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Characterisation of fast dispersible fruit tablets made from green and ripe mango fruit powders

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ABSTRACT

This study was performed to assess the compressibility and dissolution of binary fruit tablets prepared from whole green and ripe mango powder influenced by disintegrants. Mango powder was prepared by freeze-drying mango pulps. Green mango powder exhibited medium flow and was poorly compressible compared with ripe and mixed mango powders. Tabletting of powders was performed using a uniaxial die compaction machine and dissolution tester with a moving paddle for the dissolution study. Among five formulations, the tensile strength of the mixed tablets was higher than the individual and mixed-fruit tablets. The dissolution kinetics revealed that the dissolution rate of the mixed-fruit tablets was highly influenced by the disintegrant content. In conclusion, mixed mango tablets can be used as an effective vitamin C supplement if the formulation is optimised with balanced sweetness and acidity and can easily be consumed by chewing or by dissolving in water.

1. Introduction

Large amounts of fruits, including the mango, are produced in tropical and subtropical countries, which may be attractive from a commercial perspective. Mangos exhibit a high water content in a mature state and are easily decomposed by microorganisms and chemical or enzymatic reactions. Fresh mangos are extremely perishable and cannot be marketed or exported as fresh produce over long periods (Milton et al., 2005). The conversion of mango fruits into a dry particulate, which results in reduced volume and longer shelf life, is commonly practised to overcome the problems associated with decomposition. Mango fruits can be found year round in Malaysia and worldwide. However, due to their perishable nature, mangos cannot be marketed as fresh produce for long periods. Thus, the availability of mangos is limited. To meet the demand of the market throughout the year in all areas, mangos are preserved as mango powder, which may be marketed as a fruit drink. Mango powders can be stored for longer periods of time than the fresh fruit.

Dehydration via freeze-drying is a common technique used in the food industry to produce powder. Freeze-drying tends to reduce nutrient loss during processing. Under optimal processing conditions, freeze-drying is an effective method for obtaining mango powder to be marketed as a fruit drink powder in the dairy industry and in baby food formulations (Nanjundaswamy, 1998). These dried foods are also can be used for instant foods, such as soup mixes, in which good reconstitution properties are highly desired. Good reconstitution properties include regaining the original shape and structure rapidly after the addition of liquid and exhibiting characteristics similar to the fresh products (Mellor, 1978). However, most sugar-rich powders, such as fruit powders, are amorphous and are frequently associated with problems caused by hygroscopicity, stickiness, or agglomeration due to the nature of the changing phase at the glass transition temperature (T_g) (Bhandari et al., 1997). Fruit powders are sensitive to the surrounding environment and careful and costly packaging is essential for marketing and long-time storage of fruit powders. The compaction of fruit powder into tablets might be an excellent alternative for post-processing, handling, packaging, and storage of fruit powder.

Aqueous solubility is a key determinant in using tablets as ready-to-serve juices and drinks for refreshment. In pharmaceuticals, disintegrating agents are commonly incorporated in the tablet matrix to improve the dispersibility and bioavailability of the active ingredients (Shailendra and Priti, 2011). Superdisintegrant, which is a fast-dissolving disintegrant, is added to pharmaceutical tablet formulations to cause the compressed tablet to break apart when placed in an aqueous medium. Effervescent agents, which are a mixture of sodium bicarbonate and citric acid, are used for the same purpose and help dissolve the tablet, with carbon dioxide produced during the reaction with water (Shailendra and Priti, 2011). In this study, the effects of a superdisintegrant (Kollidon

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CL) and an effervescent agent on the compaction and dissolution of freeze-dried mango powder were investigated.

2. Materials and methods

2.1. Materials

Ripe and green mango fruits were purchased from a fruit stall in Seri Kembangan, Selangor, Malaysia. The mango fruits were stored in the laboratory freezer at −20 °C before the experiment. The mango fruits were washed, and the seeds were removed before the fruits were cut into cubes and blended together with peels using a laboratory fruit juice blender (Panasonic MX-799S, Malaysia). The pulps generated from fruits with peels were termed whole fruit pulp (WFP). The pulps were stored in a −20 °C freezer until freeze-drying.

2.2. Methods

2.2.1. Freeze-drying the whole fruit pulp

The WFP of ripe and green mango fruits was poured into rectangular plastic containers and covered with lids. The contents of the containers were frozen in a 20 °C freezer for two days. The frozen samples were transferred to a vacuum freeze-dryer (BEW HAY/SB4, United Kingdom) and dried at −11 °C for 48 h at 0.27 MPa pressure. After the freeze-drying process, the containers were removed from the drying chamber of the freeze-dryer, and the powder was stored in an air-tight container at ambient temperature for further analysis.

2.2.2. Powder properties

The physical properties, such as densities and particle sizes, of both powders and a mixture (1:1) of the powders were determined by the methods described by Ng et al. (2012). The absolute, tap and bulk densities of the powders were measured. The Hausner ratio (1967) and Carr index (1965) were used to indicate the flow properties of the powders using the values of the bulk density and tap density. The absolute density was determined using a gas pycnometer (AccuPyc II 1340, Micromeritics, Norcross, USA). The particle size of the ripe and green mango fruit powders was determined using a particle size analyser (Malvern Mastersizer 2000, Malvern Instrument Ltd., UK).

2.2.3. Compression of fruit powder

The Instron Universal Testing 5566 Machine (Canton MA, USA) equipped with a cylindrical 20 ± 0.1 mm diameter hardened stainless steel die was used to study the compaction behaviour of the mango fruit powders. A 2 g sample of powder was compacted to various ultimate applied stresses in the dies. The powder of each tablet was weighted using a digital balance with an accuracy range of ±0.001 g. The applied force and the cross-head displacement were recorded by computer software. All the tablets were compacted by an ultimate force of 1, 3, 5, 7, and 9 kN. The compaction of the powder was performed according to the method described by Yusof et al. (2012). The procedure was finished by unloading and removing the bottom punch and ejecting the tablet from the die. The height of the tablets was measured to calculate the density of the tablet. To calculate the tensile strength, the tablet was placed between two flattening plates, and force was applied with the Instron Universal Testing 5566 Machine at a speed of 10 mm/min with ad force of 9.8 kN until a clear crack was visible on the compacted tablet. The tensile strength was calculated using the following formula (Fell and Newton, 1970):

$$\sigma_t = \frac{2F}{\pi HD} \tag{1}$$

where F is the crushing force or tensile force (N), D the compact diameter (m), and H is the compact thickness (m).

The compressibility of the powders was measured using the Kawakita and Lüdde (1970/71) and Heckel (1961) equations. The following represents the Kawakita and Lüdde (1970/71) equation:

$$\frac{P}{C} = \frac{P}{a} + \frac{1}{ab} \tag{2}$$

where a and b are constant, and C is the degree of volume reduction under applied pressure P, and C is calculated from the initial volume V_0 and the powder volume under pressure V.

$$C = \frac{V_0 - V}{V_0}$$

The following represents the Heckel (1961) equation:

$$\ln\left(\frac{1}{1-\rho_r}\right) = KP + A \tag{3}$$

where ρ_r is the relative density calculated from the ratio of the apparent density to the true density; K, the slope of the equation, is the reciprocal of the yielded pressure P_y of the powder; and A is the constant, which is a function of the original compact volume.

2.2.4. Dissolution of fruit tablets

Both in vitro dissolution and erosion tests were performed to evaluate the dissolution of mixed mango fruit powders. The erosion of tablets in different solvents was performed according to the method described by Adiba et al. (2011). Distiled water, 0.1 N hydrochloric acid and citrate buffer (pH 4) were used as solvents. Three mixed-fruit tablet formulations, including one formulation with no disintegrant agent (NSD), one formulation with 1% effervescent agent (EFA) (equal ratio of sodium bicarbonate and citric acid) and one formulation with 1% Kollidon CL (KCL), were used to observe the erosion kinetics in the solvents. The erosion test was performed at a controlled temperature (37 °C) until complete dissolution, and the erosion percentage was calculated using the following equation:

$$R_a = \frac{W_b}{W_a} X100 \tag{4}$$

where R_a is the erosion (%), W_b is the weight of the tablet before immersion, and W_a is the weight of tablet after immersion.

In vitro dissolution of the mixed-fruit tablets was performed using a dissolution tester (PT-DT8, Germany) on 5 tablets of each tablet formulation in the 3 different medium solutions at 37 °C ± 0.5 °C at 50 rpm. Approximately 500 ml of liquid medium was prepared and poured into the dissolution beaker, and 5 tablets were simultaneously placed inside the dissolution beaker. At 10, 20, 30, and 40 min intervals, 50 ml of liquid was withdrawn from each sample and replaced with an equal amount of fresh dissolution medium. The liquid was filtered through filter paper (Whatman No. 1, 0.45 μm) (Toyo Roshi Kaisha Ltd., Japan) before storage in a 50 ml centrifuge tube for further analysis. The dissolution time was reached when 10 tablets were completely dissolved in solution. The time was recorded using a stopwatch. The kinetic release of vitamin C as influenced by disintegrant agents and solvents during dissolution was assessed. The DPPH (2,2-diphenyl-1-picryl hydrazyl) method was used to determine the antioxidant activity according to the method described by Amin et al. (2006). TROLOX was used as a standard, and the results were expressed as the IC_{50}. The vitamin C content in solution was measured by measuring the volume of the sample required to decolorise a solution of DCPIP. The results were calibrated by comparison with a known concentration of vitamin C, and the results were expressed in mg cm^{-3} (Anonymous, 2012). The kinetics of vitamin C release