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Effect of packaging materials and storage temperature on the retention of physicochemical properties of vacuum packed pink guava powder

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ABSTRACT

Storage shelf life of fruit powder is an important concern in fruit powder industry. The objective of this study was to explore the effect of storage conditions on the retention of physicochemical properties of guava powder. The spray-dried guava powder was packed by LDPE, PET laminated and OPP laminated film and stored at 5 °C and 25 °C for 10 weeks. The shelf life prediction was measured from the linear regression kinetic equation of water activity. Packaging film, storage temperature and time had significant effect on powder properties. PET laminated film showed the most significant effect in retention of moisture, water activity and lycopene. LDPE packed powder was the least effective in moisture control, which led to increase of glass transition temperature (Tg) and degree of caking (CD) and loss of color and lycopene. Higher storage temperature (25 °C) considerably increased the moisture gain, water activity, Tg and CD. The suitable storage condition for guava powder was PET laminated film at 5 °C that showed the maximum predicted shelf life (34.95 weeks) with the highest lycopene retention (74.56%) and low moisture content of < 3%.

1. Introduction

Fruit powder products are very sensitive to moisture content, which influences the color, flavor, nutritional content and antioxidant stability. Studies on powder products as a function of moisture content or water activity have allowed the development of mathematical models to predict the physicochemical changes of powder product over time (Venir, Munari, Tonizzo, & Maltini, 2007). Changes in moisture content indicate water mobility and the degree of plasticization of larger food molecules, which also affect the rates of chemical reaction (Labuza & Altunakar, 2007). Spray-dried fruit juice powders have some problematic behaviors, such as they readily become sticky at high relative humidity or high temperature, which leads to caking phenomenon as a result of plasticization of the concentrated solvents present in the product. It occurs due to the water absorption onto the surface or increase of temperature (Anglea, Karathanos, & Karel, 1993). It also depends on the surface behaviors or surface forces of the powder particles such as, electrostatic and Van der Waals, allow the particles to stick together by emerging a liquid bond. Caking of powder particles is also affected by glass transition temperature, besides its storage temperature (Adhikari, Howes, Bhandari, & Truong, 2001). Lycopene can also be measured as a valuable quality index for pink guava powder, and reports show that different storage conditions may cause degradation of lycopene (Anguelova & Warthesen, 2000; Liu, Cao, Wang, & Liao, 2010). There might be a vital correlation between caking formation and lycopene degradation during the storage period of time.

The deterioration of fruit powders during storage happens due to the most common factors, such as temperature, humidity, oxygen, light and water activity. The food quality during storage may change to such extent that it may be harmful to the consumer, and may lose its acceptance. Hence, protection is thought as the final step in the product development process, which ensures the entire quality of a product until the utilization by consumer for a certain period (Labuza & Altunakar, 2007). Davoodi, Vijayanand, Kulkarni, and Ramana (2007) suggested using metalized polyester bags to protect product against light, oxygen, and humidity and retard the quality changes of tomato powder during storage period. Pua et al. (2008) investigated that laminated ALP film was better in color retention, moisture control, overall acceptability of odor and taste than the laminated BOPP.

Previous studies had been reported on the development of pink guava powder by spray drying (Patil, Chauhan, & Singh, 2014; Shishir, Taip, Aziz, & Talib, 2014; Shishir, Taip, Aziz, Talib, & Sarker, 2016). However, there is still room to study on the storage stability of pink

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guava powder in order to investigate the effect of different storage conditions on moisture properties leading to the happening of caking formation and lycopene degradation. Therefore, the aim of this study was to explore the effect of packaging conditions and storage temperature on the retention of physicochemical properties of developed pink guava powder. This fundamental exploration is beneficial to the industrial packaging and storage of spray-dried fruit and vegetable powders.

2. Materials and methods

2.1. Materials

Pink guava juice was obtained from Sime Darby Beverages Pvt. Ltd., Perak, Malaysia and maltodextrin DE 10 from Bronson & Jacobs Pvt. Ltd., Sydney, Australia. The lycopene analytical standard (≥85% purity) was purchased from Sigma-Aldrich Chemie GmbH (Seelze, Germany), and *n*-hexane (95% purity), acetone (99.5% purity) and dichloromethane (99.8% purity) from Friendemann Schmidt (Parkwood, Australia), and ethanol (99.9% purity, Merch KGaA, Darmstadt, Germany) were used HPLC-grade solvents. HPLC-grade mobile phases, such as acetonitrile (99.9% purity), methanol (99.8% purity) and 2-propanol (99.8% purity) from Friendemann Schmidt (Parkwood, Australia) were collected. Packaging materials, such as low density polyethylene (LDPE), laminated OPP (OPP/MPET/LLDPE) and laminated PET (PET/MPET/LLDPE) were collected from Syarikat Hang Tuah Company Ltd., Penang, Malaysia. The laminated OPP made by oriented poly propylene (OPP, 30 μm), metalized polyester (PET, 12 μm) and linear low density poly ethylene (LLDPE, 40 μm). The laminated PET made by polyester (PET, 12 μm), metalized polyester (PET, 12 μm) and linear low density poly ethylene (LLDPE, 50 μm).

2.2. Powder production

The pink guava juice was diluted with distilled water at a ratio of 1:1 and subsequently sieved through a 250 μm sieve, followed by the addition of maltodextrin to the juice sample at concentrations of 17% (w/v) and homogenized at 5000 rpm for 8 min prior to adequate mixing (Carrillo-Navas et al., 2011) using Homogenizer (Wise Mix HG-15A, Daihan Scientific, Co. Ltd., Wonju, South Korea). In every case, 1 litre sample was subjected to spray drying using a spray dryer (Lab plant SD-05, Lab plant UK Ltd., North Yorkshire, UK) at inlet air temperatures of 150 °C, feed flow rate of 350 ml/h, outlet temperature of 90 ± 1 °C, air flow rate of 47 ± 1 m^3/h and compressor air pressure of 2.1 ± 1 bar. The spray drying sample formulation and drying conditions were selected from our previous optimization study (Shishir et al., 2016).

2.3. Packaging, storage and shelf life of pink guava powder

The produced pink guava powder was packed using three types of packaging materials, such as low density polyethylene (LDPE) as a control sample, laminated OPP (OPP/MPET/LLDPE) and laminated PET (PET/MPET/LLDPE). The pink guava powder (10 g) was filled in 10 cm × 7 cm pouches of LDPE, laminated OPP and laminated PET. The pouches of laminated OPP and laminated PET were carefully sealed using vacuum sealer (Vac Master SVP-40, ARY Inc., USA) and the LDPE was used as controlled sample and sealed with impulse sealer without vacuum treatment. The pink guava powder pouches were placed in vertical pouch holder to avoid the pouch contact and expose to the same environment. The pouches were stored at 5 °C and 25 °C for 10 weeks. The LDPE sample (control) stored at 25 °C. The data were collected every two weeks. The relative humidity of storage environment was monitored at around 50 ± 1% in 5 °C storage condition and 65 ± 5% in 25 °C storage condition. The shelf life prediction was measured from the linear regression kinetic equation of water activity. The water activity by 0.4 was considered as standard parameter to predict the powder shelf life (Marques, Ferreira, & Freire, 2007).

2.4. Assessment of physicochemical properties of pink guava powder

The moisture content analysis was conducted using the method of AOAC (1990). One gram of sample was carefully measured and dried in a vacuum oven at 70 °C until constant weight was obtained and the analysis was performed in triplicate. Around 2 g of powder was taken to determine the water activity by using electronic water activity meter (FA-ST Lab, GBX Instrumentation Scientifique, Romans Sur Isere, France) at approximately 25 °C (Zhang, Jiao, Lian, Deng, & Zhao, 2015). The glass transition temperature of the powders was determined by using differential scanning calorimeter (DSC 7, Perkin Elmer, Massachusetts, USA). The powder (around 5–10 mg) was scanned in a hermitically sealed 20 μl DSC aluminum pan. The purge gas used was dry nitrogen (20 ml/min). All analyses were done in triplicate. The rate of thermal scanning was carried out in 2 steps, such as i) Isothermal at −20 °C for 1 min; and ii) Heat scanning from −20 °C to 250 °C at 10 °C/min (Shrestha, Ua-arak, Adhikari, Howes, & Bhandari, 2007). In order to determine hygroscopicity (Caparino et al., 2012), the powder sample (2 g) was spread on a petri dish with three replicates and put in an airtight container containing saturated sodium chloride solution (75 ± 1% humidity) at 25 °C for seven days. Hygroscopicity was calculated as grams of adsorbed moisture per 100 g of dry solids. Degree of caking was determined following by Goula and Adamopoulos (2008). After hygroscopicity determination, the wet sample was placed in oven dryer at 70 °C for 3 h and subsequently the dried sample was cooled, weighted and transferred into 500 μm sieve and manually shaken. The remaining powder sample on the sieve was measured to determine the degree of caking as following equation:

$$\text{Degree of caking, } CD(\%) = \frac{(100 - a)}{b} \quad (1)$$

Where, a = Amount of powder used in sieving, b = Amount of powder remained on the sieve after sieving.

The lycopene content was extracted following by Sommano, Caffin, Mcdonal, and Cocksedge (2013). First, the 0.5 g powder sample was reconstituted in 10 ml of distilled water. Then, the extraction solvents of 10 ml of hexane–acetone–ethanol (2:1:1) and 5 ml of water were added and shaken at 200 rpm for 10 min using the Wise Cube Shaking Incubator (WIS-20R, Daihan Scientific Co. Ltd., Wonju, Korea). Then, the solution was centrifuged at 12,000 × *g* for 10 min using a centrifuge (5804 R, Eppendorf AG, Hamburg, Germany). The upper layer was collected and evaporated. The residue was re-dissolved in 2 ml dichloromethane and subsequently filtered through a 0.45 μm membrane filter and stored at −20 °C for HPLC analysis. The lycopene content was determined using HPLC (Waters 2996, Waters Ltd., Hertfordshire, UK) and 5 μm column (X-select HSS T3, Waters Ltd., Hertfordshire, UK). An isocratic mobile phase system of acetonitrile: methanol: 2-propanol (44:54:2 by vol.) was used followed by Anguelova and Warthesen (2000). The column temperature was set at 25 °C, flow rate at 1.5 ml/min and wavelength at 472 nm. The lycopene content was calculated using a standard calibration curve prepared at concentrations of 0.108 to 1.733 mg/ml.

The powder morphology was investigated through scanning electron microscope (SEM) analysis using scanning electron microscope (JSM-6400, Jeol, Japan). Small amount power was mounted on platinum coated SEM stubs. The SEM analysis was carried out at an accelerating voltage of 15 kV and the micrographs were captured at a magnification of × 4000, × 5000 and × 7000 at scale bar of 14 mm and 1 μm. The color of the final product was measured carefully by using a color reader (CR-10; Konica Minolta Sensing Ltd., Japan) (Kha, Nguyen, and Roach, 2010).