

Optimization of drum drying parameters for gac powder

Pornthip Suriyajunhom¹, and Maradee Phongpipatpong¹

¹Food Engineering Department, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

Abstract. Gac (*Momordica cochinchinensis* Spreng.) is a tropical fruit which contains a rich nutrient source, especially lycopene. However, fresh gac fruit can spoil rapidly due to its high moisture content. Drum drying is a process to remove moisture from food in order to preserve nutrients and extend shelf life. In this study, gac fruit powder was produced by using drum drying technique. The present research was aimed to determine the optimum drum drying condition for gac powder. Response Surface Methodology was employed with three processing variables, including drum surface drying temperature (115, 125, 135°C) maltodextrin content (100, 150, 200%) and gum arabic content (10, 20, 30%). The response variables were moisture content, solubility, hygroscopicity, total phenolic content and lycopene content of gac fruit powder. Regression analysis was then performed to obtain the mathematical relation between the processing variables and the responses in the form of second-order polynomial equations. The results showed that optimum conditions for drum drying of gac fruit was at 135°C of drum surface drying temperature, 138% of added maltodextrin and 10% of added gum arabic, which provided the highest amount of total phenolic and lycopene content.

1 Introduction

Gac is a tropical fruit which classified in the cucurbitaceae family. It grows in many countries in Asia including China, Malaysia, Vietnam and Thailand. This plant can grow fast and has a low price, but it is a good source of nutrients such as vitamin E, fatty acid, phenolic compound, carotenoid – Lycopene and beta-carotene [1,2]. However, fresh gac fruit has a short shelf life due to its high moisture content that susceptible to deterioration. Thus, food processing can be applied in order to prevent spoilage, develop and add value to the product. Drum Drying is one of popular processing technique to convert food into a dried flake or powder which can help to keep nutrition and to prolong shelf-life of fruit product. The advantage of drum drying is that the simpler structure of the dryer, less operating costs, less drying time, higher drying capacity, and can be applied to wider ranges of liquid food or viscous food [3]. A typical drum dryer may have either a single drum with smaller applicator rolls or double drums. In this dryer, pureed food is spread uniformly over the surface of a heated drum. While the drum rotates, drying takes place and dried product is scraped off as flake from the drum using a knife system. The product can further grind into powder form.[3,4].

Several studies have reported the problem of the development of stickiness and caking during fruit drying due to the presence of low molecular weight sugars and acids which have low glass transition temperature, results in lower product yield, operation shut-downs, equipment wear, difficulties in material storage and handling. This causes a considerable economic loss and consumers'

discrimination [5]. Caking and stickiness are enhanced by numerous factors such as glass transition temperature (T_g) and hygroscopicity of the food materials, and environmental temperature and relative humidity etc. Therefore carrier agents e.g. maltodextrins, gum arabic, waxy starch, and microcrystalline cellulose are usually added into the feed prior to drying step, influence the properties and stability of the powder. Maltodextrin is the most common drying aids which helps increase in T_g of the food product. The addition of maltodextrin can be applied to reduce stickiness of the powder during drying especially for sugar rich foods [6]. Gum arabic is mixture of polysaccharides and glycoproteins, it is used primarily in the food industry as a stabilizer and emulsifier to enhance the favour and stability of food product. However, the addition level of carrier agents is important to obtain the desired food powder characteristics. [7]

The optimization of processing parameters is essential in food engineering and product development. Response surface methodology (RSM) has been successfully applied to optimize food processing operations including drying. This method requires identifying and fitting experimental data and appropriate response surface model with the use of statistical experimental design, regression modeling techniques, and optimization methods.[8] The most common forms of response variables and design variables are low-order polynomials (first or second-order).

Since drum drying is an energy-efficient and low production cost process, it is interesting to apply this technique for gac fruit. Therefore, this research is aimed to study drum drying process for gac powder production and

* Corresponding author: maradee.ph@kmitl.ac.th

to optimize the process conditions to obtain the desirable characteristics of drum-dried gac fruit powder.

2 Materials and methods

2.1 Sample Preparation

Fresh gac fruits were collected from plantation area in Kanchanaburi province after approx. 150 days after flowering. Only mesocarp and endocarp were manually separated from the fruit, blended and pasteurized at 72°C for 15 sec. before packed into polyethylene bags and kept in a freezer at -18°C until be analysed and processed.

2.2 Drum Drying Operation

For drum drying experiments, the frozen gac pureed samples were thawed overnight at room temperature then mixed with Maltodextrin DE-10 and gum arabic at different amounts based on experiment design. A double-drum dryer was used for drying trials. Steam is used as heating medium and fed into the drum. Drum surface temperature can be adjusted by controlling steam pressure (at 10, 20, 30 psig). The dried gac samples were scraped out from the drums and kept in aluminum foil bag until analysis.

2.3 Experimental design

Response surface methodology was used as an optimization approach. Experimental data of gac fruits drying tests carried out based on Box-Behnken design as shown in Table 1. The effect of drum surface drying temperature, maltodextrin concentration and gum Arabic concentration, selected as independent variables, on physicochemical properties of gac powder including moisture content, solubility hygroscopicity, total phenolic content and lycopene content was described by polynomial models. The experiment results were analysed and expressed in the form of Eq. (1). Optimization procedure was finally performed using graphical analysis with superimposed contour plot.

$$Y = \beta_0 + \sum_{i=1}^n \beta_i X_i + \sum_{i=1}^n \beta_{ii} X_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^n \beta_{ij} X_i X_j \quad (1)$$

Where Y = Physicochemical properties of gac fruit powder

X_i = Variable such as drying temperature (°C)
 maltodextrin (%) and gum arabic (%)

β₀ = Regression coefficient at Y-intercept

β_i = Regression coefficient in term of linear, quadratic and interaction

Table 1 Independent variables and their levels in the Box-Behnken design.

Independent variables	symbol	Coded values		
		-1	0	+1
Drying temperature (°C)	X ₁	115	125	135
Maltodextrin content (%)	X ₂	100	150	200
Gum Arabic content (%)	X ₃	10	20	30

2.4 Physicochemical Properties Analysis

2.4.1 Moisture content

The gac powder sample was dried in the oven at 105°C until the weight of sample remained unchanged. The results were computed as shown in Eq. (2).

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \quad (2)$$

When W₁ = initial sample weight before oven drying (g)

W₂ = dried sample weight after oven drying. (g)

2.4.2 Solubility

25 gms of dried gac powder was dissolved in 30 ml of water for 10 min. and centrifuged at 3,000 rpm for 15 mins. Supernatant liquid was poured and dried in hot air oven at 105°C until the weight remained unchanged. The results were computed as shown in Eq. (3). [9]

$$\text{Solubility (\%)} = \frac{\text{Weight of solids in the dried supernatant}}{\text{Weight of initial solids sample}} \times 100 \quad (3)$$

2.4.3 Hygroscopicity

Hygroscopicity were determined according from Bhusari et al (2014) by placing 1 g of dried gac powder in saturated solution of sodium chloride for 14 days. Hygroscopicity was then calculated based on Eq. (4) and expressed in g moisture g⁻¹ dry solid. [10]

$$\text{Hygroscopicity} \left(\frac{\text{g moisture}}{100 \text{ g dry solid}} \right) = \frac{\frac{\Delta m}{m_i + m}}{\frac{\Delta m}{m} + 1} \quad (4)$$

When m_i = The free water contents of the powder before placing into the saturated environment. (g)

m = The initial mass of powder. (g)

Δm = The increase in the weight of powder after equilibrium. (g)

2.4.4 Total phenolic content [11].

Total phenolic content was determined using the Folin–Ciocalteu reagent method. The absorbance was measured using UV-vis spectrophotometer at 765 nm wave length. Total phenolic contents of gac powder were calculated using a standard curve of Gallic acid and report as mg GAE g/100 mL

2.4.5 Lycopene content

Lycopene content were determined according to the Kimura method [12]. The absorbance was measured with UV-vis spectrophotometer at different wave lengths including 453, 505, 645 and 663 nm. Lycopene content in gac juice powder were calculated based on Eq.5 and reported unit in (mg/100g).

$$\text{Lycopene content} = -0.0458A_{663} + 0.204A_{645} + .372A_{505} - 0.0806A_{453} \quad (5)$$

When A₆₆₃, A₆₄₅, A₅₀₅ and A₄₅₃ is absorbance at 663, 645, 505 and 453 nm respectively

3 Result and discussion

The relationships between the response variables and three independent variables were investigated and correlated using a 2nd order polynomial equation, Eq. 1. ANOVA evaluations of these models are presented in Table 2.

3.1 Moisture content

In this study, the experiments show that the increase in drying temperature, maltodextrin content and gum arabic content result in a negative effect on gac powder moisture content. The most significant factor on product moisture was drying temperature ($p < 0.1$). Similar results were also observed by Galaz et. al. [4], they reported that the effect of steam pressure or drying temperature on product moisture content is highest, followed by drum speed. Higher temperature reduces feed viscosity, reduces the entrainment flow of liquid on drum surface and thereby reduces dried product moisture. The minimum moisture content of gac powder was 1.5 % when drying at 135°C of drum surface temperature, 200% of maltodextrin addition and 30% of gum arabic addition to the gac fruit pureed before fed to the drum dryer. The contour plot of drum-dried gac powder is presented in Fig. 1.

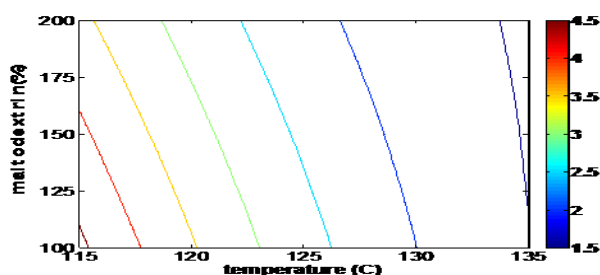


Fig.1 .Moisture content of drum-dried gac powder affected by drying temperature and maltodextrin content at 10% gum arabic

3.2 Solubility

Solubility of drum-dried gac powder was increased with drying temperature and maltodextrin content. While the addition of gum arabic had little effect on product solubility. Increasing the concentration of maltodextrin or gum arabic result in the decrease intermolecular forces by

interacting with the functional groups of the polysaccharide, providing an increase in solubility. The contour plots of product solubility is present in Fig. 2 and it shows that the highest solubility (76%) of drum-dried gac powder was at the high temperature and high amount of maltodextrin addition. Higher drying temperature increases the volume of gac powder and make it more porous. This cause product powder can dissolve faster. It was also observed that maltodextrin and gum arabic are a good dissolvable substance. [11].

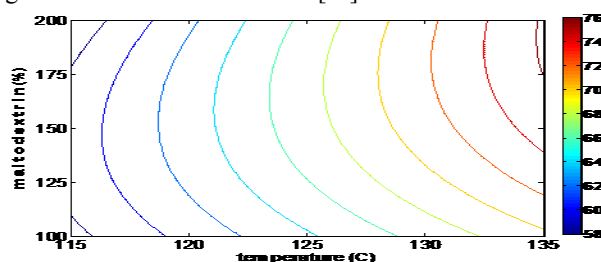


Fig. 2. Solubility of gac powder as affected by drying temperature and maltodextrin content at 10% gum arabic

3.3 Hygroscopicity

In this study it was found that the interaction of maltodextrin and gum arabic content was the most significant positive effect on hygroscopicity of gac fruit powder ($p < 0.01$). While drying temperature has little effect on hygroscopicity. The highest value of hygroscopicity of gac fruit powder also occurred at high drying temperature and higher amount of carrier agents (maltodextrin and gum Arabic) as shown in Fig 3

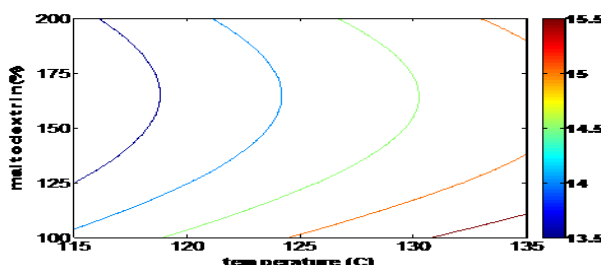


Fig. 3. Hygroscopicity of gac powder as affected by drying temperature and maltodextrin content at 10% of gum Arabic

Table 2 Regression coefficients of the second-order polynomial response models.

Variables	Regression coefficient	Moisture content (%)	Solubility (%)	Hygroscopicity (g _{water} /100g powder)	Total phenolic content	Lycopene content
intercept	β_0	87.84399	-36.4979	0.740489	-64.6843	-0.09806
x_1	β_1	-1.13828*	0.989454	0.288347	0.91774	0.001247
x_2	β_2	-0.06309	-0.22095	0.050087*	0.025576	-0.00088
x_3	β_3	-0.18276	1.312556	0.208455	0.508405	0.01567
$x_1 \cdot x_1$	β_{11}	0.003685	-0.00257	0.435144	-0.00249	1.21E-05
$x_2 \cdot x_2$	β_{22}	1.17E-06	-0.00079**	0.002973***	9.41E-05	3.44E-06
$x_3 \cdot x_3$	β_{33}	-0.00163	0.007121	0.060509	-0.00024	2.87E-05
$x_1 \cdot x_2$	β_{12}	0.00046	0.003851**	0.855142	-0.00061	-2.8E-06
$x_2 \cdot x_3$	β_{13}	0.00024	0.00052*	0.026412	0.000131	-2.1E-06
$x_1 \cdot x_3$	β_{23}	0.001667	-0.01266	0.214111**	-0.0042	-0.00013
R Square (R ²)		0.9476	0.9883	0.9794	0.8207	0.6381
Standard Error (S.E.)		0.3573	1.0032	0.2064	0.9613	0.0194

Note * Significant at $p < 0.1$, ** Significant at $p < 0.05$ and *** Significant at $p < 0.01$

3.4 Total phenolic content

Total phenolic content of gac powder is shown in Fig 4. The study shows that the maximum total phenolic content of gac powder was 8.5 mg GAE g/100 mL and occurred at high drying temperature (135°C) and less addition of maltodextrin (100%) and gum arabic (10%). Increasing drying surface temperature provided higher amount of total phenolic content due to the synthesis of polyphenols occur at high temperature, while the increase in maltodextrin and gum arabic decrease the total phenolic content of the dried gac powder.

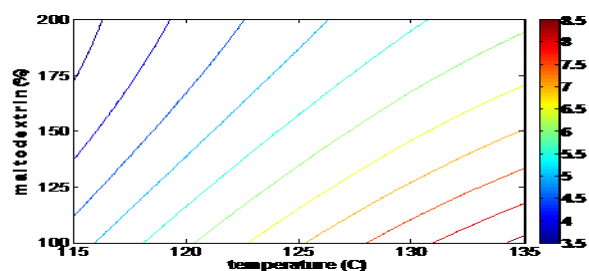


Fig. 4 . The contour plot of total phenolic content of gac powder as affected by drying temperature and maltodextrin content at 10% gum Arabic

3.5 Lycopene content

Fig 5. shows the variation of drying temperature and maltodextrin content at 10% of gum arabic. It can be seen that drum surface drying temperature has a positive effect on lycopene content, while the addition of maltodextrin results in decreasing lycopene content in gac powder. The maximum lycopene content was 0.18 mg/100g and occurred at high drying temperature (135°C) with less addition of maltodextrin (100%) due to heat induces isomerization of the all-trans to cis forms which increase with temperature. While the addition of gum arabic had little positive effect on lycopene content.

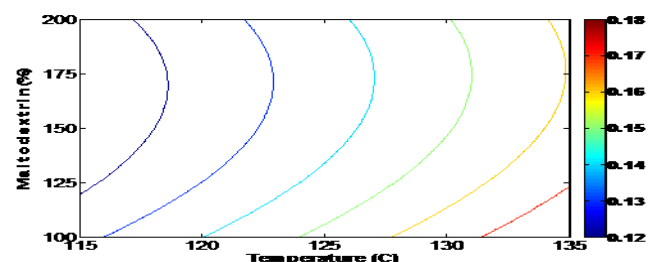


Fig. 5. The contour plot of lycopene content of gac powder as affected by drying temperature and maltodextrin content at 10% of gum arabic

3.6 Optimization of drum drying processing parameter to produce gac fruit powder

Optimization of process conditions for drum drying of gac fruits was done by using response surface methodology and superimposed of contour plots of response variables at different processing conditions. The decision criteria of drum dried gac powder properties consist of moisture content < 5%, Solubility > 70%, Hygroscopicity < 15 g_{water}/100g_{powder}, total phenolic content > 6.5 mg/g and

lycopene content > 0.15 mg/100 g_{powder}. Fig. 6 shows the graphical optimization. It was found that the optimum condition was at 135°C drying temperature, maltodextrin and gum arabic at 138% and 10% respectively. Physicochemical properties of gac powder composed with 1.48% of moisture content, 73.91% of solubility, 14.99 g /100g of hygroscopicity, 7.35 mg/g of phenolic content and 0.16 mg/100g of lycopene content.

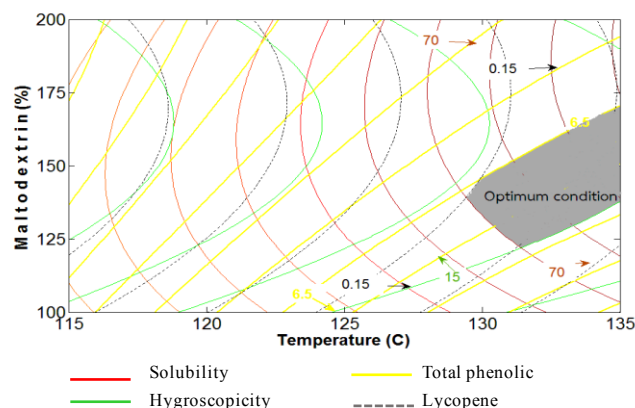


Fig. 6. Superimposed contour plot of response variables.

4 Conclusion

Drum drying was used for gac fruit powder production. Response surface optimization was carried out to determine the optimum processing condition of drum surface drying temperature, maltodextrin content and gum arabic content, that provide the desired properties of dried gac powder. The second order polynomial models were successfully developed to describe the response variables at different processing condition.

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* Corresponding author: maradee.ph@kmitl.ac.th