EVALUATION AND CHARACTERIZATION OF FREEZE-DRIED FRUIT JUICE POWDER

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Abstract

In addition to liquid foods and semi-solid foods, agricultural products such as vegetables and fruits are currently being dried and distributed to food processing companies. The purpose of such food drying processes is not only to reduce the volume and weight of the products but also to improve the product stability (shelf- life) whereas the product quality must be maintained during and after drying. For drying of vegetables and fruits, freeze-drying (FD) is known to be a good method, by which product shrinkage is eliminated or minimized, and a near-perfect preservation results are expected. The aim of this study was to investigate the production of freeze-dried papaya and watermelon in the form of powder that can be used as a natural alternative to synthetic additives used in food products such as pudding, beverages, jam, jelly and sauces for improving their flavor and aroma. To evaluate the characteristics of freeze-dried fruit powder, physico-chemical characteristics such as moisture, total fiber, ash, protein, vitamin C, total soluble solids, pH and rehydration ratio were determined. The phytochemical investigation and chemical analysis of fresh fruits were also carried out. The analysis of major and traces elements in freeze-dried papaya and watermelon were determined by using X-ray Fluorescence Spectrometry (XRF).

Keywords: freeze-drying (FD), physico-chemical characteristics, rehydration ratio, XRF

Introduction

Nowadays, the fast economic development has changed the trend of food consumption from calories assurance to diet nutrient enrichment. The consumers today are well aware of the importance of vitamins and minerals. This scenario has increased the global market demand towards the fresh fruits. In order to handle the market demand throughout the year, the fresh fruits are preserved using different drying techniques. High moisture content in the fruit leads to having high water activity which leads the quality loss in fruits by increasing the enzyme activity and microbial growth. Therefore, the reducing moisture content and water activity in fruits is always desirable to maintain the quality.

The aim of drying process is to remove moisture from raw material which generally refers to heating. The mechanism of drying consists of heat and mass transfer which affects on inferior product quality such as degradation of colour, nutritional values (vitamins and minerals), and antioxidant activities (Que et al., 2008). Freeze-drying has been used to eliminate water from a frozen material at low temperature under vacuum condition. It is a dehydration process of frozen solvent, which normally refers to water in foodstuff, at very low temperature which sublimed directly from a solid phase into a vapour phase.

Fruit powders are convenient, easy to handle and can be used to prepare several products such as snacks, beverages, jam, jellies, bakery goods and pastes (Khalil et al., 2002).The advantages of freeze-drying are to produce a highly dried product where the main constituents are preserved compared to other methods of food drying due to a low temperature processing

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(Khalloufi and Ratti,2003; Marques et al., 2007). However, freeze-drying is an expensive method because of its equipment and operation cost compared to the other drying methods.

In this study, it was intended to investigate the production of freeze-dried papaya and watermelon in the form of powders. In order to obtain the powder products, each fruit with maltodextrin (Dextrose Equivalence of 10-12, as 10 % by weight) addition were freeze dried. The maltodextrin contributed to the reduction in moisture content and hygroscopicity of the material.

Papaya

English name - Papaya
Botanical name - *Carica papaya.* L
Kingdom - Plantae
(Unranked) - Angipsperms
(Unranked) - Eudicots
(Unranked) - Rosids
Order - Brassicales
Family - Caricaceae
Genus - *Carica*
Species - *C.papaya*
Part of uses - Leaves, Fruits, Bark
(http://www.en.wikipedia.org/wiki/papaya)

Figure 1 Fresh and Mature Papaya

Watermelon

English name - Watermelon
Botanical name - *Citrulluslanatus* var. *lanatus,*
(Unranked) - Angiosperms
(Unranked) - Eudicots
(Unranked) - Rosids
Order - *Cucurbit ales*
Family - *Cucurbitaceae*
Genus - *Citrullus*
Species - *C.lanatus*
Part of uses - Leaves, Fruits, (http://www.en.wikipedia.org/wiki/watermelon)

Figure 2 Fresh and Mature Watermelon

Materials and Methods

Fresh, mature and ripe papaya fruits (*Carica papaya* L.) were collected from Pyin Oo Lwin Township, Mandalay Region. Fresh papaya was washed thoroughly with water. Then, it was peeled and chopped into pieces, about 1 cm length and 0.7 mm thickness, air-dried and then ground to obtain a fine powder form. The fine powder was stored in air-tight bags until analysis.

Fresh mature watermelons from Tada- U Township, Mandalay Region were collected and thoroughly washed with distilled water to remove dirt, dust, pesticide residues and then rinds were washed with pure ethanol to remove micro flora on the surface of the fruit. Then, it was peeled and chopped into pieces, about 1 cm length and 0.7 mm thickness, air-dried and then ground to obtain the fine powder form. Fine powder was stored in air-tight bags until analysis.

Phytochemical Investigation of Fresh Papaya and Watermelon

Phytochemical tests for fresh papaya and watermelon were carried out according to the following standard procedures; test for Alkaloids, Tannins, Protein, Phenol, Glycosides, Flavonoids, Saponins, Carbohydrates, and Phenolic compounds. The results of phytochemical investigation of papaya and watermelon are shown in Table (1).

Preparation of Tropical Fruit Powders Using Freeze-Drying Method

Fresh mature papaya fruit was washed thoroughly with water and cut into about 15mm length and homogenized by a juice extractor to obtain a homogeneous juice. The juice was mixed with maltodextrin (Dextrose Equivalence of 10-12, as 10 % by weight) and poured into each 300ml autoclaved screw-top glass bottles and freeze-dried by using a freeze dryer (**Operon** Ultra-Low Temperature Freezer -86°C, Korea) with total pressure and temperature inside a vacuum chamber(between 0.1 to 2.0 torr) and -50°C, respectively. Average freeze-drying time was approximately 72 h and after the stage of drying, the final product reached a final temperature of about 25°C. The freeze-dried papaya was ground by grinder and sieved through 60-mesh sieve to obtain a homogeneous powder. The freeze-dried powder was stored in a desiccator until further analysis. To compare the characteristics of freeze-dried papaya powder with hot- air oven dried papaya powder, fresh mature papaya juice mixed with maltodextrin was dried at 60°C by using hot -air oven dryer.

Fresh mature watermelons with uniform in color and size were collected from Tada-U Township, Mandalay Region and stored at 25˚ C. The fruits were thoroughly washed with distilled water to remove dirt, dust, pesticide residues and then cut into quarters and the flesh was scooped out and cut into small cubes. The cubes were placed in a juice processor. The extracted juice was then centrifuged and filtered. The filtered juice was placed in autoclaved screw-top glass bottles. The filtered watermelon juice, in screw-top glass bottles, was freeze-dried as previously mentioned for encapsulated papaya powder and stored for further analysis.

Evaluation of the Characteristics of Fresh Fruit and Freeze-dried Fruit Powders

Physico-chemical Analysis of Fresh Papaya and Watermelon

The physico-chemical characteristics such as moisture content ,crude fiber content, ash content, protein content, vitamin-C, total soluble solids content and pH of fresh fruits and freeze-dried fruit powder were determined by AOAC(2000) method.

The solubility test and color reaction test of freeze-dried papaya powder were carried out with various solvents and reagents. Water absorption index, water solubility index, loose bulk density, packed bulk density and rehydration ratio of freeze-dried papaya powder were compared with those of hot- air oven dried papaya powder.

Determination of Elements Content by X-ray Fluorescence Spectrometry (XRF)

The analysis of major and trace elements in fresh fruit (papaya and watermelon) and freeze-dried fruit powder were determined by using Energy Dispersive X-ray Fluorescence Spectrometry and data are shown in Table (4) and (8).

Results and Discussion

Fruits contain various phytochemical compounds that are similar in composition to vegetables. All contain a high percentage of water averaging 85%. Fat, protein and carbohydrate (cellulose and starch) are present in small amounts (Ihekoronye and Ngoddy, 1985). Most fruits are eaten as desserts and they can be processed into liquid product which includes fruit juices, wines and other preserves like; marmalade, jams, jellies etc. Fruit products are marketed canned, bottled or packaged in tetra-packets. Spoilage of fruits usually occurs during storage, transportation and while waiting to be processed. It has been recognized for many years that fruits continue undergoing biochemical changes even after harvest until spoilage occurs by microorganisms. This contributes to high post- harvest losses (Akande, 1995). An effective method of fruit preservation should retain the original characteristics of fruit as convenient as possible.

Papaya (*Carica papaya* L.) is well known for its nutritional and medicinal properties throughout the world. The whole papaya plant including its leaves, seeds, ripe and unripe fruits and their juice is used as a traditional medicine.

Watermelons are an excellent source of lycopene and are a great option for consumers who want to consume lycopene but do not like the taste or texture of tomatoes and tomato products.

The aim of the present research was to prepare the freeze-dried tropical fruit powders such as papaya and watermelon. The phytochemical investigation, chemical analysis of fresh fruits and the solubility of product with different reagents were also determined.

The phytochemical analysis revealed that the presence of tannins, proteins, phenols, glycosides, flavonoids, saponins, reducing sugar, carbohydrates and phenolic compounds in both fruits except alkaloids which is absent in watermelon. The presence of tannin contributes towards antioxidant activity of food. According to the literature, main papayas nutrition's are phenolic compounds, carotenoids, soluble dry matter, β carotene, sugars and others.

Compounds found in the papaya influence the flavor of the papaya include the sugar (glucose, fructose, sucrose) which contribute to sweetness and alkaloids compounds which impart bitterness (Table 1).

Table 1 Phytochemical Investigation of Fresh Fruit

No.	Text	Solvent	Reagent	Observation	Result	
					Papaya	Water-melon
1.	Alkaloids	1% HCl	Wagner's reagent, Dragendroff's reagents	Blue and bluish black	+	-
2.	Tannins	H_2O	Gelatin and 1% $FeCl_3$	Pale Yellow	+	+
3.	Protein	H_2O	10% NaOH solution and 3% $CuSO_4$ solution	Reddish brown	+	+
4.	Phenols	H_2O	10% aqueous $FeCl_3$	Greenish yellow color	+	+
5.	Glycosides	H_2O	10% NaOH solution	Pale yellow ppt.	+	-
6.	Flavonoids	EtOH	Conc: HCl & Mg ribbon	Pale green color	+	+
7.	Saponins	H_2O	Distilled Water	Frothing	+	+
8.	Reducing Sugar	H_2SO_4	5 N NaOH solution & Benedict's solution	Pale brown color	+	+
9.	Carbohydrates	H_2O	10% α-naphthol and H_2SO_4	Purple ring	+	+
10.	Phenolic Compounds	H_2O	Benedict's solution	Brown ppt.	+	+

(+) Present (-) Absent ppt. = precipitate
These experiments were carried out at Laboratory of Industrial Chemistry Department, Yadanabon University

For the preparation of fruit juice powder, Maltodextrin is an adjuvant widely used in drying processes, including freeze-drying process. Maltodextrin is especially used in hard drying materials, such as fruit juices in order to reduce the problems of agglomeration during storage and to improve product stability. Currently, maltodextrin is the most widely used additive to obtain fruit juice powders since it satisfies the demand and is also reasonably cheap. The addition of drying aids is necessary during drying of fruit juices, adding amount not exceeding the operational limits of the equipment or altering the flavour properties.

From Table (2), although the moisture content and pH of fresh papaya were in close agreement with the literature value, other constituents such as total soluble solids, dietary fiber, ash and protein content were quite different with literature value because of the cultivated conditions, the climate and the nature of soil. The decrease in total soluble solids was due to the respiration process of the fruit. Respiration is the oxidative breakdown of the more complex materials such as starch, sugars and organic acids into simpler molecules such as carbon dioxide and water.

Table 2 Physico-chemical Characteristics of Fresh Papaya Fruit (*Carica papaya* .L)

No.	Characteristics	Experimental Values (per 100 g)	Literature Values *
1.	***Moisture (%)	84	85.7
2.	**Crude Fiber (%)	0.065	1.7
3.	**Ash (%)	4.42	5.8
4.	**Protein (%)	0.375	0.47
5.	Vitamin-C	0.215	0.3549
6.	***Total Soluble Solids (^{o}Brix)	10	12.94
7.	***pH	5.3	5.36

* Source: Nutritive Value of Indian Foods., National Institute of Nutrition, Indian council of Medical Research, Hyderabad. India 1984.

** These values were determined at Myanmar Pharmaceutical Factory (Sagaing), Ministry of Industry.

***These values were determined at Laboratory of Industrial Chemistry Department, Yadanabon University.

To evaluate the characteristics of freeze-dried papaya powder, the physico-chemical characteristics of freeze-dried papaya powder were compared with hot-air oven dried papaya powder and the results are shown in Table (3). According to Table (3), some characteristics of freeze-dried papaya powder was differed slightly from that of hot-air oven dried papaya powder. It was found that the prepared sample by using freeze-drying had low moisture content and high Vitamin C content. However, protein content, the water absorption index, water solubility index and rehydration ratio of both of papaya powders were not quite different.

Table 3 Comparison of Physico-chemical Characteristics of Freeze-dried Papaya Powder with Hot- Air Oven dried Papaya Powder

No.	Characteristics	Experimental Values (per 100 g)	
		Freeze-dried Papaya Powder	Hot Air Oven –dried Papaya Powder
1.	*** Moisture (%)	1.65	7.10
2.	** Crude Fiber (%)	0.021	0.065
3.	** Ash (%)	4.83	4.42
4.	** Protein (%)	5.37	5.31
5.	** Vitamin-C (%)	0.473	0.215
6.	*** Total Soluble Solids (^{o}Brix)	89.00	78.0
7.	*** pH	4.61	4.5
8.	WAI**	1.9	1.83
9.	WSI*	50.78	50.8
10.	Loose Bulk Density (g/ml)	0.38	0.55
11.	Packed Bulk Density (g/ml)	0.53	0.35
12.	Rehydration Ratio (%w/v)	5.3	5.455

** These values were determined at Myanmar Pharmaceutical Factory (Sagaing), Ministry of Industry

*** These values were determined at Laboratory of Industrial Chemistry Department, Yadanabon University

WSI*= Water Solubility Index WAI** = Water Absorption Index

It was also noted that the potassium content, calcium content and iron content of freeze-dried papaya powder were lower than that of fresh papaya (Table 4).

Table 4 Elements Content in Fresh Papaya and Freeze-dried Papaya Powder by X-ray Fluorescence Spectrometry (XRF)

No.	Elements	Experimental Values* (% by weight)		Literature Values * (% by weight)
		Fresh Papaya	Freeze-dried Papaya Powder	
1.	Potassium (K)	4.37	0.196	5.0
2.	Calcium (Ca)	0.45	0.060	1.52
3.	Iron (Fe)	0.32	0.005	1.0

*These values were investigated at Universities' Research Centre, Yangon.
*http://www.en.wikipedia.org/wiki/papayas

On comparing the solubility of papaya powders, the powder using freeze-drying method was more soluble in water, ethyl alcohol, acetic acid, acetone, and formaldehyde than the papaya powder using hot air oven method but both of them were insoluble in petroleum ether, shown in Table (5).

The different drying methods of papaya powder affected the physical and physico-chemical properties as well as aroma retention of powders. From the analysis of solubility and color reaction of prepared papaya powder using different drying methods, freeze-drying method was a suitable method for the preparation of fruit powders, shown in Table (5) and (6).

Table 5 Comparison of Solubility on Papaya Powder Using Different Drying Methods in Different Solvents

Amount of Papaya Powder = 0.01 g
Volume of Solvent = 15 drops

No.	Drying Methods	Solubility						
		Water	Vegeta-ble Oil	Ethyl Alcohol	Acetic Acid	Acetone	Formal-dehyde	Petroleum Ether
1.	Freeze-drying	Very Soluble	Soluble	Soluble	Very Soluble	Slightly Soluble	Very Soluble	Very Soluble
2.	Hot Air Oven	Slightly Soluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Insoluble

Table 6 Color Reactions of Papaya Powder using Different Drying Methods

Amount of Papaya Powder = 0.01 g
Volume of Reagent = 15 drops
Coating Material = maltodextrin

No.	Types of Method	Different Reagents		
		(% w/v) Sodium Hydroxide Solution	Hydrochloric Acid (Conc:)	Sulphuric Acid (Conc:)
1.	Freeze-dried Method	orange	orange	pale yellow
2.	Hot Air Oven Method	orange	orange	pale yellow

From Table (7), the findings of investigation for moisture content, pH and total soluble solids of fresh watermelon are in accordance with the literature value, other constituents such as crude fiber, ash and protein content were quite different with the literature value because of the cultivated conditions, the climate and the nature of soil and the physico-chemical characteristics of freeze-dried water melon powder was slightly differed from that of fresh watermelon.

Table7 Physico-chemical Characteristics of Fresh Watermelon and Freeze-dried Watermelon Powder

No.	Characteristics	Experimental Values of fresh watermelon (per 100 g)	*Literature Values of fresh watermelon(per 100 g)	Experimental Values of freeze-dried watermelon powder (per 100 g)	*Literature Value for Dried Watermelon (per 100 g)
1.	***Moisture (%)	90.1	92.02±1.65	4.78	11.92
2.	**Crude Fiber (%)	0.02	0.32±0.06	0.29	1.25
3.	**Ash (%)	1.5	0.27±0.03	3.42	3.56
4.	**Protein (%)	1.81	0.49±0.02	10.09	6.51
5.	** Vitamin-C (%)	0.037	0.6	0.11	0.06
6.	***Total Soluble Solids (^{o}Brix)	9.3	9.4	12.0	9.4
7.	***pH	5.43	5.3	5.43	5.72
8.	Rehydration Ratio (%w/v)	-	-	0.88	0.91

* Source: Nutritive Value of Indian Foods., National Institute of Nutrition, Indian council of Medical Research, Hyderabad. India 1984.
** These values were determined at Myanmar Pharmaceutical Factory (Sagaing), Ministry of Industry.
***These values were determined at Laboratory of Industrial Chemistry Department, Yadanabon University.

According to Table (8), it was also observed that the potassium content and calcium content of freeze-dried watermelon powder were lower than that of fresh watermelon although the iron content of freeze-dried watermelon powder was higher than that of fresh watermelon.

Table 8 Elements Content in Fresh Watermelon and Freeze-dried Watermelon Powder by X-ray Fluorescence Spectrometry (XRF)

No.	Elements	Experimental Values* (mg/100g) Fresh Watermelon	Experimental Values* (mg/100g) Freeze-dried Watermelon Powder	Literature Values * (mg/100g)
1.	Potassium (K)	112	30.49	126±2.36
2.	Calcium (Ca)	7	2.45	5.60±0.21
3.	Iron (Fe)	0.24	0.35	0.26±0.01

*These values were investigated at Universities' Research Centre, Yangon.
*http://www.en.wikipedia.org/wiki/papayas

According to Figures [4. (a),(b),(c),(d),(e),(f),(g) and (h)],the color and appearance of tropical fruits powder (papaya and watermelon) were the same as those of fresh fruits .In addition it was noted that the color of powders was darker than the that of fresh fruits after the shelf life was nine months because of storage condition. Nevertheless the freeze dried powder could be reconstituted instantly with water at room temperature.

Figure 3 Preparation of Tropical Fruit Powders Using Freeze-Dryer

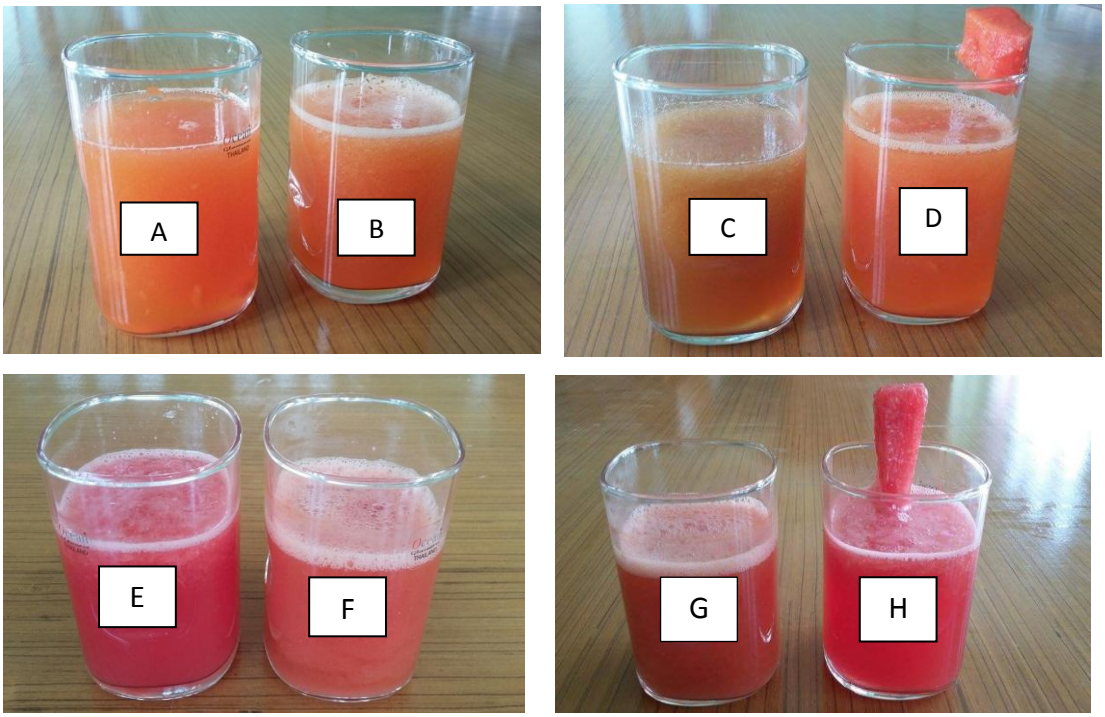

Figure 4 (A) Freeze-dried Papaya Juice (B) (D) Fresh Papaya Juice
(C) Freeze-dried Papaya Juice (shelf-life - 9 months)
(E) (H) Fresh Watermelon Juice (F) Freeze-dried Watermelon Juice
(G) Freeze-dried Watermelon Juice (shelf-life - 9 months)

Conclusion

For the food industry, the application of fruit juice powders has many advantages because of the reduced volume or weight, reduced packaging, easier handling and transportation, and much longer shelf life. Besides, their physical state provides a stable, natural, and easily measurable ingredient, which generally finds usage in many foods and pharmaceutical products such as flavoring and coloring agents.

In this research, preparation of fruit juice powder was carried out by using freeze drying with drying aid (maltodextrin).The addition of maltodextrin reduced the hygroscopicity of the powders. The instant properties of powders involve the ability of a powder to dissolve in water. The prepared fruit powder would be utilized in coloring some food products included jam, jelly, candy, and juice.

The different drying methods of papaya powder affected the physical and physicochemical properties as well as aroma retention of powders. From the analysis of solubility and color reaction test, freeze-drying method was the suitable method for the preparation of papaya powder.

Therefore, freeze-drying method was again chosen for the preparation of watermelon powder. Although some of the physico-chemical characteristics were quite different with the literature value, the aroma and flavor of fresh freeze-dried watermelon were also attractive as well as those of original fresh fruit. Moreover, packaging was important factor for fruit powders because the color was slightly changed after nine months. If stored in air-tight container, dried fruit powder will last for six to twelve months in the pantry and up to twenty -four months in the refrigerator. For maximum shelf-life, the sample should be stored in a vacuum sealed bag in the freezer.

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