International Food Research Journal 22(2): 707-712 (2015)
Journal homepage: *http://www.ifrj.upm.edu.my*

Physicochemical properties of tamarind and pineapple fruit pulps and powders

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Article history

Received: 9 April 2014
Received in revised form: 31 July 2014
Accepted: 3 September 2014

Keywords

Physicochemical properties
Tamarind
Pineapple
Fruit

Abstract

Tamarind and pineapple fruit pulps and powders were assessed based on their physicochemical properties such as crude protein, crude fibre, fat, ash, moisture content, water activity *(Aw)*, particle shape, particle size distribution, and density. Both of the fruit powders were subjected to a similar spray-drying process with the addition of 10% w/v of maltodextrin. The nutritional value in terms of crude protein (0.33 - 0.60%), moisture content (4.80% - 25.31%), crude fiber (16.92 - 79.92%), and fat (0.40 - 0.63%) for both fruit pulp and powders shows a significant difference at $p<0.05$. Therefore the fruit powders can be developed and improved for further processing into tablets.

Introduction

Tamarind (*Tamarindus indica* L.) is a multi-use tropical fruit tree grown mostly for its fruits. The tamarind fruits are usually eaten fresh or processed, used as a seasoning or spice, or the fruits and seeds are processed for non-food uses. The species has a wider geographical distribution in the subtropics and semiarid tropics and is cultivated in numerous regions. Tamarind belongs to the dicotyledonous family Leguminosae, which is the third largest family of flowering plants with a total of 727 recognized genera and the number of species is estimated at 19,327 (Lewis *et al.*, 2005).

Pineapple (*Ananas comosus* L.) is an important representative of the Bromeliaceae family and is cultivated in tropical and subtropical countries, including Malaysia, Hawaii, South Africa, Philippines and Thailand for local consumption as well as for export (Elss *et al*., 2005). Based on its potential economic and commercial value, pineapple has been identified as one of the priority commodities to be developed for domestic and international markets in The Third National Agriculture Policy (Samah, 2004). Malaysian pineapple varieties include Moris, Gandol (N19), Sarawak, MD2, Josapine and Maspine.

Tamarind and pineapple powders are an interesting product because of their features. The powder can be employed as an element of cooking food or as a seasoning agent in some products. Its advantages consist of a long shelf life at ambient temperature due to the low water action, low logistic expenditure due to less weight and volume, and it is easy to utilise compared to squeezing juice from tamarind and pineapple flesh. In summation, this form of product development would help reduce tamarind and pineapple losses caused by microorganisms and chemical and enzymatic reactions during the height of the cropping season (Weerachet *et al*, 2011).

The main objective of this study is to investigate the physicochemical properties of tamarind and pineapple pulps and powders including morphology, moisture content, density, crude protein, crude fibre, fat, ash and water activity after addition of 10% maltodextrin towards the fruits sample. An understanding of the physicochemical properties in the processing steps of the fruit powder is essential and important for future improvement and product development. The future work such as dissolution studies could be more systematic for the fruit powder tablets that have been produced. Dissolution testing is a new component in food tableting development and manufacturing, especially for natural fruit tablets. The design of new formulations of fruit

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tablet is seldom guided and assessed based on in vitro dissolution rates by means of the USP apparatus method (Jennifer *et al*., 2005).

Materials and Methods

Tamarind and pineapple fruit pulp preparation

Fresh tamarind fruits were purchased from the wet market in Serdang, Selangor, Malaysia (Selangor wholesale market) while pineapples of the MD2 variety were purchased from the Pineapple Information Centre, Malaysian Agro Exposition Park Serdang (MAEPS), Selangor. The tamarind pulp was picked and the seeds were removed from the tamarind pulp. The pineapples were selected from the MD2 variety in batches of 10 for analysis in the laboratory. After the purchase, the fruits were transported immediately to the laboratory. For a maximum sanitising effect prior to processing, the working area, cutting board, knife, plastic containers and other utensil used were washed and sanitized with sodium hypochlorite solution at pH 7. After the removal of the crown and skin, the whole fruit was crushed into a pulp using a domestic blender. The pulps were then placed in airtight plastic containers and kept in a freezer (-20°C) to await further analysis.

Tamarind and pineapple fruit powder preparation

The tamarind and pineapple pulps were prepared in several containers and added with 10% (w/v) maltodextrin. A food grade maltodextrin DE 10 (R&M Chemicals, Essex, UK) was used. The samples were transferred to a spray dryer (Ben Hay, United Kingdom) with constant operational conditions of inlet and outlet air temperatures at 190°C and 90°C, respectively, with a blower velocity of 25,000 rpm and a feed rate of 0.18 kg/m. The spray dried tamarind and pineapple powders were then compressed in sealed plastic containers and stored in a refrigerator (4°C ± 0.5) until further tests were carried out.

Proximate analysis

The proximate analysis included analysis of the tamarind and pineapple pulps and powders for moisture content, ash, crude protein, fat, and crude fibre. Moisture content was measured using a standard oven method. Ash content was determined using a standard method, whereby 5 g of sample was kept in a muffle furnace and converted to ash at the maximum temperature (525°C) for 6 hours. The ash was then cooled in a desiccator and weighed (AOAC, 1990). The protein content was determined according to Oko *et al*. (2012) using Kjeldahl extraction method (Kjeltec TM 2300, Germany), while Soxhlet extraction method was used for fat determination (Soxtec TM 2050, Germany). The determination of fibre was adapted from the method of using 0.1N sulphuric acid followed by 0.1N sodium hydroxide (Ranganna, 1997). The total carbohydrate content of the sample was calculated by the difference of the total weight of the sample (100%) and the summation of all the other constituents (crude protein, fat, moisture content, ash and crude fibre) (Bernan, 2003). All proximate analysis was performed in triplicate and the average reading was determined.

Particle size and size distribution test

Particle size and size distribution of both the tamarind and the pineapple powders were measured by using a particle size analyser (Malvern Mastersizer 2000 Instrument Ltd., U.K) with a dry dispersion method. The Mastersizer 2000 utilises the laser light diffraction technique to analyze the size of the particles. Three samples of 500 mg of both powders were used to determine the mean particle diameter for each powder (Amidon *et al*., 2009). Experiments were conducted at 1.0 bars of dispersion pressure and the particle sizes were reported in terms of d10, d50 and d90 (Ghoroi *et al.*, 2012). The analysed data was recorded using the Mastersizer 2000 software.

Density

Bulk density, ρb

The bulk densities of the powders were determined by measuring the volume of the measured mass of a powdered sample. For each of the tamarind and pineapple powders, a 10 g of sample was poured gently through a funnel into a dry 25 ml graduated cylinder. As most pharmaceutical powders have densities in the range 0.1-0.7 g/ml, hence, at least 60% of the cylinder was filled with sample (Amidon *et al*., 2009). Then, without compacting and tapping, the untapped volume was read directly to the nearest graduated unit of the cylinder and the value was recorded. This method was repeated three times for each sample. The value of bulk density was calculated by using the following equation:

$$\rho b = \frac{m}{v} \ (kg/m^3) \qquad (1)$$

Where ρb is the bulk density of the powder, *m* is the mass of powder and *v* is the untapped volume of the powder in the graduated cylinder.

Tapped density, ρt

Based on the international standard ISO designation 3953 (1993), the tapped density was determined by tapping a measured mass of the powder

sample in a container until no further decrease found in the volume of that sample occured (Stephenson, 1993). In this study, the tapped density of each tamarind and pineapple powder sample was measured using a tapped density tester (Micromimetics GeoPyc 1360, U.S.A.).

Three measurements were performed for each powder. For each determination, 2.0 g of powder sample was filled in the test tube through a funnel (Guerin *et al*., 1999) then the tapping operation of that sample was carried out using the tester. The tester stopped automatically when the equilibrium volume after tapping was obtained, and thus the tapped density was calculated using the following equation:

$$\rho t = \frac{m}{Vt}(kg/m^3) \quad (2)$$

Where ρt is the tapped density, m is the mass of powder, and Vt is the volume of tapped powder.

True density

True density measures the weight per unit volume of powder material, excluding the voids (Michcrafy *et al.*, 2007). The true density of single-components and binary mixtures was measured using a helium gas pycnometer (AccuPyc II 1340; Pycnometer Micromimetics, U.S.A.). The test was carried out by measuring 1.0 ± 0.1g of each sample. The results of the true densities of powders and mixtures were carried out in three replicates.

Porosity

The porosity of tamarind and pineapple fruit powders was calculated using the following equation (Paronen and Ilkka, 1996):

$$\varepsilon p = 1 - \frac{\rho b}{\rho true} \ (\%) \quad (3)$$

Where, εp is the porosity of the powder, ρb is the apparent density or bulk density of the powder column and ρtrue is the true density of the powder.

Water activity (A_w)

The water activity of the samples was determined using a digital water activity meter (Model 3TE, Aqualab, WA). For all the analysis, the average value of triplicated samples was reported.

Particle shape of powders

The morphology of the received powders such as particle size, shape and texture were examined by using a variable pressure scanning electron microscope (SEM Hitachi S-3400N, U.S.A). SEM was used in the present research due to the high resolution and depth of field generated by its images. The image was an artificial map of the surface and there were no direct ray paths linking the specimen to the projected image, as is the case in optical and transmission microscopes. The tamarind and pineapple powder samples were pre-coated with gold using a sputter coater to enhance conductivity under SEM. In addition, the samples were coated prior to examine in order to obtain the best images and to avoid charging the specimens.

Statistical tool

The analysis of variances (ANOVA) created from Microsoft Excel 2007 was used for the statistical analysis. The mean and standard deviation were determined from the triplicate measurements.

Results and Discussion

The results show that the pineapple fruit pulp and powder have higher moisture content compared to the tamarind fruit pulp and powder (Table 1) as the pineapple fruit powder has high juice content and lower viscosity compared to the tamarind.

Table 1. Proximate analysis of tamarind and pineapple pulp and powder

Proximate Analysis	Pulp + 10% w/v Maltodextrin		Powder + 10% w/v Maltodextrin	
Properties	Tamarind	Pineapple	Tamarind	Pineapple
Moisture Content (%)	5.15 ± 0.15	25.31 ± 3.11	4.87 ± 0.18	5.00 ± 0.18
Crude Protein (%)	0.43 ± 0.02	0.60 ± 0.04	0.33 ± 0.00	0.35 ± 0.01
Crude Fibre (%)	79.92 ± 0.85	78.99 ± 0.84	17.39 ± 0.42	16.92 ± 0.44
Ash (%)	17.80 ± 2.59	2.10 ± 0.27	4.62 ± 0.11	0.59 ± 0.05
Fat (%)	0.43 ± 0.18	0.63± 0.12	0.40 ± 0.18	0.63 ± 0.11

*Data represents means ± standard deviation of triplicate analysis

The moisture content of the tamarind pulp and powder was in the range of 5% and was close to the results reported by Tummala *et al.* (2006). The pineapple pulp showed high moisture content probably due to high water content in the fruits, but the powder had low moisture content. The tamarind and pineapple fruit powders were produced by the spray drying method with the addition of 10% w/v maltodextrin and 90% fruit juices. In the spray drying system, the moisture content of the feed had an effect on the final moisture content of the powder produced (Abadio *et*

al., 2004). The addition of maltodextrin to the feed prior to spray drying increased the total solid content and reduced the amount of water for evaporation. Hence, it decreased the moisture content of the powder thus produced. However, if the percentage of the maltodextrin was too high, the powder produced would be of lower quality as the nutrients from the tamarind and pineapple juice would be diluted. The percentage of crude protein and fat contents showed significant differences as ($p< 0.05$) between the pulp and powder. According to Samson (1980) low levels of fat show that fruits are not good sources of energy and hence need to be supplemented with other sources of fats for better body nutrition. Further, the crude fibre of the tamarind and pineapple pulps showed higher values than the powder as both the fruit pulps had a higher percentage of cellulose, hemicellulose and lignin in the crude fibre. Nevertheless, the proximate composition of the tamarind and pineapple fruit depended on locality.

The bulk and tapped density of the pineapple fruit powder was higher than the tamarind fruit powder as the pineapple fruit powder had a higher moisture content than the tamarind fruit powder (Table 2).

Table 2. Basic material properties of tamarind and pineapple fruit powders

Material Properties	Tamarind fruit powder	Pineapple fruit powder
Bulk density (kg/m3)	0.476 ± 0.002	0.487 ± 0.003
Tapped density (kg/m3)	0.718 ± 0.001	0.882 ± 0.002
True density (kg/m3)	1.403 ± 0.00	1.317 ± 0.00
Hausner ratio, HR Hausner (1967)	1.508	1.808
Carr Index, CI (%) Carr (1965)	33.70	44.78
Porosity (%)	24.26	37.50

*Data represents means ± standard deviation of triplicate analysis

Most food powders are known to be cohesive and, therefore, open bed structures supported by inter-particle forces are very likely to exist (Moreyra and Peleg, 1981; Scoville and Peleg, 1981; Dobbs *et al*., 1982). Since the bulk density of food powders depends on the combined effect of interrelated factors, such as the intensity of attractive inter-particle forces, particle size, and number of contact points (Rumpf, 1961), it was clear that a change in any of the powder characteristics may result in a significant change in the powder bulk density. Eventually, these densities affect the Hausner's ratio (HR) and Carr Index (CI) values, which with decreasing density values will increase the Hausner's ratio and Carr Index. The HR is a good indicator of powder flow and the CI is a measure of the tendency for a powder to consolidate. The HR and CI values were calculated according to Hausner (1967) and Carr (1965). The results showed that the HR and CI of the pineapple fruit powder was higher than the tamarind fruit powder as the bulk and tapped density of the pineapple fruit powder was higher. The powders were easily compacted and may form strong, coherent junctions between the particles (Yusof *et al*., 2005).

The water activity value for tamarind and pineapple fruit powders was less than the pulps (Table 3).

Table 3. Water activity *(Aw)* for tamarind and pineapple powders and pulps

Sample	A_w measured
Tamarind	
Powder + 10% w/v maltodextrin	0.53 ± 0.01
Pulp + 10% w/v maltodextrin	0.69 ± 0.01
Pineapple	
Powder + 10% w/v maltodextrin	0.44 ± 0.01
Pulp + 10% w/v maltodextrin	0.94 ± 0.001

*Data represents means ± standard deviation of triplicate analysis

This indicated that there was less free water in the powder available for biochemical reactions, which would be advantageous for a longer shelf-life. Water activity *(Aw)* measures the activity of free water in the food system which is responsible for any biochemical reactions. Food with an *Aw* of less than 0.6 is considered to be microbiologically stable, indicating no growth of spoilage organisms and pathogens (Betts *et al*., 2006). Based on the results, all the Aw values for both of the powders were lower than 0.6 which, therefore, it indicated that the powder samples were microbiologically stable compared to the pulp.

The particle size distributions for the tamarind and pineapple powders are presented in Table 4.

Table 4. Particle size of pineapple and tamarind fruit powders with the addition of 10% w/v maltodextrin

Material Properties	Tamarind	Pineapple
$d_{[0.5]}$ / µm	30.30 ± 0.19	36.72 ± 0.16
$d_{[0.9]}$ / µm	61.69 ± 1.91	69.68 ± 0.27
$d_{[0.1]}$ / µm	12.45 ± 0.09	15.96 ± 0.22
Span *	1.584	1.452

*Span was calculated as: (d[0.9] – d[0.1]) / d[0.5]. All results are means of three determinations

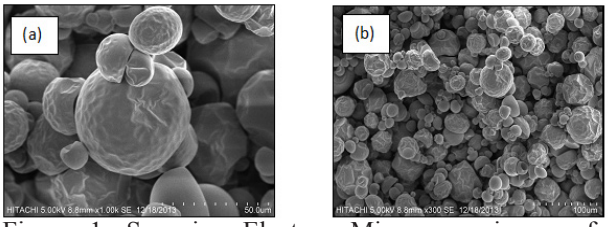

Figure 1. Scanning Electron Microscope images for Tamarind fruit powder with the addition of 10% w/v maltodextrin [at (a) 300 and (b) 1000 magnification]

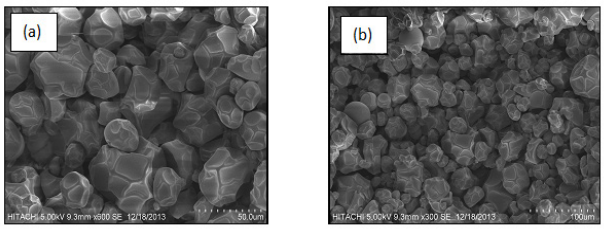

Figure 2. Scanning Electron Microscope images for Pineapple Fruit Powder with the addition of 10 % w/v maltodextrin [at (a) 600 and (b) 300 magnification]

In the table, the $d_{[0.1]}$, $d_{[0.5]}$ and $d_{[0.9]}$ are the upper volumetric diameter limits for 10%, 50% and 90% of the particles. Particle size plays a vital role in tablet formation and processing as it can directly affect the quality of the final product. All particle size analysis measures some property of the particles and reports results as equivalent spherical diameters. The particle size also influences the powder flowability and separation (Fitzpatrick *et al*., 2007). A figure of 10%, 50% and 90 % of the tamarind fruit powder particle size was lower than the pineapple fruit powder (Table 4). Therefore, the tamarind particles have a higher surface area compared to the pineapple in terms of particle size. According to Kaerger *et al*. (2004) an increase in surface area is mainly caused by a reduction in particle size.

In addition, the amount of span represents the measurement of the width of the particle size distribution. The span value of the tamarind fruit powder particles was 1.548, while the span value of the pineapple fruit powder particles was 1.452. The span value of pineapple particles was smaller than tamarind particles. As a result, pineapple particles had a narrower particle size distribution compared to the tamarind particles due to the smaller value of the span. The particle size distributions of both powders were clearly evident in the SEM pictures (Figure 1 and Figure 2).

The SEM involved the study of the outward appearances of the particles, including the shape, structure and pattern. Both of the tamarind and pineapple fruit powders were produced using a spray drying technique with an inlet air temperature of 130°C and outlet air temperature of 85°C. The SEM images of the tamarind and pineapple powders showed differences in morphological structure (Figure 1 and Figure 2). The tamarind showed agglomerate spherical shaped particles, while the pineapple showed agglomerate irregular shaped particles. Moreover, the spherical shape of the tamarind and the irregular shape of the pineapple included attached by small irregular particles which indicated shrinking. The appearance of shrinking and wrinkles is caused by high temperature heat during the spray drying process. Similar results have been reported on the formation of particles in the spray drying process (Vehring, 2008).

Conclusion

The physicochemical property data of the tamarind and pineapple fruits in the form of powder and pulp of crude protein, crude fibre, ash, and moisture content in tamarind and pineapple fruit have been analyzed. The addition of 10%w/v maltodextrin had a significant effect on the physicochemical properties of both fruits. Therefore, the addition of 10%w/v maltodextrin to the tamarind and pineapple fruit powders is recommended to preserve the nutritional value of the tamarind and pineapple fruit powders as the nutrient content did not degrade after the fruit pulps were spray dried into powders. After understanding the properties, the tamarind and pineapple fruit can be developed for in-vitro dissolution rate of its active ingredients content for future studies.

Acknowledgements

The authors would like to acknowledge the Ministry of Higher Education for the Fundamental Research Grant Scheme (FRGS) with grant No: 03-02-13-1289FR for funding of this research. The authors would also like to thank Mr Md Saifullah, Miss Faridatul Ain and Mr Fakhri Zainuddin for their invaluable assistance in the laboratory.

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