RESEARCH ARTICLE
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Preservation of Fiber-Rich Banana Blossom as a Dehydrated Vegetable

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ABSTRACT: Banana blossom is an excellent source of crude fiber in the human diet. Hot water blanching adopted at cottage level is found ineffective for preserving the banana blossom due to enzymatic browning which reduces market demand of the processed product. Therefore, attempts were made to develop a ready-to-cook dehydrated product from the banana blossoms, while maintaining the quality and minimizing enzymatic browning and use of controversial sulfating agents.

Cutting the banana blossoms into slices of 3 mm directly into a 0.2 % citric acid solution and keeping the slices immersed for 30 minute duration followed by drying at 50°C for 6 hr gave an acceptable product with respect to appearance, flavor and overall quality. The quality of the product remained almost unchanged when stored in Aluminum foil laminated with high density polyethylene (Al/HDPE) for more than a month. Oriented polypropylene laminated with cast polypropylene (OPP/CPP) was by far inferior for storage of the dehydrated banana blossom, of which moisture content increased by 2.9 % and L' value decreased from 41.23 to 37.42.

KEYWORDS: processed banana blossom, enzymatic browning, dehydration, rehydration ratio.

INTRODUCTION

Blossom of the banana plant (*Musa acuminata* Colla) is often consumed as a vegetable in many Asian countries such as Sri Lanka, Malaysia, Indonesia and the Philippines.[1] In Sri Lanka more than 32 million the banana bunches are produced annually.[2] Banana blossom is a popular dish in Sri Lankan cuisines. It is consumed as a curry as well as a boiled or deep fried salad with rice and wheat bread. Despite the absence of data on dietary fiber content and composition of the banana blossom, it is generally valued as a fiber-rich source.

Dietary fiber has demonstrated its benefits in health and disease prevention in medical nutrition therapy. Consumption of dietary fiber is known to lower blood cholesterol levels, [3] normalize blood glucose and insulin levels,[4,5] promote normal laxation, avoid constipation,[6,8] prevent diverticulosis and diverticulitis,[9] lower the risk of colon cancer[10] and breast cancer,[11] and prevent obesity etc. According to American Dietetic Association, except in certain therapeutic situations, dietary fiber should be obtained through consumption of food.[9] The recommended intake of dietary fiber is 20-35 g/day for a healthy adult,[12] which is not frequently met due to low intake of good sources of dietary fiber such as fruits, vegetables, whole and high fiber grain products, and legumes.[9]

Although the banana blossom is highly valued for its fiber content, consumption may be constricted due to cumbersome preparation procedures. Developing a preserved product from the banana blossom would eliminate such difficulties and offer benefits to the consumers such as prolonged shelf life, convenience in preparation as well as promoting the intake of fiber rich vegetables among people. This will also allow exploring more marketing niches in the western countries. Although dehydration is considered as a low cost preservation process to produce ready-to-cook food items,[13] not many studies on preservation of the banana blossom have been reported.

Color and rehydration ratio are very important quality attributes of the dehydrated products.[14] Banana blossoms are highly susceptible to enzymic browning which is attributable to polyphenol oxidase (PPO) activity and substrate concentration. Processing steps such as slicing, cutting and drying always promote the browning,[15,16] which leads to reduction in visual and organoleptic quality of the dried the banana blossom. Developing a method to control the occurrence of enzymatic browning is important for dehydration of banana blossoms, especially due to increasing consumer concern over sulfating agents, which were banned by Food and Drug Administration.[17]

This study was therefore, conducted to develop a ready-to-cook form that could be promoted to the market as a preserved item of the blossom of the banana of a widely grown cultivar, *Embul,* by dehydration.

Materials and Methods

This study was conducted in the Food Science and Technology Laboratory, Faculty of Agriculture, University of Peradeniya, Sri Lanka during January to May, 2000. Evenly mature banana blossoms of the cv. *Embul* (an extensively grown cultivar in Sri Lanka) were procured from the fruit orchards of the Department of Agriculture. The banana blossoms were snapped off leaving a 15 cm long part in the distal end of the fruit bunch after cessation of fruit formation on the banana bunch.

Preliminary Studies

Since no studies have previously been reported, preliminary studies were carried out to establish basic processing methods prior to commencing the main study. Outcomes of these methods were selected for later testing and processing. In a systemic manner, thickness of the banana blossom slices, measures to avoid browning of cut slices and processing temperature-time requirement to develop a product that is preferred by the consumers were determined in the preliminary study.

Four sizes of thickness of slices (viz. 1, 2, 3 and 5 mm) were tested to determine the most appropriate thickness that gives an attractive product after processing. Among the four thicknesses of the banana blossom, 5 mm slices were found too thick and not good in texture and appearance after rehydration, while 1 and 2 mm slices appeared curled and twisted. Slices of 3 mm thickness showed least changes in appearance, and hence it was selected.

Since the banana blossom develops a dark brown colour when sliced and later added to water, in this study slicing was directly done into separate solutions, namely hot water (at 96-98 °C for 3-4 minutes), solutions containing table salt, potassium metabisulfite, ascorbic acid, and citric acid over a broad range of concentrations, separately.

The results of the preliminary study indicated that hot water blanching at 96-98 °C for 3-4 minutes caused a rapid browning giving a dark black color to the final dehydrated product, and hence it was not selected for further processing purpose. Pre-treatment with salt or ascorbic acid was inferior to potassium metabisulfite or citric acid as the former two substances resulted in the darker dehydrated product. Of the latter two, citric acid was selected as the pre-treatment[18] due to controversial issues on potassium metabisulfite.[19] However, both potassium metabisulfite and citric acid had relatively lower color change than the rest. Out of the concentrations used in the range of 0.1 % - 0.3%,[20] a 0.2 % citric acid solution was found effective in minimizing browning, and hence used foregoing experiments.

Furthermore, the optimum temperature for the activity of 0.2 % citric acid solution was determined using four temperatures (viz. 25°, 65°, 75° and 85 °C) for about 3-4 minutes and assessing color changes and rehydration ratio of the dehydrated product. It was found that the activity of citric acid was better at 25° C (Table 1). However, as longer immersion times are generally adopted for pretreatment at room temperature, a longer immersion time of 30 minutes was compared against 3-4 minutes. Immersion time of 30 minutes was found to be effective in lowering browning.

Three drying temperatures (viz. 45°, 50° and 55° C) were tested to determine the most suitable temperature-time combination to reduce water activity below 0.6 and moisture content below 5 % in slices. The water activity value below 0.6 was reported as water activity minima for most microorganisms.[21] The time taken to reduce water activity below 0.6 at 45, 50, and 5 °C was 8 hr, 6 hr and 5 hr 30 min, respectively. The best temperature-time combination for dehydration was 50 °C for 6 hrs.

Dehydration of The banana Blossom

Freshly harvested the banana blossoms were washed under running water after removing 3 to 4 outermost fibrous bracts, and fresh weight of each banana blossom was recorded in order to determine the final yield of the processed product after dehydration. The blossoms were then sliced to a thickness of 3 mm (according to the findings of the preliminary study) directly into 0.2% citric acid solution using a vegetable slicer (Nakazato-54781). To fully immerse 250 to 260 g of the banana blossom slices, 1 liter of 0.2% citric acid solution was needed. All the core tissues in the slices were then removed while in the solution, and the slices were left in the solution for another 30 minutes. At the end of 30 minute duration, slices were spread over plastic trays at a loading density of 2.2 kg/m^2 and allowed to drain out excess liquid. Based on the result of temperature-time combination in the preliminary study, slices were kept at 50 °C in a dehydrator (Phoenix TK-Mini 10) for 6 hours in cross flow of hot air at a flow rate of 0.305 m s^{-1}. Processing steps for dehydration of the banana blossom is given in Fig. 1. This process was replicated three times with newly harvested the banana blossoms. At the end of dehydration, the weight of dehydrated product was recorded. The product was then stored in desiccators until they were used for sensory assessment and analysis for physical properties.

The extent of browning of the dehydrated product was assessed in terms of L' value (100 for perfect transmission to zero for opaque) [22] using a color difference meter (ZE-2000 Nippon Denshuku).

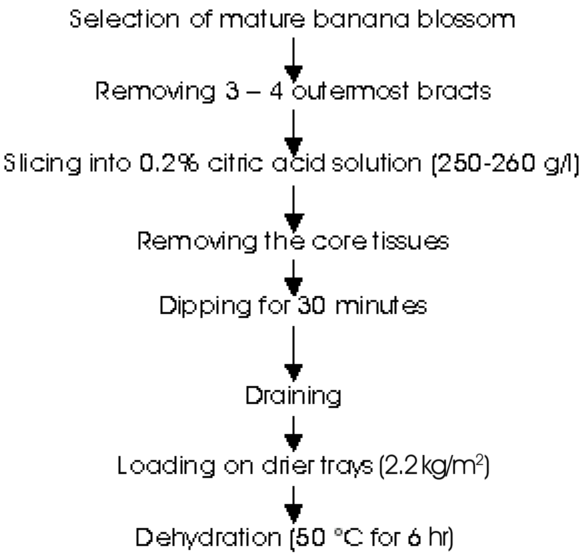

Fig 1. Processing steps of dehydration of banana blossom.

Rehydration ratio of the dehydrated product, i.e. the ratio of weight of processed food after rehydration to the weight of dehydrated processed food without water (g rehydrated product/ g dried product), was determined as described by Ranganna.[23] The moisture content of both dehydrated and fresh the banana blossom was determined by oven drying.[24] Water activity of dehydrated product, i.e. ratio between the vapor pressure of the food itself, when in a completely undisturbed balance with the surrounding air media, and the vapor pressure of distilled water under identical conditions, was determined at 27°C by measuring the equilibrium relative humidity using a hygrometer (Testo 635) in an incubator (Yamato- IC600) according to the method of Karel et al.[21] The crude protein, crude fiber, total ash and mineral contents of the dehydrated and fresh the banana blossoms were determined according to the standard methods of AOAC.[24]

The processed product was assessed for consumer preference using sensory analysis. One set of processed blossom pieces was used for immediate assessment of the quality. A sensory panel was selected based on the ability to recognize and rate basic taste, odor and texture when consumed. [25] Thirty graduate students between 24-27 years old with a background in food science were selected as judges. Two separate curry dishes were prepared from fresh the banana blossom pieces and the dehydrated banana blossom in sufficient quantities. Both samples were evaluated in parallel by the thirty judges when the samples at room temperature were presented randomly to them. Each judge was asked to rate the banana blossom curry in terms of appearance, flavor, texture and overall quality based on the degree of liking on each sample on a 5-point hedonic scale (i.e. 1 = dislike extremely; 2= dislike; 3 = neither like nor dislike; 4= like 5 = like extremely). The responses were marked on separate sheets provided to the judges. Each sample was evaluated twice when presented randomly for the uniformity of the results.

Two sets of the processed product were stored for assessment of physical properties after a storage period of one month. These two sets were stored separately in 12 cm x 9 cm pouches (6-8 g each) of oriented polypropylene laminated with cast polypropylene (OPP/CPP) and aluminum foil laminated with high density polyethylene (Al/HDPE). The pouches were stored under ambient conditions (i.e. at 30 ± 2 °C and 75% RH) for one month. At the end of one month of storage, the samples were analyzed for moisture content, water activity, rehydration ratio and color (L' value) as adopted previously. The samples were visually observed for the presence of fungal colonies and color changes, if any.

Statistical Analyses

The repeated measurements of L' value and rehydration ratio of the dehydrated products from different pre-treatments were subject to analysis of variance ($p=0.05$) and means were compared using Fisher's protected least significant difference (LSD) test[26] using SAS statistical software (Version 6.02). Sensory scores were analyzed using Friedman test in MINITAB statistical software (Minitab Inc., State College, PA). The data from storage study and physico-chemical analyses were subjected to analyses of variance and mean comparisons using LSD.

Results and Discussion

The rehydration Ratio

The effect of temperature on rehydration ratio of dehydrated product was significant ($p=0.01$), but there was no significant effect of chemical treatment nor interaction between temperature and chemical treatment on rehydration ratio (Table 1). There was a reduction of rehydration ratio with increasing temperature (Table 2). The highest rehydration ratio of 10.79 was at 25 °C (Table 2). As Potter and Hotchkiss [27] reported, increasing temperatures cause distortion of cells and capillaries in plant tissues which may lead to textural changes, thus lowering water absorption and adsorption characteristics affecting rehydration ability and rehydration ratio.

The L' Value

The L' value shows the lightness or darkness, i.e. zero for opaque to 100 for white color.[22] There were significant effects of temperature and chemical pre-treatments ($P = 0.01$) as well as their interaction on the

Table 1. ANOVA Table for rehydration ratio and L' value of the processed banana blossom slices.

Source of variation	Degrees of freedom	Mean Squares	
		Rehydration Ratio	L' Value
Temperature - T	3	39.53 ***	158.00 ***
Chemical – C	1	0.27	233.68 ***
T x C	3	0.05	5.36 *
Error	40	0.39	1.39
CV%		7.42	3.42

No. of replicates = 6.

Table 2. Effect of pre-treatment with temperature and chemicals on rehydration ratio of the dehydrated banana blossoms at an immersion time of 3-4 minutes.

Treatments	Rehydration ratio
Temperature, °C	
25	10.79 ± 1.0
65	8.78 ± 0.63
75	7.44 ± 0.31
85	6.64 ± 0.24
LSD (p=0.05)	0.52
Chemical	
Citric acid (0.2%)	8.34 ± 0.50
Water	8.49 ± 0.59
LSD (p=0.05)	ns
CV%	7.42

L' value of the processed product (p = 0.01) (Table 1). The results of the interaction between temperature and pre-treatment showed that the L' value was highest at 25 °C, and decreased with an increase in temperature (Fig. 2). There was a significantly greater L' value when citric acid (2%) was used as a pre-treatment compared to water which suggests greater effectiveness of 0.2% citric acid in minimizing browning compared to water. This shows that when 2% citric acid was used, the processed product remains lighter in color when compared to water as a pre-treatment. This may be either due to chelating of copper ions in active sites of the PPO enzymes by citric acid as suggested by Dziezak,[20] or lowering pH which inhibits polyphenol oxidase (PPO) enzyme,[28] or both.

The decrease in the L' value indicates an increase in brown color development, which reduces the marketability of the processed product. The brown color development in plant tissues occurs due to activities of enzymes. In particular, the formation of brown pigments are developed when PPO enzyme reacts with phenolic compounds.[29] PPO generates *o*-quinones, which subsequently undergo non-enzymatic

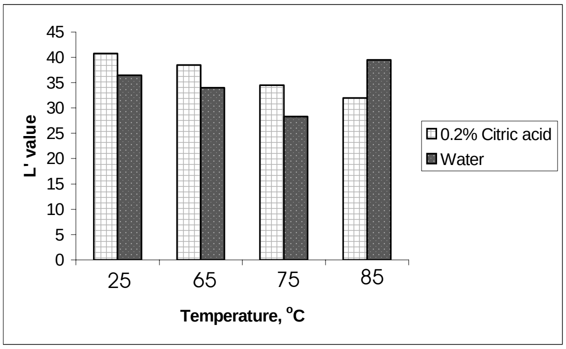

Fig 2. Effect of the interaction between temperature and pre-treatment chemical on the L' value of the dehydrated banana blossoms. [LSD $_{(p=0.05)}$ = 1.37]

oxidative polymerization leading to development of brown color pigments.[29] Therefore, in order to reduce the brown color development, a very rapid inactivation of PPO is required before PPO generates *o*-quinones. Devece et al.[30] reported that PPO in mushroom remained active for more than 6 min and produced brown pigments at a blanching temperature of 92°C. However, hot water blanching or pretreatments with high temperatures could become less effective in minimizing oxidative browning if the reaction between PPO and phenolic compounds is rapid, as observed in the case of the banana blossom. However, there are other non-enzymatic browning reactions in plant tissues such as oxidation of ascorbic acid and Millard reaction, that may also contribute to the browning of the product while hot air drying is continued.[31]

The highest L' value (41.23) and the highest retardation ratio (11.0) were found with 0.2% citric acid at 25°C (room temperature) with an emersion duration of 3-4 minutes (Fig 2). When the immersion duration was increased to 30 minutes at the same temperature, the L' value significantly increased to 44.23. This may suggest prolonged immersion period for minimizing browning, which also agrees with Manimegali and Ramah,[18] who also reported a considerable reduction in browning with increasing immersion duration of 30 minutes for bitter guard in 0.2% citric acid solution. The possible reason may be the increased penetration of citric acid into cells and thereby inhibiting the PPO, which otherwise oxidizes polyphenolic compounds in the banana blossom resulting browning of end products.

Chemical Properties

There were non-significant decreases in crude protein and total ash contents due to processing of the banana blossoms compared to the fresh blossoms (Table 3). However, crude fiber, Ca and Fe contents significantly decreased due to processing. Crude fiber

Table 3. Physico-chemical properties of fresh and processed banana blossoms.

Parameter	Fresh banana blossoms	Dehydrated banana blossoms*
Water activity	0.92±0.01 a**	0.58±0.00 b
Moisture (g/100g)	88.75±1.17 a***	5.18±0.12 b
Crude protein (g/100g of DM)	21.01±0.10 a	20.54±0.61 a
Crude fat (g/100g of DM)	6.02±0.31 a	5.79±0.41 a
Crude fiber (g/100g of DM)	20.31±1.38 a	17.41±1.42 b
Total ash (g/100g of DM)	8.74±0.11 a	8.53±0.20 a
Ca (mg/g of DM)	3.42±0.13 a	2.82±0.10 b
Fe (mg/g of DM)	0.13±0.12 a	0.01±0.11 b

* Dry matter (DM) basis
** Values within a row followed by different letters are significantly different according to t-test at p = 0.05.
*** Based on fresh weight basis.

content significantly decreased from 21.31 g/100 g dry weight in the fresh blossoms to 17.41 g/100 g dry weight in the processed product (Table 3). The higher crude fiber content of the banana blossom usually leads to increases in the absorption and adsorption of water.[32] Considerably, a higher value in the rehydration ratio was found in the dehydrated banana blossom when compared to some dehydrated vegetables in previous studies.[18, 33] This may be attributed to higher fiber content of the banana blossom than most of other vegetables. Drying leads to curling and twisting, which makes fiber more susceptible to degradation under the assay condition.[34] This supports the significantly lower fiber content in the dehydrated banana blossom compared to the fresh blossoms. Observed reduction in Fe and Ca content might be due to leaching of minerals during blanching according to Puupponen-Pimiä et al.[35]

Sensory Evaluation

The estimated medians of preference for overall quality and flavor of the curry prepared from the dehydrated banana blossom were above 4 of the 5-point Hedonic scale (Fig. 3). Comparison between the mean scores of sensory quality attributes of two curries made out of the fresh and dehydrated banana blossom revealed that scores of the panelists did not vary significantly ($p<0.05$) in flavor and overall acceptability. However, significantly lower scores were found for appearance and texture in the curry made of the dehydrated banana blossom. The estimated median of the scores for texture was below 3, which suggests the need for further improvement in texture of the dehydrated product. Comments from the panelist showed preference for smaller particle thickness. However, smaller particles resulted from thinner slices of 1 and 2 mm made processed product very much twisted and curled, which would distract the consumer preference.

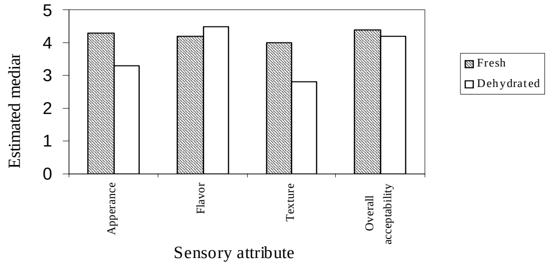

Fig 3. Estimated median of sensory attributes for curries made from fresh and dehydrated banana blossom.

Physical Properties of Processed Product after Storage

After storage of one month, the dehydrated banana blossoms packed in OPP/CPP and Al/HDPE were found to gain moisture contents of 2.9% and 0.81%, respectively based on the moisture content at the time of storage (Table 4). This indicates the superiority of Al/HDPE over OPP/CPP for storage of the processed banana blossom slices. In addition, the data also show that the processed product possesses high rehydration ability, which is a proof of undamaged texture of the processed product, and which helps maintain the water absorption due to its hygroscopic nature. Sagar and Mani[36] have reported that there is a structural deterioration in products when stored in OPP/CPP leading to reduction in rehydration ratio, thus affecting consumer preference after sometime.

The L' value decreased from 41.23 to 37.42 for the dehydrated banana blossoms stored in pouches made of OPP/CPP, while in Al/HDPE, the L' value decreased slightly from 41.23 to 39.56 at the end of the one month storage (Table 4). In the Al/HDPE packaging material, there is a higher resistance to light, moisture and gas exchange, thus either avoidance or lowering the oxidative deterioration or both could be the reasons

Table 4. Effect of packaging materials on physical properties of dehydrated banana blossoms after one month of storage under ambient condition.

Parameter	Prior to storage	After storage for 30 days*	
		OO/CPP package	Al/HDPE package
Moisture (g/100g DW)	5.2±0.70	8.1±1.81 a**	6.0±0.92 b
Rehydration ratio	10.0±0.97	8.6 ± 1.02 b	10.0 ± 0.91 b
L' value	41.23±1.30	37.42±1.42 a	39.56±1.10 b
Water activity	0.58±0.01	0.67±0.01 a	0.59±0.01 b

* OO/CPP-oriented polypropylene laminated with cast polypropylene (0.02 mm); Al/HDPE-Aluminum foil laminated with high-density polyethylene (0.04 mm).
** Values within a row followed by different letters are significantly different according to t test at p=0.05.

for maintaining the moisture free condition of the processed product. These characteristics in Al/HDPE would have prevented any deterioration and browning thus retaining the color of the processed product. In these characteristics, OPP/CPP packaging material appeared to be inferior.

Water activity has increased from 0.58 without storage to 0.61 in dehydrated product stored in OPP/CPP (15.5% increase), while in Al/HDPE, the increase in negligible, i.e. from 0.58 to 0.59 (a 1.7% increase, Table 4).

Conclusion

Results of this study showed that the banana blossom could be processed to reduce browning, which is a major defect observed. Increased temperatures aiming at inhibiting polyphenol oxidase enzyme and its reactions were ineffective as it increased browning and reduced rehydration ratio. As a pretreatment, emersion of the banana blossom slices in 0.2 % citric acid solution for 30 minutes followed by drying at 50 °C for 6 hrs gave the dehydrated end product with reduced browning, which was ready-to-cook and acceptable with respect to appearance, flavor and overall quality. Aluminum foil laminated with high density polyethylene was highly superior to oriented polypropylene laminated with cast polypropylene (OPP/CPP) as a promising packaging material for the dehydrated banana blossom. The product could also be stored for an extended period beyond one month, since the current storage was conducted for one month and the product remained unchanged during the one month period .

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