Impact of drying techniques on physical quality of bamboo shoots: Implications on tribal’s livelihoods

Poonam Singhal¹*, Shalini Gaur Rudra², Ranjay K Singh³, Santosh Satya¹ & SN Naik¹

¹Centre for Rural Development and Technology, Indian Institute of Technology, Delhi, India;
²Division of Food Science and Postharvest Technology, Indian Agricultural Research Institute, Pusa, New Delhi-110 012, India;
³ICAR-Central Soil Salinity Research Institute, Karnal-132 001, Haryana, India
E-mail: singhalpoonam6@gmail.com

Received 3 April 2017, revised 6 October 2017

Use of bamboo shoots is an integral component of indigenous knowledge, food and livelihood security of many tribal communities of India. Bamboo shoots are being consumed in different forms including dried, fermented and fresh. These three forms of bamboo have different qualities with respect to physical and chemical properties affected by its processing technique. Taking the insights from previous field studies with tribal communities of India, this study investigates the effect of drying treatment on the drying rate, rehydration ratio, texture and color of fresh bamboo shoot, and its implication on the livelihoods of tribal communities of India. Samples were dehydrated with five different drying methods: sun drying (SD), oven drying (OD), tray drying (TD), microwave drying (MWD) and freeze drying (FD). Drying rate was fastest with MWD reducing the moisture content to 8.54 % in 420 seconds. FD sample had higher rehydration ratio both at 25 °C and 100 °C, required less force to puncture the rehydrated sample and were lighter in color and appealing in appearance as compared to other drying treatments. MWD sample dried quickly due to high temperature but did not prove to be a quality product in terms of rehydration potential, texture and color. Although an expensive and energy requiring technique, freeze drying produced a good quality product with good reconstitution properties for convenience foods and can be used as a potential technique to preserve bamboo shoot by the food industries. Enabling policies on solar energy can be integrated to enhance quality of bamboo shoots being sun-dried by the tribal communities, and enhance their livelihood prospects.

Keywords: Bamboo shoot, Drying techniques, Rehydration, Color, Texture, Tribal’s livelihood security, Adi tribe

IPC Int. Cl.: B27J, F26B, B01D 43/00

Bamboos a group of giant arborescent grasses belong to the family Poaceae and sub-family Bambuseae. Bamboos are mainly found in the mixed deciduous and tropical evergreen forests and partly found in the dry dipterocarps forest. More than 1250 species belonging to 75 genera have been reported to be distributed worldwide. Bamboo shoots exhibit a great potential as a food resource, particularly of tribal communities of South East Asia and Africa. For centuries young shoots have been consumed by the tribal communities of North Eastern region of India and other Asian countries. They are consumed in fresh, fermented, canned and dried forms. Bamboo shoots substitute as food for the tribal and poor communities during lean period and drought years, thus ensuring their livelihood security. They have been reported to be a good source of nutrition being high in fiber and low in fat. They are not only a storehouse of nutritional elements but also contain some important antioxidants and medicinal components which can help prevent the onset of metabolic disorders. Bamboo shoot is consumed with plant and animal resources, primarily by the tribal communities of North east India. Socioeconomic and cultural capitals of these communities are intermingled with bamboo shoots consumption and income generation. As per the season and demand, bamboo shoots are used in fresh and or fermented forms, and dried in sun or on the traditional system (energy harvester) set in kitchen. Such processed shoots vary in their qualities, are thus consumed at home level and sold in market for income by the tribal women. Thus, different processing techniques of bamboo shoots impact consumers’ demands and overall livelihood security of those who collect, process and sale bamboo shoots for their livelihood security.

Studying plant based traditional knowledge relating to food and ethnomedicines requires a systematic exploration, characterization, identification of active
ingredients (in case of ethnomedicines and compounds in functional foods), validation of claimed knowledge, making refinement if required, and finally applying the tested knowledge for the sustainable development\(^4,5\). These steps are suggested to be pursued through ethical protocols and following participatory approaches among various stakeholders to valorize the knowledge\(^5\). This study includes few of the above described steps such as the exploration of bamboo based knowledge applied by Adi women was done using ethical protocol in previous studies, while the value addition aspect through drying process pursued in the laboratory conditions. Largely, the work on food based traditional knowledge from North eastern region covered the exploration part, and lacks value addition aspects\(^2,3\). Thus, refinement of knowledge with formal knowledge, as covered in this study, gives strength to the policy implications to generate and enhance the livelihood of knowledge holding communities. The inextricable relations of value addition of plant based knowledge and livelihood of local communities provides foundations to conserve biodiversity and associated culture\(^6\).

Bamboo shoots are highly perishable and thus are edible only for few days. High moisture content leads to deterioration in terms of physical and chemical quality due to increased enzymatic activity and microbial degradation. Physiological changes such as browning and lignifications further lead to deterioration which affects the commercial value. Therefore, it is important to develop preservative technology for bamboo shoots which are most often used by tribal and poor communities. Drying is one way by which the moisture content can be reduced and shelf life can be extended. One study evaluated the quality of bamboo shoots dried by hot airflow drying followed by vacuum freeze drying and the reverse of the process\(^7\). In another study by Madamba 2003, shrinkage, density and porosity of hot-air dried bamboo was checked\(^8\). In a more recent study effect of microwave power on colour change kinetics of bamboo shoot slices was investigated during microwave drying\(^9\). Different researchers have used different drying treatments to see its effect on physical-chemical properties. Comparison of different drying methods to see the quality of bamboo shoots in terms of color, texture and rehydration ratio has not been attempted yet. Therefore, this study was carried out with objective to know the effect of different drying treatments on the physical properties of bamboo shoot slices, and its overall implications on industrial use and livelihood security of tribal communities.

**Insights and hypothesis of research**

First hand information about seasonal availability, collection and use of bamboo shoots were collected from previous studies from Adi tribe and other communities of North east regions of India\(^2,3,10\).

Insights were generated from these previous studies and field works with Adi tribe of Arunachal Pradesh about drying techniques of bamboo shoots being used. While going through the previous studies, some of key knowledge holders who process and dry bamboo shoots for market sale commented as:

*Using traditional methods of processing bamboo shoots for market sell limits our scale and quantity. Now we need fast, more scientific and drudgery-free methods so that process of bamboo shoot drying is made easy, and better in quality for enhanced livelihood.*

(Orik Rallen, a key knowledge holder Adi woman, Sibut village, East Siang, Arunachal Pradesh)

Taking insight from above comment, a hypothesis was developed on strengthening the impacts of drying technique on physical attributes of bamboo shoots. Such knowledge can further be transferred to impart skill among Adi women on bamboo shoot drying to enhance their livelihoods by enabling government policies of skill development and entrepreneurship.

**Research methodology**

Following the social-ecological research methodology and ethical protocols, the field insights on exploration of knowledge and process involved in making bamboo shoots were already explored in previous studies from Adi women of East Siang district\(^3\). This study further carried out the advanced laboratory work involving the value addition of bamboo shoot through a combination of traditional and modern drying technique. Laboratory research was carried out with following procedure and techniques:

**Sample preparation**

Bamboo shoot of *B. vulgaris* species was procured from TERI Gram, Haryana. Raw shoots were washed and peeled off. The initial moisture content of bamboo shoot slices was determined by the oven method by placing shoot at 105 °C in an oven\(^11\). Fresh
bamboo shoot was evenly cut into rings and dried by five different methods including both traditional and modern techniques:

1. **Oven drying**
   Sample was distributed uniformly on the trays and dried in an oven (Scientific Systems, India) at 60±0.5 °C and the weight of the sample was recorded every hour till it became constant.

2. **Sun drying**
   Shoot was dried in the direct sunlight at temperatures 30-37 °C and dried till the moisture came down to less than 10 %.

3. **Microwave drying**
   Shoots were placed in the centre table of the Domestic Microwave (IFB Model No: 20MP1S, 800 W power and 2450 MHz) and weight of the sample was recorded after every 30 seconds.

4. **Tray drying**
   Shoots were evenly spread on an aluminum tray (1.05m X 0.45m) and dried in cross flow hot air (air flow rate of 1.2-1.8 m/s) at 70±2 °C (Kilburn make, Model 0248) for 6 h so that the moisture content is reduced to below 10 %.

5. **Freeze drying**
   The shoot sample was first frozen in a deep freezer and then placed in a freeze drier (Labconco, Freezone 2.5, US) at a temperature of -49 °C at 0.76 mbar pressure.

**Rehydration ratio**
The rehydration potential of dried bamboo shoot slices was evaluated by immersing 2 g of sample in water at 25 °C and 100 °C. Samples were drained and weighed at 30, 60, 90 and 120 min for those at 25 °C and at 3, 6, 9 and 12 min for those at 100 °C. The water absorbed (g) divided by the dry sample weight (g) was expressed as the rehydration ratio. The slope of rehydration ratio vs. rehydration time was defined as the rehydration rate.

**Texture**
Texture measurements were taken using a texture analyzer (TA-XT2i; Stable Micro Systems Ltd., Godalming, Surrey, UK), with a 2 mm diameter stainless steel cylinder probe. A single texture measurement was taken on each sample using the following parameters: 1 mm/s test speed, 5 mm/s post speed and the deformation was 70 % of the original height. Hardness (maximum peak force, N) was used as indicator. The dried samples were rehydrated first before taking the measurements. At least ten measurements were taken for each sample.

**Color**
Color of fresh and dried samples was evaluated with a Hunter Lab colorimeter (Model No. Miniscan XE plus 4500 L, Hunter Associates Laboratory, Inc., VA, USA). The instrument (45 % geometry, D 65 optical sensor, 10 ° observer) was standardized with black and white reference plates (No. LX-17760, X = 79.30; Y = 84.11; Z = 88.94). The results were expressed as L (whiteness/darkness), a (red/green), and b (yellow/blue) values. In addition, the total colour change (ΔE) was calculated from the L, a & b values.

**Statistical analysis**
All the experiments were done in triplicate and the data presented here represents the mean of three replicates with standard deviation. The results obtained were subjected to analysis of variance (one way ANOVA) using SPSS 10.0 statistical software. The means were compared using Duncan’s multiple range test and the statistical difference with p < 0.05 were considered significant.

**Results and discussion**

**Effect of different drying system on drying time**
Variations in drying time were observed with different drying treatments, viz. Oven drying (OD), Tray drying (TD), Sun drying (SD) and Microwave drying (MWD), and are shown in Figs. 1&2, respectively. The initial moisture content of bamboo shoot was 90.57 % on wet weight basis as measured by the oven dry method. The final moisture content came down to 8.41, 8.17, and 8.25 % for OD, TD and SD in 16, 6 and 112 h. MWD resulted in a faster drying rate with 420 sec and reducing the moisture content to 8.54 % due to its special heating system. Sun drying took the longest of all because of the non-uniform erratic drying pattern and uncontrollable weather conditions. Bal et al. also reported a decrease in drying time with increased microwave power level in case of bamboo shoot. It was also found that the hot air-microwave drying reduced the convection drying time of bananas by about 64.3 %. Similar results were obtained by different authors on drying of fruits and vegetables by various drying techniques. These authors explained that the shorter drying time under microwave heating conditions could be due to
the additional energy input, rapid heat penetration by microwave and forced expulsion of gases.

**Effect of drying treatments on rehydration potential**

The rehydration curves of bamboo shoot slices at 25 °C and 100 °C are shown in Figs. 3 & 4. The rehydration ratio of FD sample was highest initially and after 60 min the rehydration rate of FD and SD samples were found to be equivalent. Because of the porous structure of FD sample they are able to absorb more water during the first 30 min. No statistical difference (p < 0.05) was found between TD, SD and OD samples at 30, 60, 90 and 120 min, respectively. MWD sample because of its hard texture could not absorb much water as compared to the other samples and hence showed the lowest rehydration potential. The rehydration capacity of freeze-dried acerola (also known as West Indian cherry) was high because the samples did not suffer from cellular rupture and were able to preserve its original porous structure. Similarly rehydration ratio of sea cucumber dried by freeze drying was more than air and microwave dried treatments.

When water temperature was increased to 100 °C, less rehydration time was required for reconstitution. FD sample showed a continuous increase in the rehydration rate. No significant difference (p < 0.05) was observed between TD, OD and MWD at 6, 9 and 12 min, respectively. FD sample showed an extremely high reconstitution potential as compared to the other samples followed by SD sample. Similar results were obtained for carrot dried by FD as compared to air drying and vacuum microwave drying.

**Effect of drying on texture**

Dried bamboo shoot slices were first rehydrated and then the force was measured required to puncture the slices (Fig. 5). The puncture force measures the hardness of a product's surface and is an indicator of the case hardening occurring during the drying process. Fresh shoots were the hardest to puncture requiring a force of 10.08 N. The puncture force required to break TD, SD, OD, MWD and FD bamboo shoot slices were 8.34, 7.5, 8.4, 8.55 and 4.6 N, respectively, indicating that least puncture force is
required to break FD samples indicating its porous structure. No significant difference was found between TD, OD and MWD samples. MWD samples required the maximum cutting force because of the case hardening occurred during high temperature drying. Overall drying treatments resulted in decreased hardness in the rehydrated samples. Similar results have been supported by Zheng et al., where FD bamboo shoot slices possessed same hardness as that of the fresh ones. The freeze drying treatment was found to induce a softening effect and required the least puncture force in pumpkin, garlic, carrot. Microwave drying of sea cucumbers led to a poor chewing properties and higher hardness. Higher and rapid shrinkage in kiwi-fruit sample dried in microwave oven was found due to excessive heat generation and fast removal of the water from the sample tissues.

Effect of drying methods on color

Bamboo shoots processed by different drying methods were distinguishable based on both visual and instrumental assessment of color (Table 1). L value was found to significantly vary for the fresh sample and other samples dried by different drying methods. L value of freeze dried sample was highest indicating lightness as compared to microwave dried sample which was darkest with an L value of 44.19. In microwave drying due to high temperature there is uneven heating at the sides and corners of the product which leads to charring and hot spots in the final product. A positive a value indicates redness whereas a negative a value indicates greenness. a value of all the samples was positive indicating redness with the control sample having the lowest value of 0.09. Amongst the different drying treatments, FD had the lowest value indicating highest degree of lightness. FD retains the natural color of the product and hence gives an eye appealing close to natural product. b value was found to be different for all the drying methods but the value for TD and OD (33.95 and 35.18) and MWD and FD (26.43 and 25.06) were not significantly different from each other. b value was found to be lowest for fresh sample and highest for OD sample indicating more degree of yellowness in the OD samples. The results were found in agreement to the recent study where FD bamboo shoot samples were found to have a light color as compared to the hot air dried samples because of the inhibition of the non-enzymatic browning due to vacuum which happened in other drying processes where heat was involved.

Previous studies indicated that bamboo shoot is dried in sun (energy less process) but take longer time and sometimes it gets spoil due to climatic anomalies. In addition, when women try to make larger amounts of dry bamboo shoots, quality of product is also compromised. As a result, establishing a viable enterprise becomes a challenge. The freeze drying method (although a high investment technique but delivers good quality product) can be taken into account to impart the skill among tribal women (mostly women pursue bamboo shoots drying) to add value into drying process of bamboo shoots, and thus can enhance

![Fig. 5 — Effect of different drying treatments on hardness of rehydrated bamboo shoot slices](image-url)
the marketability. Such process of value added bamboo shoots could also be integrated with the policy of government of India on organic farming since bamboo shoots are naturally grown and conserved for food and other purposes. This process of integrating informal knowledge with formal knowledge and policy may further strengthen the policy of conserving biodiversity and culture together. The policy of imparting skill and knowledge among rural women to enhance entrepreneurship and livelihoods is the prime concern of government. The freeze drying process need to be further strengthened through intense scientific inputs and research protocols and alternative low energy requiring ways like solar drying need to be explored so as to be integrated with already existing government policies of skill development and entrepreneurship.

Conclusion and lessons

It can be concluded from the above research findings that FD samples showed a better reconstitution potential, porous texture and an appealing light color close to the natural color among all the drying techniques employed. Since the technique is expensive and energy intensive it cannot be utilized at the domestic level in the rural sector, particularly among tribal people, to preserve bamboo shoots. But the preservation through freeze drying can be taken up by the food industries at a commercial scale. To carry out healthy and qualitative drying at the home level, research attempts on low cost drying treatments should be explored. Solar drying being inexpensive and sustainable technology could be seen as an alternative to sun drying keeping in view the quality of final product and socio-cultural and economic conditions in rural areas for enhancing the business potential of bamboo shoot.

Channelizing the energy to enhance home-scale enterprises especially bamboo shoots is widespread challenge among many tribal communities of India including North eastern region. Using the right form of energy to make bamboo shoots available when not in season is the need of the hour for food industries. Duration of rainy days in the North eastern regions, when bamboo shoots is consumed and sold at large scale in either fresh or fermented form is very short and also remains the hindrance in sun-drying of bamboo shoots. Therefore, traditional techniques of drying bamboo shoots of tribal communities of this region can be integrated with solar-energy led techniques. A number of state and central government’s policies on solar energy can be mainstreamed with traditional techniques of drying bamboo shoots. This will have promising impacts on reducing bamboo shoots wastage, enhancing quality of products.

Findings of this study further open an avenue that, how best traditional knowledge of drying bamboo shoots by many tribal communities in India could be integrated as part of knowledge co-production on value added and quality bamboo shoots using scientific knowledge (solar energy led drying techniques) to make a plural knowledge. This will have significant impact on enhancing livelihood resilience of tribal communities, who depend heavily on bamboo shoots. The knowledge on drying of bamboo shoots developed in this study can further be transferred to impart skill among Adi women (who are major stakeholder of related knowledge) to enhance their livelihoods. The methods developed in this study with applications at household and industrial scales (micro/macro), can also enable government policies of skill development and entrepreneurship to rural women, particularly of tribal communities (North eastern region and other parts of India) where drying and selling of bamboo shoot is common. The value added products of bamboo shoots through suggested methods may scale-up product(s) for large-scale production to reach among non-tribal population also. Therefore, the inextricable relations of demand and supply chain will provide the future avenues to conserve the bamboo species being used in bamboo shoot based foods.

Acknowledgement

The financial support for carrying out this work was provided by Ministry of Rural Development, New Delhi India (Project No. RP02011). We acknowledge the Adi community from where knowledge and insights on traditional knowledge and drying techniques of bamboo shoots was drawn during previous studies which formed the base for this study.

Conflict of Interest: Authors hereby declare that there is no conflict of interests in this paper.

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