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Physicochemical and flow properties of fruit powder and their effect on the dissolution of fast dissolving fruit powder tablets

M. Saifullah [a,b], Y.A. Yusof [a,*], N.L. Chin [a], M.G. Aziz [a,c]

[a] Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang, Selangor, 43400, Malaysia
[b] Department of Agro Product Processing Technology, Faculty of Applied Science and Technology, Jessore University of Science and Technology, Jessore, 7408, Bangladesh
[c] Department of Food Technology and Rural Industries, Faculty of Agricultural Engineering and Technology, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

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ABSTRACT

This research was conducted aiming to assess the flow and physicochemical properties of fruit powder and their relationship with the dissolution of tablets containing effervescent agents. Commercial pitaya, pineapple, mango and guava fruit powders were used as samples in this research. Fruit powder tablets were prepared by using direct compaction method. Powder properties of individual fruits as well as their tablet formulation (fruit powder + effervescent agent + artificial sweeteners) analysed using standard methods were found significantly different at $P < 0.001$. The flowability and cohesiveness as determined by Carr index and Hausner ratio of individual fruit powders and their formulation were also different but in the range of passable class. The relationship of total dissolution time with moisture, protein, fat content and porosity of fruit powder tablets was polynomial as determined by multiple regression analysis. Dissolution rate of effervescent fruit powder tablets was much higher compared to normal fruit powder tablets in both dissolution medium (water and simulated saliva fluid). Among the fruit powder tablets, pitaya powder tablet went for fast dissolution (6 min) in simulated saliva fluid whereas guava powder tablets took the longest time (90 min) for complete dissolution in water. Based on this study, a better understanding of the physicochemical properties of fruit powder and their relationship with the dissolution rate and the effect of effervescent agents on the dissolution rate has been obtained, which is essential for processing and handling of fruit powder and tablet preparation as well as for the improvement of the dissolution rate.

1. Introduction

Tropical and subtropical parts of the world are blessed with different types of fruit which are very popular all over the world in terms of taste and nutritional value. Most of the fruits are seasonal. Fruits are mainly consumed fresh in the peak season and also processed into different types of products for preservation and further use, such as juice, squash, nectar, concentrate, puree, jam, jelly and pickle [1–4]. Fruit selection for processing into a specific type of product depends upon the content of the fruit. For example, fruits with high sugar and juicy pulp content are mostly processed into juice and squash. Fruit juices and fruit based drinks are equally popular with people of all ages. Juice processing requires number of unit operations that increase the chance of contamination and the cost of production. Further, due to the presence of a high amount of water and sugar, fruit juices are prone to spoilage by yeasts, moulds and bacteria [5,6]. Enzymatic reactions are also responsible for degradation of the quality of fruit juices. Hence, fruit juices possess a very short shelf life. To increase the shelf life, food processors use different physical and chemical treatments of juices. However, sometimes these treatments affect the quality of the juice.

Food scientists adopt a simultaneous heat and mass transfer approach to dry the fruit juice into powder form. Fruit juice powders provide a number of benefits over their liquid counterparts such as, (1) reduced volume, weight and packaging; (2) easier preservation, handling, transportation and storage; (3) and increased shelf life [7]. Fruit powders are mainly used as instant fruit drink powder and consumed directly as refreshing drink after dissolving in water. The potential other uses of fruit powder are as ingredients in baby food, sweets, fruit yogurt, soup, cake, ice cream and confections [8–10], to enhance the colour, flavour and nutritional value of the products. Several drying methods are available for fruit juices such as spray drying, drum drying, freeze drying and vacuum drying. Each type of drying method has its own limitations and advantages [1]. The different methods operate under different drying conditions. Therefore, the physicochemical properties of fruit powder are varied according to the method. Among the various drying methods the most common, convenient and widely practiced by the industry is the spray drying method [11,12]; which provides rapid production through continuous operation.

Fruit powder is a dry and granular material. It is also bulky and highly hygroscopic in nature. Therefore, it requires careful handling and

* Corresponding author.
E-mail address: yus.aniza@upm.edu.my (Y.A. Yusof).

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Table 1
Flowability classification (Lebrun et al., 2012).

Flowability	Carr Index (*CI*), %	Hausner Ratio (*HR*)
Excellent	0–10	1.00–1.11
Good	11–15	1.12–1.18
Fair	16–20	1.19–1.25
Passable	21–25	1.26–1.34
Poor	26–31	1.35–1.45
Very poor	32–37	1.46–1.59
Very, very poor	>38	>1.60

packaging during storage and transportation. Adiba et al. [13], Zea et al. [8] and Ong et al. [14] reported the compaction of fruit powder for the preparation of fruit drink tablets, which offers a few benefits over the powder form such as good physical and chemical stability, prolonged shelf life, less space required for storage and transportation, elegant appearance and greater acceptance in terms of presentation [15]. However, in tablet form the hygroscopicity of the powder becomes low due to the reduction of the surface area of the powder. Therefore, it takes a longer time for dissolution. However, people usually prefer rapid dissolving tablets. The application of super disintegrants to reduce the total dissolution time has been reported by Zea et al. and Ong et al. [8,14]. The dissolution of a fruit powder tablet is a physicochemical process, which is influenced by the physical and chemical properties of the ingredients. Though a super disintegrant can improve the dissolution rate of fruit powder tablets, conversely it may affect the physical properties of the fruit powder. However, to the knowledge of the authors, no studies have been carried out to demonstrate the effects of a super disintegrant on the properties such as bulk density, tap density, flowability and compressibility of the powder. This includes the porosity and dissolution of the fruit powder tablet when effervescent agents used as super disintegrants are mixed with the fruit powder to produce fast dissolving fruit powder tablets. Thus the objectives of this work were to investigate the physical and chemical properties of four types of fruit powders; the physical properties of the fruit powders after adding effervescent agents; and finally the effect of physicochemical properties of the fruit powders on the dissolution of fast dissolving fruit powder tablets in different dissolution mediums.

2. Materials and methods

2.1. Materials

Four types of fruit powders, namely pitaya, pineapple, guava, and mango were used in this research. Spray dried fruit powders containing 10% maltrodextrin were bought from Syarikat Sains Maju, Petaling Jaya, Selangor, Malaysia. Citric acid (Chem Pure®, R&M Marketing, Essex, UK), and sodium carbonate (Merck KGaA, 64,271 Darmstadt, Germany) were used as effervescent agents; these chemicals were brought from the local company LGC SCIENTIFIC, 43,200 Balakong, Selangor Darul Ehsan, Malaysia. Stevia (Botanical Essence Marketing Sdn Bhd, Malaysia) was used as a natural sweetener in the formulation of the fast dissolving fruit powder tablets.

2.2. Formulation and mixing of fast dissolving tablets

Each tablet contained 47.3% fruit powder, sodium carbonate 32.7%, citric acid 10% and stevia 10% [16]. All samples were measured and put into a plastic container, then mixed thoroughly in a mixing machine (Glas-Col, S/N 477625, USA) for 30 min at 15 rpm with 15 min clockwise and 15 min anticlockwise directions to create a uniform mixture. Then the sample mix was measured into 2.5 g portions and placed in plastic containers for further use, such as tablet preparation and analysis of physical properties.

2.3. Physical/powder properties

2.3.1. Particle size

The particle size and size range of the powder samples were measured by using a particle size analyser (Malvern Mastersizer 2000 Instrument Ltd., U.K.) using dry dispersion method. The Mastersizer 2000 utilises a laser light diffraction technique to analyse the size of the particles. For this experiment, the powder samples were placed in the particle size analyser and the data was recorded automatically.

2.3.2. Morphology of fruit powder and mixture of ingredients for tablet preparation

The morphological structure of powder particles and the distribution of different ingredients in the mixture were observed through a scanning electron microscope (SEM) (Hitachi High Technologies America Inc., IL). The samples were placed on double adhesive tape stuck on gold aluminium pins. Then, the pins were positioned in the SEM machine, and the particle shape and particle distribution visualised through a computer.

2.3.3. Bulk density

The bulk density of the samples was determined manually by pouring 2.5 g of fruit powder into a 10 mL graduated measuring glass cylinder. The bulk density was calculated from the ratio of the mass of powder to the volume occupied by the powder [17].

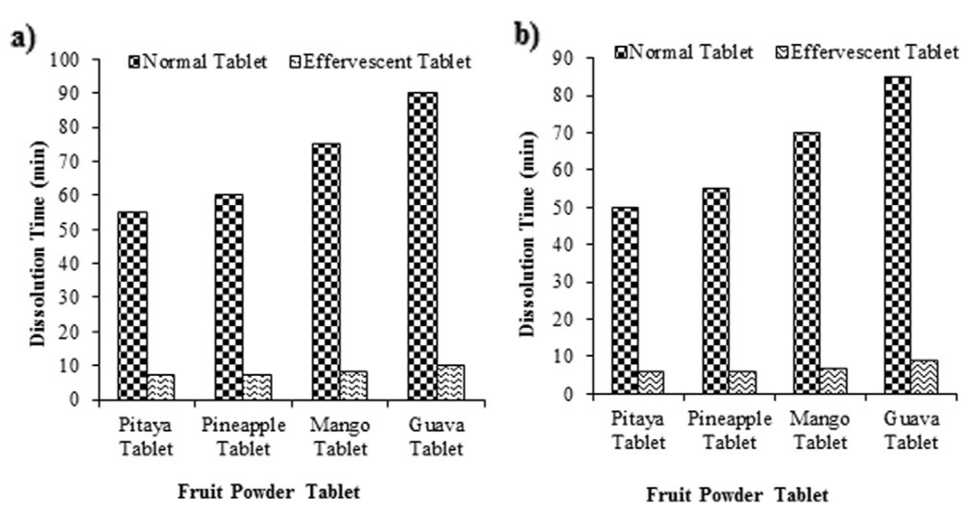

Fig. 1. (a) Dissolution of fruit powder tablet in water; (b) dissolution of fruit powder tablet in simulated saliva.