a new technique for cooking shoots at the domestic level. Freeze drying giving a good quality product can be used by the small-medium food processing enterprises to dry highly perishable bamboo shoots. Improved solar drying system can be employed as another alternative for this purpose. Fermentation of bamboo shoots with additives like salt, sugar, mustard seeds, inoculum not only help in reducing the fermentation time but also add flavor to the final product. It can easily be incorporated in traditional bamboo shoot fermentation technique for its further improvisation.

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LIST OF ABBREVIATIONS

S. No.	Abbreviation	Full form
1.	NTFP	Non-timber forest products
2.	MFP	Minor forest produce
3.	FAO	Food and Agricultural Organization
4.	USD	United State Dollar
5.	ERG	Engineering Resources Group
6.	US	United States
7.	USA	United States America
8.	TERI	Tata Energy Research Institute
9.	DPPH	2, 2-diphenyl-1-picrylhydrazyl
10.	ORAC	Oxygen radical absorbance capacity
11.	AOA	Anti-oxidant activity
12.	HCN	Hydrogen cyanide
13.	TPO	Thyroid peroxidise
14.	DPSD	Double-pass solar drier
15.	CD	Convection solar drier
16.	OSD	Open-sun dryer
17.	RSM	Response surface methodology
18.	OC	Open cooking
19.	PC	Pressure Cooking
20.	MWC	Microwave cooking
21.	fw basis	Fresh weight basis
22.	dw basis	Dry weight basis
23.	CHN Analyzer	Carbon Hydrogen Nitrogen Analyzer
24.	ICP-AES	Inductively Coupled Plasma Atomic Emission Spectrometer
25.	TPC	Total phenolic content
26.	GAE	Gallic acid equivalent
27.	FRAP	Ferric Reducing Antioxidant Power
28.	CE	Catechin equivalent
29.	TETZ	Tripyridyltriazine
30.	TE	Trolox Equivalent
31.	IP	Inhibition percentage

32.	TEAC	Trolox equivalent antioxidant capacity
33.	OD	Open drying
34.	SD	Sun drying
35.	MWD	Microwave drying
36.	TD	Tray drying
37.	FD	Freeze drying
38.	TVC	Total Viable Count
39.	LAB	Lactic acid bacteria
40.	NA	Nutrient Agar
41.	PDA	Potato Dextrose Agar
42.	MRS	Man, Rogosa and Sharpe
43.	cfu	Colony-forming units
44.	MR	Methyl Red
45.	VP	Voges-Proskauer
46.	RW	Refractance Window
47.	UV	Ultra violet
48.	IMViC	Indole Methyl Red (MR), Voges-Proskauer (VP) and Citrate
49.	RF	Radio-frequency
50.	NaCl	Sodium chloride
51.	NaOH	Sodium hydroxide
52.	HCl	Hydrochloric acid
53.	H_2SO_4	Sulphuric acid
54.	$NaNO_2$	Sodium nitrite
55.	$AlCl_3.6H_2O$	Aluminum Chloride Hexahydrate
56.	$FeCl_3$	Iron chloride
57.	CO_2	Carbon dioxide
58.	$	Dollar
59.	º	Degree
60.	%	Percentage
61.	C	Celsius
62.	min	Minutes
63.	max	Maximum
64.	sec	Seconds

65.	cms	Centimeters
66.	mm	Millimeter
67.	approx	Approximately
68.	hrs	Hours
69.	mg	Milligram
70.	g	Gram
71.	μg	Microgram
72.	ml	Microlitre
73.	l	Litre
74.	μl	Microlitre
75.	ppm	Parts per million
76.	kg	Kilogram
77.	nm	Nanometer
78.	mM	Millimolar
79.	w/v	Weight by volume
80.	v:v:v	volume:volume:volume
81.	rpm	Rotations per minute
82.	psi	Pounds per square inch
83.	mbar	millibar
84.	mHz	Megahertz
85.	W	Watt
86.	kw	kilowatt
87.	Ca	Calcium
88.	Mg	Magnesium
89.	P	Phosphorous
90.	Na	Sodium
91.	K	Potassium
92.	Zn	Zinc
93.	Fe	Iron
94.	Cu	Copper
95.	Se	Selenium
96.	Ar	Argon