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# Optimization of drum drying processing parameters for production of jackfruit (*Artocarpus heterophyllus*) powder using response surface methodology

Chun Kiat Pua[a], Nazimah Sheikh Abd. Hamid[a,1], Chin Ping Tan[b,*], Hamed Mirhosseini[b], Russly Bin Abd. Rahman[b], Gulam Rusul[c]

[a] *Department of Food Science, Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia*
[b] *Department of Food Technology, Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia*
[c] *School of Industrial Technology, Universiti Sains Malaysia, 11800 Penang, Malaysia*

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A B S T R A C T

Response surface methodology (RSM) was used to investigate the effect of the two drum drying parameters namely steam pressure and drum rotation speed on the physicochemical properties of jackfruit powder. The quality of jackfruit powder was assessed by determining moisture content, water activity, solubility, Hunter *L*-, *a*-, *b*-values, Quantitative Descriptive Analysis (QDA) and hedonic test. The responses as function of independent variables studied were fitted to the second-order polynomial equations. The results indicated that both steam pressure and rotation speed of drum drastically ($p \leq 0.05$) affected the overall quality and acceptability of final product. Moisture content and water activity considerably ($p \leq 0.05$) decreased with increasing drum temperature. The desired QDA scores decreased when drum temperature was increased. The optimum drum drying process performed at 336 kPa steam pressure, 1.2 rpm rotation speed was recommended to provide the jackfruit powder with optimum quality.



## 1. Introduction

Jackfruit (*Artocarpus heterophyllus*), also known as jacquier (French), nangka (Javan and Malay), langka (Philippine), khnaor (Cambodia), makmi, khanum, banum (Thailand), or mit (Vietnamese) fruit is indigenous to south-western India and is cultivated throughout South-east Asia and most of the tropics (Rajendran, 1992). It belongs to the family *Moraceae* which includes the fig and mulberry. The genus *Artocarpus* contains about 50 species; most of them are native to Asia. Jackfruit is one of the 15 species that produce edible starchy fruits (Nakasone & Paull, 1998). The jackfruit bulbs are normally eaten fresh or used in ice cream and also processed into various products such as canned jackfruit juice (Seow & Shanmugam, 1992), and jackfruit leather from the unfertilized floral parts (Che Man & Sin, 1997). Jacob John and Narasimham (1993) produced a carbonated beverage from jackfruit waste.

The drum dryer consists of hollow metal cylinders that rotate on horizontal axes while heated internally by steam, hot water, or other heating medium. Drum dryer conducts an indirect heat transfer through a solid surface. The performance of double drum dryer is influenced by feed concentration, steam pressure; drum rotation speed and level of pool between the drums (Gavrielidou, Vallous, Karapantsios, & Raphaelides, 2002; Kostoglou & Karapantsios, 2003; Vallous, Gavrielidou, Karapantsios, & Kostoglou, 2002). The main advantages of drum drying include high drying rates and economic usage of heat (Vega-Mercado, Góngora-Nieto, & Barbosa-Cánovas, 2001). Drum dryers are dedicated to the dehydration of slurries, purees and manufacture of dehydrated powders and flakes. Drum-dried products are widely used in bakery goods, beverages, cereal and dairy foods.

Response surface methodology (RSM) is one of the most commonly used optimization technique in food science, probably because of its comprehensive theory, high efficiency and simplicity. RSM encompasses a group of techniques used to study the relationship between one or more measured responses and input variables. RSM can be used in problems that have ingredients and/or processing conditions as variables (Arteaga, Li-Chan, Vazquez-Arteaga, & Nakai, 1994). It has been successfully applied to optimize food processing operations by many researchers (Frank, 2001; Lee,

* Corresponding author. Tel.: +64 3 479 4052; fax: +60 3 89423552.
*E-mail addresses:* nazimah.hamid@otago.ac.nz (N. Sheikh Abd. Hamid), tancp@putra.upm.edu.my (C.P. Tan).
[1] Tel.: +64 3 479 4052; fax: +64 3 479 7567.

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Yusof, Sheikh Abdul Hamid, & Baharin, 2006; Luciane, Hilary, Aparecida, & De Silva, 2001; Mirhosseini, Tan, Sheikh Abdul Hamid, & Yusof, 2008; Pietrasik & Li-Chan, 2002). RSM is appropriate experimental design in applications where several responses are measured for each set of experimental conditions and a model is fitted for each response.

The cultivation of jackfruit has been increased, thus led to enhance the post-harvest storage problems. Jackfruit is a climacteric fruit with short shelf life, thus it readily becomes unacceptable to consumer. Development of shelf stable product from fresh fruit is an important consideration to reduce post-harvest losses. The main objective of this study was to investigate the effect of processing parameters of drum dryer namely steam pressure and drum rotation speed on the physicochemical properties (i.e. colour, water activity and moisture content) and sensory attributes of jackfruit powder by using RSM.

## 2. Materials and methods

### 2.1. Materials

Arabic gum (food grade) was provided by Colloides Naturels International Co. (instant gum AS IRX 40830, Rouen, France). Soy lecithin (Centrol 3F-UB standard grade lecithin) was purchased from Bunge Alimentos (Sao Paulo, Brazil). A firm type (cultivar J3) of jackfruit (*A. heterophyllus*) obtained from a local farm (Bidor, Perak, Malaysia) was used throughout this study. Jackfruit ripeness was determined by estimating the skin's firmness and the number of day after harvesting. Jackfruits used in this study were stored for 5 or 6 days after harvesting to reach 80–90% fruit maturity.

### 2.2. Preparation of jackfruit puree for drying

Jackfruit pulp was prepared by removing the seed from the fruit. Subsequently, deseeded jackfruit pulp was blended using a 4 L Waring blender (Waring blender 32BL80, Torrington, CT, USA) for 30 s at low speed and 1 min at high speed. The puree was mixed with 40% v/w filtered water to reduce the solid content and viscosity. Soy lecithin and gum Arabic were incorporated at 2.65 and 10.28 (g/100 g), respectively. The optimum concentration of soy lecithin and gum Arabic was determined in our previous study (Pua, Sheikh Abdul Hamid, Rusul, & Rahman, 2007).

### 2.3. Drum drying operation

The jackfruit puree was passed through the heated double drum drier at 0.01 inch drum clearance and 10 cm pool level. The drum rotation speed was set between 1 and 3 rpm. The steam pressure ranged from 300 to 440 kPa. The dried material was removed as a thin film from the drum surface by two doctor blades, one for each drum. Dried flake was immediately stored in a laminated aluminium foil and sealed. The flake was then ground into powder form using a heavy-duty analytical mill (IKA M20, IKA Labortechnik, Staufan, Germany) and sealed in laminated aluminium foil, and then stored for further analyses.

### 2.4. Experimental design

Response surface methodology (RSM) was used in this experiment to study the effects of drum drying parameters namely steam pressure and rotation speed of drum on the physicochemical properties (i.e. colour, water activity and moisture content) and sensory attributes of jackfruit powder. The experiment was established based on a face-centred central composite design. In this experimental design, three coded levels for each variable were selected: −1, 0 and +1 corresponded to the low level, mid level and high level of each independent variable, respectively. The independent variables and representative coded and uncoded levels are given in Table 1. The behaviour of the response surface was investigated for the response function ($Y_i$) using the polynomial regression equation. The generalized response surface model is given below:

**Table 1**
Independent variables and their levels in the central composite design.

| Independent variables | Symbol | Coded values | | |
|---|---|---|---|---|
| | | −1 | 0 | +1 |
| Steam pressure, kPa | $X_1$ | 300 | 370 | 440 |
| Rotation speed of drum, rpm | $X_2$ | 1 | 2 | 3 |

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2$$

where $Y$ is response calculated by the model; $\beta_0$ is a constant; $\beta_i$, $\beta_{ii}$ and $\beta_{ij}$ are linear, squared and interaction coefficient, respectively. The experimental design matrix, data analysis and optimization procedure were performed using the Minitab v. 13.2 statistical package (Minitab Inc., State College, PA, USA).

### 2.5. Physical and instrumental analyses

#### 2.5.1. Colour measurement

The colour of dried jackfruit powders was measured using a spectrocolorimeter (Hunter associates laboratory Inc., Reston, Virginia, USA) with the lightness, redness, and yellowness opposable colour scales (Hunter Associates Laboratory, 2002). The instrument was equipped with a CIE 1964 10 Standard observer and illuminant D-65, and calibrated against a white and a black tile before measurements. The colour was expressed in terms of *L* (lightness), *a* (redness) and *b* (yellowness). A sample was homogenized and placed in a polypropylene (pp) bag for colour measurement.

#### 2.5.2. Determination of moisture content

Moisture content of the dried jackfruit powders was determined using the oven method (AOAC, 1984). The sample was dried in the oven at 105 °C for 24 h. Moisture content was calculated from the weight difference between the original and dried sample and expressed as percentage of the original sample.

#### 2.5.3. Water activity

The water activity of the samples was determined using an AquaLab water activity meter (Series 3TE, Decagon Devices Inc., WA, USA). Each water activity measurement was the average of three determinations.

#### 2.5.4. Solubility index

The solubility index was determined according to the modified American Dairy Products Institute Method (ADPI, 1992). For measurement of solubility index, 10 g of jackfruit powder was blended in 100 ml of distilled water at 24 °C for 10 min in a beaker. Consequently, 50 ml of solution was then transferred into a centrifuge tube and centrifuged at 3000 rpm (1089 × g) for 5 min. The sediment was resuspended in distilled water and then centrifuged at 3000 rpm for 5 min. The volume (ml) of sediment remaining in each tube after the second centrifugation represented the solubility index of the sample.