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Development of Bilimbi (*Averrhoa bilimbi* L.) Powder: Physico-chemical, Microbial and Organoleptic Qualities

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Abstract: Underutilized plant species are defined by their unexploited economic potential, making them an appropriate focus for commercialization. Fruits of these plants are an important supplement to human diet as they provide the essential minerals, vitamins and fibre required for maintaining health. A research was conducted to develop bilimbi fruit powder with good nutritional qualities and to assess the shelf life. Unripe mature bilimbi fruits were collected, washed and cut into 12 mm thick slices. The slices were dipped into potassium metabisulphite solution of 0.05 % (w/v) for 5 minutes. These slices were placed in a single layer on trays, dried in sun for 18 hours and in dehumidifier at 40 °C, 50 °C, 60 °C and 70 °C for 16, 14, 12 and 10 hours, respectively and ground into powder. The developed powders were assessed for physico-chemical, microbiological, sensory qualities and shelf life. Physico-chemical analyses revealed that among the tested treatments the powder developed from the unripe bilimbi dried at 50 °C had 3.4 % of moisture content, 1.4 % of fibre, 10.9 % of tritratable acidity (as % oxalic acid), 20.8 mg/100 g of ascorbic acid and 11.3 % of total sugar content. Microbiological analysis indicated that there was no total plate count observed in the tested treatments. Sensory attributes showed that powder developed from the unripe bilimbi dried at 50 °C was most preferred based on the organoleptic characteristics. Among the treatments, the bilimbi powder obtained from the unripe bilimbi dried at 50 °C for 14 hours had the highest shelf life which could be preserved minimum of six months without any significant changes in the quality characteristics.

Keywords: Bilimbi powder, dehydration, organoleptic quality, physico-chemical characteristics.

1. Introduction

The perishable fruits and vegetables are available as seasonal surpluses during certain parts of the year in different regions and are wasted in large quantities due to absence of facilities and know-how for proper handling, distribution, marketing and

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storage. Furthermore, massive amounts of the perishable fruits and vegetables produced during a particular season results in a glut in the market and become scare during other off-seasons. Quality of fruits in pre and postharvest influences the consumer acceptance. The changes that occur in various physical and chemical characters determine the quality and in turn the economic returns to the producers and processors (Agrawal and Mangaraj, 2005). Fruits and vegetables needed simple technologies for processing, preservation and transport to various places of need, have suffered postharvest losses, estimated to nearly 40−60 % (Ikram *et al.*, 2009).

Food preservation has an important role in the conservation and better utilization of fruits in order to avoid the glut and utilize the surplus during the off-seasons. It is necessary to employ modern methods to extend storage life for better distribution and also processing techniques to preserve them for utilization in the off-seasons in both large scale and small scale. Preservation processes include: heating to kill or denature organisms (e.g. boiling), oxidation (e.g. use of sulphur dioxide), toxic inhibition (e.g. smoking, use of carbon dioxide, vinegar, alcohol etc), dehydration (e.g. drying), osmotic inhibition (e.g. use of syrups) and low temperature inactivation (e.g. freezing). One of the oldest methods of food preservation is by drying, which reduces water activity sufficient to delay or prevent bacterial growth.

Historically, food was dried in the sun. Nowadays, we can sun dry or dry in an oven or a dehydrator that is especially designed for home drying (Loesecke, 1999). Most fruits such as berries, cherries (pitted), seedless grapes, melons, prunes and plums require no pretreatment before drying. Light-coloured fruits especially apples, apricots, peaches, nectarines and pears, tend to darken during drying and storage. This process, called oxidation, drops the fruit of flavour, colour and vitamins A and C. To preserve the colour of these fruit, the most effective pretreatment is "sulfuring" (Srilakshmi, 2001).

Averrhoa bilimbi L., commonly known as bilimbi, belongs to the family of the Oxalidaceae and it is widely cultivated in the tropics. Bilimbi fruits are very sour and used in the production of vinegar, wine, pickles and in the preparation of Hindu dishes. The mature fruits can be eaten as raw or processed into jams and jellies. The dried powder is one of the value added product of unripe bilimbi fruit used in curries, dishes and powdered drinks etc. Medicinal uses are attributed to bilimbi, which include mixtures against cough, mumps, pimples and scurvy. The fruit juice has high levels of oxalic acid (Wong and Wong, 1995) and it is a good source of vitamin C. Most of the raw fruits are wasted due to their sour taste and shorter shelf life due to rotting and decay.

As bilimbi is a highly under-utilized fruit, it can be preserved by making it as a processed food to use it during off-seasons. Realizing the importance of fruit, as a cheap, highly nutritious and because of perishable nature and seasonally available it was decided to make a preserved product for human

consumption throughout the year. Therefore, this study was carried out keeping in view the nutritional importance of bilimbi, to utilize the fruit by preserving as dried powder and to evaluate the quality characteristics of developed bilimbi powders.

2. Materials and Methods

2.1 Material Collection and Sample Preparation

Unripe mature bilimbi fruits were obtained from the Regional Agricultural Research Station, Batticaloa. They were washed and cut into 12 mm thick slices. Potassium metabisulphite solution of 0.05 % (W/V) was prepared and the slices were dipped into the solution for 5 minutes. These slices were placed in a single layer on trays. The following dehydration methods and temperatures were used to dry the bilimbi slices: sun drying for 18 hours and in dehumidifier (ANDEN Model 1830) at 40 °C, 50°C, 60 °C and 70 °C for 16, 14, 12 and 10 hours, respectively. The temperature and duration for dehydration were identified by preliminary experiments carried out in the laboratory. The dried slices were ground into powder using a grinder for 3 minutes and the resultant powder was sieved into a particle size of 100 µm. The powders were stored in airtight plastic containers at ambient temperature of 30±1°C and Relative humidity of 80−85 % (R.H) for further analysis.

The treatments are listed as follows:

T_1 - Bilimbi powder obtained from unripe bilimbi dried in sun for 18 hours

T_2 - Bilimbi powder obtained from unripe bilimbi dried at 40 °C for 16 hours

T_3 - Bilimbi powder obtained from unripe bilimbi dried at 50 °C for 14 hours

T_4 - Bilimbi powder obtained from unripe bilimbi dried at 60 °C for 12 hours

T_5 - Bilimbi powder obtained from unripe bilimbi dried at 70 °C for 10 hours

2.2 Physico-chemical Analysis of Developed Bilimbi Powders

Physico-chemical qualities of dried bilimbi powder such as moisture, fibre, tritratable acidity (as % oxalic acid), ascorbic acid and total sugar content were analyzed using recommended standard AOAC methods (2002). Three replicates were used from each treatment during the physico-chemical assessment.

2.3 Microbial Test

The microbial assessment was carried out by estimating total plate count according to the method described by Arachchi (2003) in raw mango powder. The total plate count was determined by observing the colonies formed especially bacteria.

2.4 Organoleptic Assessment

Organoleptic assessment was carried out by a panel consisting of 30 untrained members to determine consumer preference using a nine-point hedonic scale in 1 is denoted as “dislike extremely” and 9 denoted as “like extremely’’. The organoleptic parameters such as taste, colour, flavour, absence of off-flavour and overall acceptability of the dried bilimbi powder were judged by the panelists.

2.5 Shelf Life Evaluation

The developed powders were stored in airtight plastic containers at ambient temperature of 30±1°C and 80−85% RH for shelf life evaluation. The samples were nutritionally tested for fiber, tritratable acidity, ascorbic acid, total sugar and moisture at 2 weeks interval and observations were made on samples to evaluate the shelf life of the development of powders.

2.6 Statistical Analysis

Data obtained in physico-chemical analysis were subjected to Analysis of Variance (ANOVA) and mean separation was done with Duncan's Multiple Range Test (DMRT). Descriptive statistics was done on sensory attributes and the means were compared using the Tukey's test ($p<0.05$).

3. Results and Discussions

The main objective of drying the fresh material is to prolong its shelf life by inhibiting the growth and development of pathogenic and spoilage micro-organisms. The unripe mature bilimbi slices were dried at different dehydration temperatures until the slices became dry but not sticky and leathery. Srilakshmi (2001) reported that the optimal temperature and time for drying of fruits is 50 °C and 6−24 hours, respectively. Changes in the nutritional quality of foods may occur as a result of drying.

3.1 Physico-chemical Parameters of Dried Bilimbi Powders

The results of physico-chemical analysis with respects to moisture, fibre and tritratable acidity of developed bilimbi powder samples are as presented in Table 1. There were significant differences ($p<0.05$) in moisture content of dried bilimbi powders obtained by different dehydration temperatures. The products had moisture contents ranging from 3.4 to 4.1 %, in which the dried powder obtained from unripe bilimbi dried at 50 °C had the lowest moisture content (Table 1).

Table 1: Moisture, Fibre and Tritratable acidity of Dried Bilimbi Powders

Treatment Code	Moisture (%)	Fibre (%)	Tritratable acidity (% oxalic acid)
T_1	3.8±0.05^{c}	1.2±0.006 ^{b}	10.1±0.02 ^{b}
T_2	3.9±0.05^{b}	1.3±0.005 ^{a}	10.6±0.01 ^{a}
T_3	3.4±0.03^{e}	1.4±0.010^{a}	10.9±0.03 ^{a}
T_4	3.7±0.01^{d}	1.1±0.003 ^{c}	9.8±0.05 ^{c}
T_5	4.1±0.03^{a}	0.9±0.005 ^{d}	8.6±0.01 ^{d}

Values are means of triplicates ± standard error. Means in the each column followed by the same letters are not significantly different at $p<0.05$. (T_1 - Bilimbi powder obtained from unripe bilimbi dried in the sun for 18 hours; T_2 - Bilimbi powder obtained from unripe bilimbi dried at 40 °C for 16 hours; T_3 - Bilimbi powder obtained from unripe bilimbi dried at 50 °C for 14 hours; T_4 - Bilimbi powder obtained from unripe bilimbi dried at 60 °C for 12 hours, T_5 - Bilimbi powder obtained from unripe bilimbi dried at 70 °C for 10 hours).

The moisture content for the dried and powdered products should be less than of 3.5 % and therefore exceeding the limit will directly impact on shelf life of the product (Mallawa, 2001). If the moisture contents of the products are within the acceptable limits and then, this can be considered as safe in terms of shelf life.

Fibre is a measure of the quantity of indigestible cellulose, pentosans, lignins and other components of this type present in foods. Aurand *et al*. (1987) stated that these components have little food value but provide the bulk necessary for proper peristaltic action in the intestinal tract. Among the treatments bilimbi powder obtained from the unripe bilimbi dried at 70 °C shows lowest fibre content than the dried powder obtained from the unripe bilimbi dried at 40 °C, 50 °C, 60 °C and in the sun (Table 1). This is due to the higher extent of thermal degradation of fibres at high temperature than that of low temperature (Brennan, 1994). Statistical analysis conducted on the data indicated that there were significant difference ($p<0.05$) among treatments except the treatments of bilimbi powder obtained at 40 °C and 50 °C (T_2 and T_3).

The titratable acidity content of fresh unripe bilimbi was 16.4 % which was higher than the dried powder of bilimbi. This is due to the evaporative losses of acid during drying. The titratable acidity in bilimbi dried powders ranged between 8.6 and 10.9 % as oxalic acid. Manjunath *et al.* (1991) reported that the percentage of total acidity in commercial samples of powder was in the range of 8.7−11.1 % as citric acid. The powder obtained from the unripe bilimbi dried at 70 °C showed low acid content than the other treatments (Table 1). This is supported by Josyin (1980) high temperature treatment cause high losses of acids in fruits.

The ascorbic acid content of bilimbi powder is shown in Figure 1. This is to compare the effects of dehydration temperatures on the ascorbic acid content of bilimbi powder.

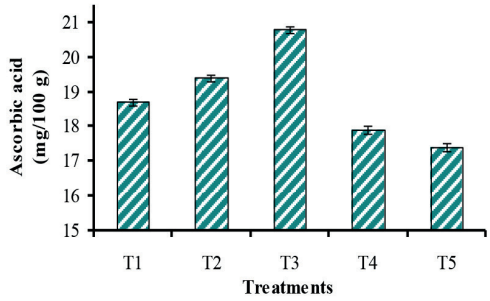

Figure 1: Ascorbic acid Content of Bilim− bi Powders

Values are means of triplicates. Vertical bars indicate the standard errors. (T_1 - Bilimbi powder obtained from unripe bilimbi dried in the sun for 18 hours; T_2 - Bilimbi powder obtained from unripe bilimbi dried at 40 °C for 16 hours; T_3 - Bilimbi powder obtained from unripe bilimbi dried at 50 °C for 14 hours; T_4 - Bilimbi powder obtained from unripe bilimbi dried at 60 °C for 12 hours, T_5 - Bilimbi powder obtained from unripe bilimbi dried at 70 °C for 10 hours).

The bilimbi powder obtained from the unripe bilimbi dried at 70 °C showed minimum amount of ascorbic acid content than the powder obtained from the unripe bilimbi dried at 40 °C, 50 °C, 60 °C and in the sun.

This is due to the more oxidative losses of ascorbic acid by thermal degradation. This was supported by Watada *et al.* (1991). According to the statistical analysis there were significant differences ($p<0.05$) between the treatments for the ascorbic acid content of bilimbi powder.

The total sugar content of the dried bilimbi powders showed differences between the various treatments at 5 % significance level except the treatments that the bilimbi powder obtained from the unripe bilimbi dried at 60 °C and in the sun. Among the treatments the bilimbi powder obtained from the unripe bilimbi dried at 70 °C contains low total sugar content than the bilimbi powder obtained from the unripe bilimbi dried at 40 °C, 50 °C, 60 °C and in the sun (Figure 2). High losses of sugars due to browning reactions and caramalization process at high temperature than that of low temperatures. This is supported by Peacock *et al.* (1990). Saltveit (1984) also reported that high caramalization of sugars taken place at high temperature than that of low temperature.

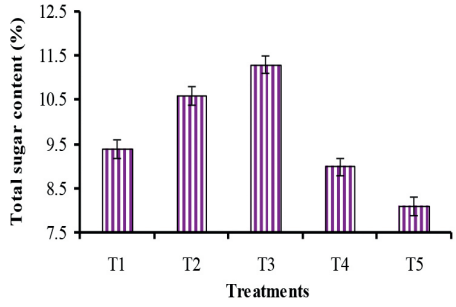

Figure 2: Total Sugar Content of Bilimbi Powders

Values are means of triplicates. Vertical bars indicate the standard errors. (T_1 - Bilimbi powder obtained from unripe bilimbi dried in the sun for 18 hours; T_2 - Bilimbi powder obtained from unripe bilimbi dried at 40 °C for 16 hours; T_3 - Bilimbi powder obtained from unripe bilimbi dried at 50 °C for 14 hours; T_4 - Bilimbi powder obtained from unripe bilimbi dried at 60 °C for 12 hours, T_5 - Bilimbi powder obtained from unripe bilimbi dried at 70 °C for 10 hours).

3.2 Microbiological Test

The microbiological examination, in terms of total plate count revealed that there were no any microbes observed after 6 months of storage in the developed bilimbi powders because low pH value of 1.3−1.5 inhibited bacterial growth. This was supported by Manjunath *et al*. (1991) in tamarind powder. Therefore, these samples are suitable for consumption. Micro-organisms play significant role in the determination of shelf life of food products. They are usually responsible for spoilage of many food items. A high total plate count could indicate the presence mixed population of micro-organisms, which may consist of spoilage types. Limits of microbial counts (Aerobic plate count/g at 30 °C should be <10) have been recommended in most foods to keep them safe for consumption (Ogunjobi and Ogunwolu, 2010).

3.3 Organoleptic Assessment

The mean values of organoleptic qualities for treatments are shown in Table 2. Results revealed that there were significant differences between the treatments for bilimbi dried powder in terms of taste, colour, flavour, absence of off-flavour and overall acceptability at 5 % level of significant.

Table 2: Mean Values of Organoleptic Qualities of Dried Bilimbi Powders

Treatment Code	Taste	Colour	Flavour	Absence of off-flavour	Overall acceptability
T_1	7.50±0.25^{a}	6.95±0.34^{bc}	6.95±0.29^{c}	7.70±0.26^{a}	6.55±0.21^{d}
T_2	7.35±0.13^{b}	7.25±0.14^{b}	6.60±0.15^{cd}	7.60±0.21^{a}	7.50±0.12^{b}
T_3	7.50±0.11^{a}	7.75±0.20^{a}	7.25±0.18^{b}	7.45±0.11^{a}	7.70±0.11^{a}
T_4	7.20±0.21^{c}	6.95±0.19^{c}	8.40±0.27^{a}	7.70±0.26^{a}	7.45±0.15^{b}
T_5	6.20±0.09^{d}	6.60±0.15^{d}	6.30±0.13^{d}	6.40±0.28^{b}	6.35±0.20^{c}

Values are means of 30 replicates ± standard error. Means in the each column followed by the same letters are not significantly different at $p<0.05$. Nine point hedonic scale: 1- dislike extremely, 9- like extremely.

Taste is the primary factor, which determines the acceptability of any product, which has the highest impact as far as market success of product, is concerned. In case of taste, the experimental results designated that, all the products were significantly differed ($p<0.05$), and the bilimbi powder obtained from the unripe bilimbi dried at 50 °C occupied the first rank, followed by dried powder obtained from the unripe bilimbi dried in sun. One of the most important sensory quality attribute of a food is colour. As the results of sensory analysis shown in Table 2 the scores ranged from 6.60 to 7.75; and the products significantly differed at 5 % significance level. The bilimbi powder obtained from the unripe bilimbi dried at 50 °C ranked as first, where as the bilimbi powder obtained from the unripe bilimbi dried at 70 °C ranked as last.

Flavor has a great impact on the consumption of food products. According to Tukey's test, there were significant differences between treatments at 5 % significance level. The treatment that the dried powder obtained from the unripe bilimbi dried at 60 °C had the highest mean value and the bilimbi powder obtained from the unripe bilimbi dried at 70 °C had the least mean value. In the case of absence of off-flavor, there was no significance difference ($p<0.05$) among treatments except the bilimbi powder obtained from the unripe bilimbi dried at 70 °C. Overall acceptability assessment showed that the bilimbi powder obtained from the unripe bilimbi dried at 50 °C had the most superior quality among the tested samples while the bilimbi powder obtained from the unripe bilimbi dried at 40 °C was rated as sub-superior.

The bilimbi powder obtained from the unripe bilimbi dried at 50 °C for 14 hours had the highest shelf life based on the physico-chemical, microbial and organoleptic quality characteristics compared to other treatments which could be preserved for a minimum period of 6 months at ambient conditions of 30±1°C and 80−85 % R.H without any significant changes in quality characteristics.

4. Conclusions

This research was designed to utilize the bilimbi which is still largely regarded as an under-utilized fruit and thereby increasing the shelf life of bilimbi through the process of development of dried powder. The findings

of the study showed that the bilimbi powder obtained from the unripe bilimbi dried at 50 °C for 14 hours was found to be most suitable temperature and treatment based on the physico-chemical, microbial and organoleptical point of view. Based on the shelf life evaluation, bilimbi powder obtained from the unripe bilimbi dried at 50 °C for 14 hours could be kept at ambient conditions of 30±1°C and 80−85 % R.H for a minimum period of 6 months without any significant changes in quality attributes.

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