Optimisation of pretreatments prior to hydraulic pressing of Gac aril oil using response surface methodology

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Introduction

Gac fruit (*Momordica cochinchinensis* Spreng) is considered as one of the "super" fruits, containing extraordinarily high levels of β-carotene and lycopene, and a significant amount of polyunsaturated fatty acids. Moreover, α-tocopherol (vitamin E) concentration is also comparatively high. Vitamin E, as a natural antioxidant, helps protect Gac oil from oxidation. These nutrients have proved to be beneficial to humans.[1-3]

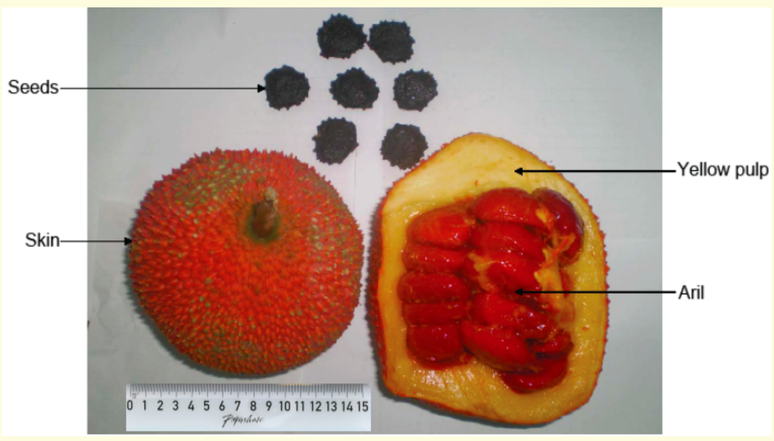

Figure 1. Gac fruit and its components

Recently, traditional extraction of plant oil (using harmful organic solvents) has been discarded due to health concerns, environmental problems and quality degradation. It is important therefore to find a suitable alternative extraction method of Gac oil using food grade solvents or eliminating the use of solvents completely. Microwave-assisted extraction prior to hydraulic pressing, a novel alternative method for oil extraction offers several benefits: it is environmental friendly, solvent free, and allows for reduced processing times and for uniform heating.

Response surface methodology (RSM) is the most popular optimisation technique used in recent years. It is effective in determining the relationships between the response and the independent variables and optimising the processes or products. The technique also allows the evaluation of the effect of multiple parameters and their interactions on the output variables with reduced number of trials.

This study aims to optimise Gac oil extraction conditions, including microwave drying time (X_1), steaming time (X_2) and working hydraulic pressure (X_3), for maximising extraction efficiency (EE), β-carotene and lycopene, using response surface methodology.

Materials and methods

Fresh Gac fruits, of uniform yellow-red skin and size, were purchased from a local market in Ho Chi Minh City, Vietnam. The red arils containing seeds were then scooped out and frozen at temperature of -18°C until use.

Microwave drying treatment: Frozen Gac aril was thawed at 4°C prior to microwave drying treatments. About 900 g of the aril including seeds were spread into the turntable plate with a thickness of 5 mm. The samples were then dried at the microwave power of 630W for different times (Table 1).

Steaming treatment: The microwave dried Gac samples were powdered using a laboratory blender. The ground samples were placed into a stainless-steel tray with a thickness of about 0.5 mm and then placed inside a stainless-steel steam cooker. The samples were steamed under atmosphere pressure for different times (Table 1).

Hydraulic pressing: For each test, the samples after steaming were wrapped inside 4 layers of filtration cloths and pressed at different designed pressures (Table 1).

Analysis: - the EE (%) was determined as ratio of mass of extracted oil after subtracting moisture (AOCS Ca 2c-25, 1998) and mass of oil in starting material using Soxhlet extraction.

- β-carotene and lycopene contents in the oil samples were measure at 450 nm using an Agilent 1200 HPLC.

Table 1. The coded and uncoded levels of independent variables

Coded - variable levels	Exposure time X_1, minutes	Steaming time X_2, minutes	Hydraulic pressure X_3, kg/cm^2
+1.682	66.7	35.1	186.8
+1	65.0	30.0	180.0
0	62.5	22.5	170.0
-1	60.0	15.0	160.0
-1.682	58.3	9.9	153.2

References

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2. Strobel, M.; Tinz, J.; Biesalski, H.K. The importance of β-carotene as a source of vitamin A with special regard to pregnant and breastfeeding women. European Journal of Nutrition **2007**, 46 (suppl. 1), 11-20.
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Results

Results showed that the data were adequately fitted into three second-order polynomial models for EE, β-carotene and lycopene with R^2 values of 0.93, 0.85 and 0.86, respectively (Table 2).

The response surface plot shows relationship between the independent variables and the responses, whilst the contour plot helps to visualise the shape of a response surface (Figures 2, 3 and 4). Therefore, it is useful to use the plots to evaluate the fits of model.

Table 2. Regression coefficients of the fitted quadratic equation and standard errors for EE, β-carotene and lycopene

Regression coefficient[a]	EE (%)		β-carotene (mg/100 mL)		Lycopene (mg/100 mL)	
	Regression coefficients	t ratio	Regression coefficients	t ratio	Regression coefficients	t ratio
a_0	87.832		171.163		496.146	
Linear						
a_1	2.280*	2.52	-5.210	-0.77	-15.778	-0.93
a_2	-4.113**	-4.55	-0.548	-0.08	-32.149	-1.89
a_3	-1.923	-2.13	31.453***	4.65	49.664*	2.92
Quadratic						
a_{11}	-0.656	-0.74	-22.203**	-3.37	-74.944**	-4.52
a_{22}	-2.169*	-2.46	-28.238**	-4.29	-92.011***	-5.55
a_{33}	-4.566***	-5.19	-5.120	-0.78	-15.617	-0.94
Interaction						
a_{12}	7.026***	5.95	-9.283	-1.05	-25.165	-1.13
a_{13}	-5.426***	-4.59	-10.614	-1.20	1.040	0.05
a_{23}	3.904**	3.30	23.454*	2.65	21.912	0.98
R^2	0.93		0.85		0.86	
P-value of lack of fit	0.174		0.08		0.43	

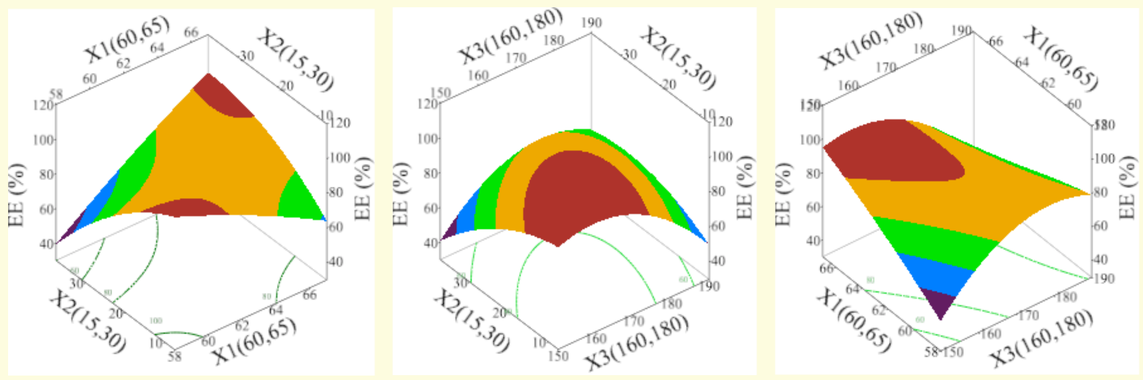

Figure 2. The 3D response surface and 2D contour plots of the EE affected by microwave time (X_1), steaming time (X_2) and working hydraulic pressure (X_3)

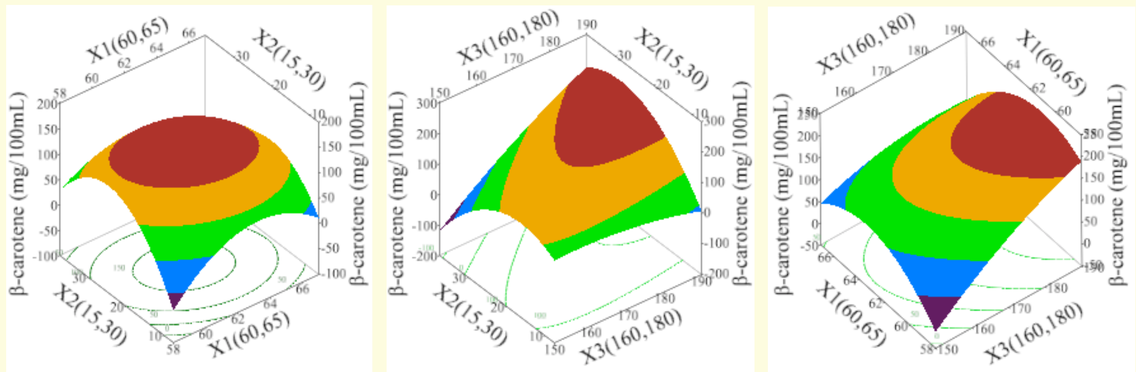

Figure 3. The 3D response surface and 2D contour plots of β-carotene content affected by microwave time (X_1), steaming time (X_2) and working hydraulic pressure (X_3).

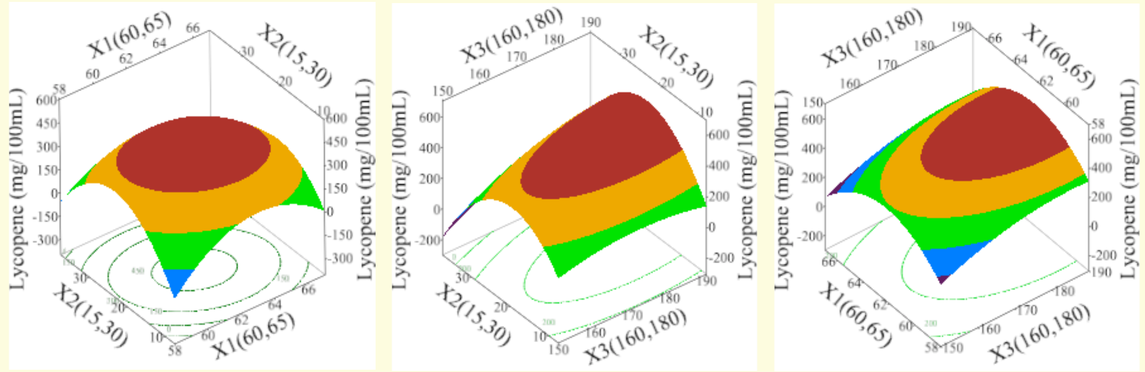

Figure 4. The 3D response surface and 2D contour plots of lycopene content affected by microwave time (X_1), steaming time (X_2) and working hydraulic pressure (X_3).

Conclusions

It was predicted that the optimum extraction conditions within the experimental ranges would be the microwave time of 62 minutes, steaming time of 22 minutes and hydraulic pressure of 175 kg/cm^2. Under such parameters, the maximum EE of 85.27%, β-carotene content of 191.71mg/100mL oil and lycopene content of 527mg/100mL oil could be achieved.

It can be concluded the response surface optimisation for the aril processing conditions for Gac oil is useful and has been successfully applied.

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