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Optimisation of Alpha Mangostin Extraction Using Supercritical CO_2 from Garcinia Mangostana

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This study is designed to optimise the extraction of α mangostin using supercritical carbon dioxide. The extraction parameters were optimised by Box Behnken Design (BBD) with 17-run experiments. The maximum yield of α mangostin is 58.7 wt% under optimum conditions as follows: extraction pressure of 20.01 MPa, the temperature of 46.25 °C and percentage of co-solvent at 2.9 % of ethanol. To date, this is the first report depicting the optimisation of α mangostin from the pericarp of Garcinia Mangostana Linn using supercritical carbon dioxide.

1. Introduction

Mangosteen (Garcinia mangostana L.) is a tropical evergreen tree that is widely distributed in Malaysia, India, Thailand, Vietnam, Singapore, Philippines and Myanmar. Over the years, the world has witnessed intense research on the plant due to its major compound, α mangostin which was reported to possess strong anti-inflammatory properties, inhibiting cyclooxygenase (COX), capable of treating tuberculosis, strong cardiovascular protective effects, antimicrobial, and remarkable antioxidant activity (Sampath and Vijayaraghavan, 2007). Extraction is a key step to separate phytochemicals from plant origin by means of differences in size, volatility, solubility and ionic strength. In recent years, supercritical CO_2 has received much attention due to its advantages such as the ability to minimise undesirable oxidation reaction, the low viscosity of the supercritical fluid and fine selectivity property (Ansari and Goodarznia, 2012). Zaidul et al. (2007) believed that the extraction time can be shortened up to 10 min compared with soxhlet extraction system that requires up to 15 h of extraction. Temperature and pressure can be manipulated to achieve the optimum solvent strength with high selectivity (Bimakr et al., 2012). Based on these facts, this study is designed to optimise the extraction of α mangostin using supercritical CO_2. This is the first report focusing on optimisation using supercritical fluid CO_2.

2. Methodology

2.1 Materials, chemicals and reagent

The certified reference material (CRM) of α-mangostin (98.77 %) (Figure 1) was purchased from Chengdu Biopurify Phytochemicals Ltd. Methanol, acetonitrile and ethanol (HPLC grade) were obtained from Mallinckrodt Co., USA while ortho-phosphoric acid was purchased from Qrec Reagent Chemical. Mangosteen fruits were bought from kasuma2u Sdn. Bhd. The dried samples were ground into fine powder and pass through a sieve (0.10 - 0.50 mm and 0.60 - 1.0 mm).

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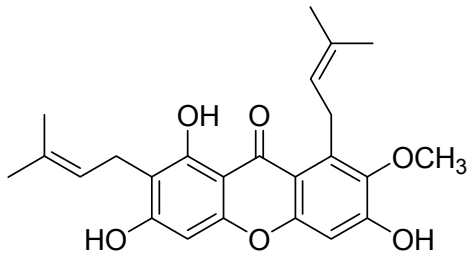


Figure 1: Chemical structure of α-mangostin

2.2 Supercritical Carbon Dioxide Extraction

Extraction was carried out at Centre of Lipid Engineering and Applied Research (CLEAR), University Teknologi Malaysia using a supercritical fluid extractor (SSI, State College Pennsylvania, US). The instrument consists programmable back pressure regulator (Model BP-2080, JASCO, Japan) to control the pressure (Figure 2).

5.0 g of dried mangosteen pericarp sample were loaded into extraction vessel where the pressure vessel was sealed tightly. High-pressure CO_2 was supplied from CO_2 cylinder to the extractor equipped with a back-pressure regulator unit. Samples were collected from collector valve and excess solvent was removed using rotary evaporator. The crude extracts were kept in the fridge (4 °C) until further used.

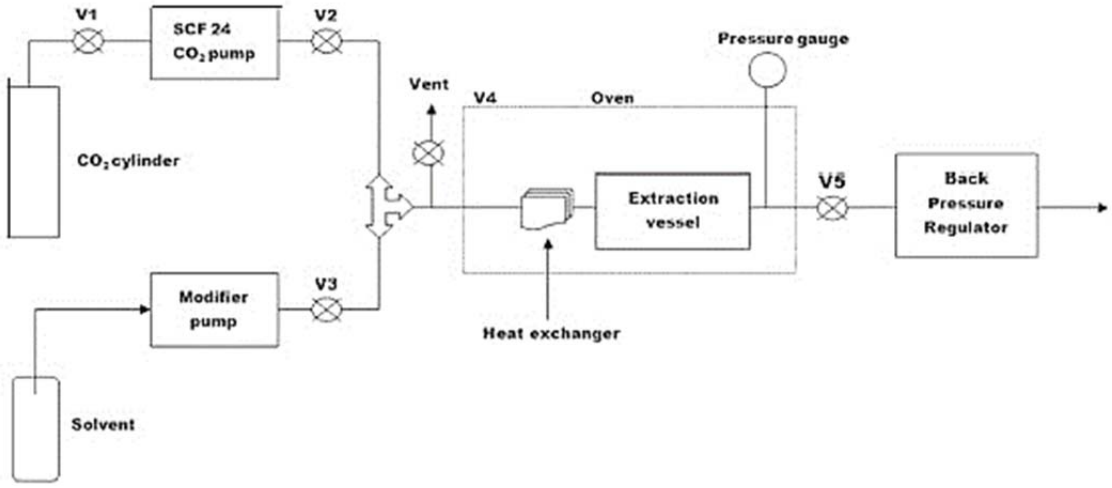


Figure 2: Schematic diagram of the SC-CO_2 extractor (Courtesy of CLEAR UTM Skudai)

2.3 RSM modelling

Box Behnken design (BBD) was employed to determine the optimal parameters of phalerin extraction in $scCO_2$ process. Three parameters which are ethanol concentration (X_1, %), pressure (X_2, MPa) and temperature (X_3, °C) were selected to optimise the extraction process tested in 17 experiments with 5 replicates at the centre point.

The independent variables were transformed into three levels (-1, 0, and 1) as tabulated in Table 1. The predicted response was calculated by second-order polynomial equation as follows:

$$Y = \beta_O + \sum \beta_i X_i + \sum \beta_{ii} \beta_i^2 + \sum\sum \beta_{ij} X_i X_j \quad (1)$$

Where Y is the response variables, β_0 is a constant and β_i, β_{ii}, β_{ij} represents the linear, quadratic and interaction terms. The optimal conditions of extraction were analysed by Design Expert 6.0.6 (2005).

Table 1: Independent variables and their coded levels chosen for the Box-Behnken design

Independent Variables	Coded Factor	Level		
		-1	0	+1
Pressure (MPa)	X_1	20	25	30
Temperature (°C)	X_2	40	50	60
Co-solvent (ethanol) concentration (%)	X_3	0	1.5	3

2.4 High-Performance Liquid Chromatography

The analytical HPLC Waters apparatus (2487 Dual λ Absorbance and 2690 Separation Module) was used to analyse α-mangostin concentration in each experiment. The system was equipped with online degasser, binary HPLC pump, PDA detector, Auto sampler and Column heater and a reversed phase C18 Gemini column (4.6 mm x 150 mm), with 5 µm particle size or equivalent. The mobile phase consists of 0.1 % ortho phosphoric acid (solvent A) and acetonitrile (solvent B). The elution was carried out by an isocratic solvent system with 1 mL/min flow rate. Separation was carried out in isocratic elution with 20 % of A and 80 % of B respectively according to the previous report by Yodhnu et al. (2009) with slight modification. PDA detector is set at 320 nm due to highest sensitivity and best wavelength obtained for α-mangostin extracts. The HPLC chromatogram of the pure compound and one of the extracts are shown in Figure 3.

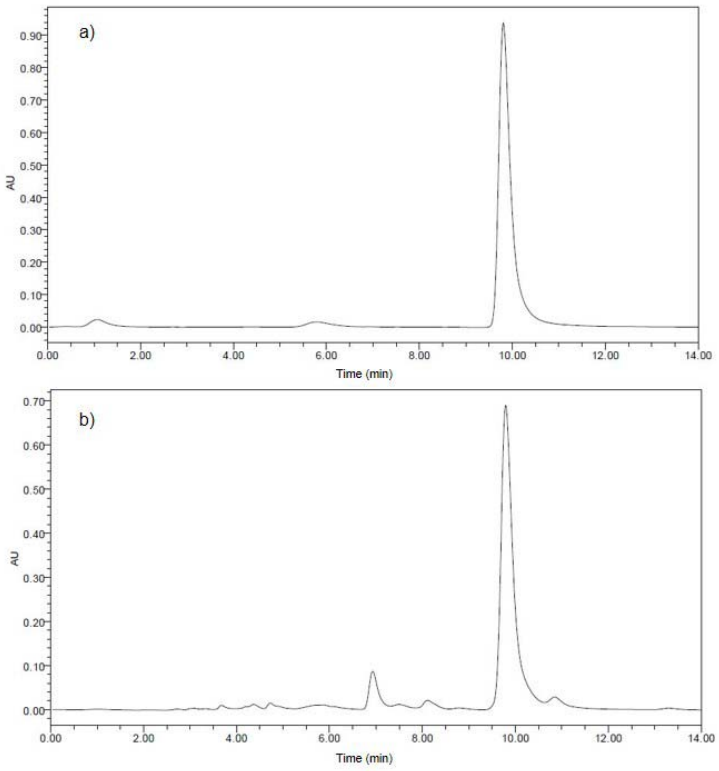


Figure 3: HPLC chromatogram profile for (a) standard of α mangostin (b) one extract of $scCO_2$

3. Results and discussion

3.1 Model fitting

The maximum yield was recorded under experimental conditions of X_1 = 20 MPa, X_2 = 50 °C and X_3 at 3 % and can be predicted by the following second order polynomial Eq(2).

$$Y = 1.49X_1 + 1.32X_2 - 5.47X_3 + 2.47X_{12} + 6.38X_{22} + 2.27X_{32} - 3.61X_1X_2 - 8.67X_1X_3 + 2.0 + 46.59 \quad (1)$$

Where Y is α mangostin (wt%), X_1 is the pressure (MPa), X_2 is the temperature (°C) and X_3 is the concentration of co-solvent (%). Analysis of variance (ANOVA) was shown in Table 2. At 95 % confidence

level, the *p*-value was <0.0001 suggested that the model was highly significant. The regression coefficient (R^2) of the model (0.9772) is reasonably close to 1, which implied a high degree of correlation between the experimental and predicted values.

The calculated model could explain 97.7 % of the results in the case of α mangostin yield. A good statistical model should have adjusted R-squared close to R^2. According to the statistical analysis, adj R^2 (0.9480) indicates only 2.93 % of total variation was not explained by the model. The lack of fit of this model was not significant with *p*-value of 0.3184 indicating the second order polynomial equation was adequate for predicting the yield of α mangostin under any combination of values of the variables. A very low value of the coefficient of the variance (4.13) confirms a good degree of precision with which the experiments were carried out.

Table 2: Analysis of Variance (ANOVA) for the response surface quadratic model for α mangostin extracts using $scCO_2$

Source	Sum of squares	Mean Df	Mean square	F Value	P value
Model	878.32	9	97.59	33.4	< 0.0001***
X_1	17.79	1	17.79	6.09	0.0430*
X_2	13.97	1	13.97	4.78	0.0650
X_3	239.21	1	239.21	81.88	<0.0001***
X_1^2	25.72	1	25.72	8.80	0.0209*
X_2^2	171.36	1	171.36	58.66	<0.0001***
X_3^2	21.64	1	21.64	7.41	0.0297*
X_1X_2	52.06	1	52.06	17.82	0.0039**
X_1X_3	300.88	1	300.88	102.99	<0.0001***
X_2X_3	17.52	1	17.52	6.00	0.0442*
Lack of Fit	11.22	3	3.74	1.62	0.3184

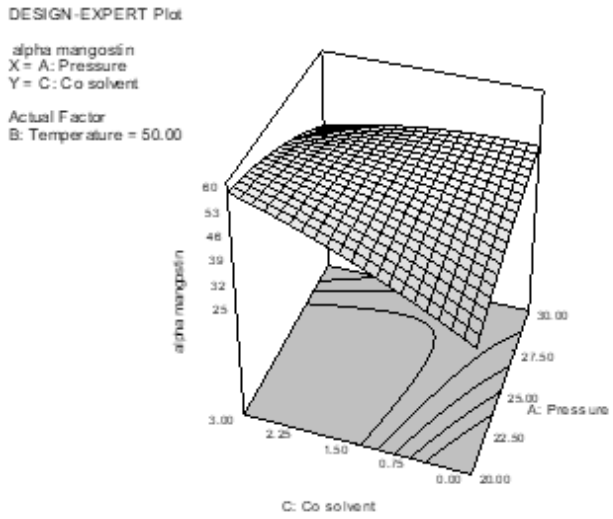
3.2 Response surface analysis

The interactions between parameters on the yield of α mangostin are presented in 3D response surface shown in Figure 4a to 4c. All of three variables had a substantial effect on the yield of α mangostin ($p < 0.05$). As shown in Figure 4a, at certain range of co-solvent concentration (1.5 - 3 %), the yield of α mangostin significantly increased with increasing pressure until 25 MPa, however, the trend was reversed and led to a gradual decrease of α mangostin concentration as the pressure exceeds 25 MPa. This phenomenon could be explained by the fact that at high-pressure level, the solute-solvent interactions became repulsive due to the volatility and polarity of α mangostin extracts. Gomes et al. (2007) stated that at high pressure, low recovery of non-volatile compounds will be obtained. Since α mangostin is a non-volatile compound, such observation was acceptable.

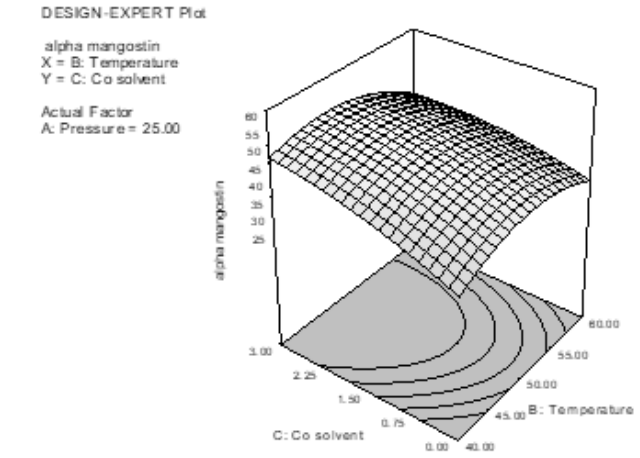
Jusoh et al. (2017) reveal the significant of ethanol concentration in extracts phenolic compounds from apple peel. Figure 4b reveals the influence of extraction temperature and percentage of co-solvent on the yield of α mangostin at a fixed pressure of 25 MPa. At a certain extraction temperature, (40 - 55 °C) increment amount of co-solvent to a certain value resulted in increment yield of α mangostin with no further significant improvement (Figure 4a and 4b). The same result was gained by (Zarena and Udaya Sankar, 2011), where at operating condition of 280 bar pressure, 50 ºC temperature and 5 % of ethanol as co-solvent, the highest yield of total xanthones (75.29 ± 20.26 wt%) was extracted from Garcinia. mangostana. Similarly, Bimakr et al. (2012) pointed out the outcome of co-solvent percentage on the yield of phenolic compounds extracted. According to the rule of thumb; polar constituents would be easier to extract with a more polar solvent. Thus, the increasing amount of ethanol as the co-solvent affect the polarity and solvating power of the supercritical carbon dioxide resulted in higher yield of α mangostin (Figure 4a and 4b).

As shown in Figure 4b and 4c, the optimal range for temperature to obtain the highest yield of α mangostin is 40 - 50 °C. The yield of α mangostin seems to be decreased when extraction temperature exceeds 50 °C. This observation was in agreement with (Bimakr et al., 2012) in the optimisation of supercritical carbon dioxide extraction of bioactive flavonoid compounds from Spearmint (Mentha spicata L.) leaves when the total flavonoids content was reduced as the extraction temperature exceeds 50 °C. This is probably due to the fact that high temperature may enhance solubility and mass transfer between cell walls; however, excessive heating promotes degradation of a phenolic compound which in return reduce the rate of α mangostin extraction (Junior et al., 2014). Furthermore, extraction temperature and pressure play a crucial role in $scCO_2$ as they define the density of the supercritical fluid. From the 3D graph, it can be deduced that lower extraction temperature resulted in higher extraction yield of α mangostin (Zarena et al., 2012).

a)



b)



c)

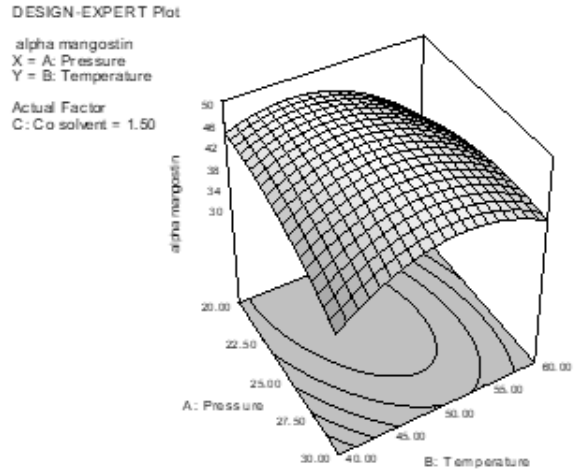


Figure 4: 3D representation of a) Pressure (MPa) vs. Percentage of Co-solvent b) Temperature (°C) vs. co-solvent (%) c) Percentage of Pressure (MPa) vs Temperature (°C)

From statistical analysis, the highest yield of α mangostin extracted (58.86 wt%) was obtained at a pressure of 20.01 MPa, extraction temperature of 46.25 °C and percentage of co-solvent at 2.9 %. To ensure the predicted result was not bias to the practical value, extraction under these optimal conditions were carried out with experimental conditions of 20 MPa, 46 °C and 2.9 % of ethanol as co-solvent to yield 58.81 % (w/w) of α mangostin which is comparable to the predicted value (58.86 wt%) at 95 % confidence interval. The results indicate a close interaction between experimental and modelling values of α mangostin yield.

4. Conclusions

Response surface methodology (RSM) was used to optimise the extraction variables such as extraction temperature (°C), the percentage of co-solvent (%) and pressure (MPa). The results indicate that the optimal conditions to obtain the highest yield of α-mangostin (58.81 wt%) were determined to be 20 MPa of pressure value, 46 °C of extraction temperature and percentage of co-solvent ethanol of 2.9 %. These discoveries imply that supercritical carbon dioxide is a powerful tool to extract α-mangostin whereas, in terms of mathematical modelling, RSM showed high efficiency to optimise the extraction parameters. These data might be useful for the development α-mangostin extraction in industrial scale.

Acknowledgements

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Reference

Ansari K., Goodarznia I., 2012, Optimisation of supercritical carbon dioxide extraction of essential oil from spearmint (Mentha spicata L.) leaves by using Taguchi methodology, Journal of Supercritical Fluids, 67, 123–130.

Bimakr M. Rahman R.A., Ganjloo A., Taip F.S., Salleh L.M., Sarker M.Z.I. 2012, Optimisation of Supercritical Carbon Dioxide Extraction of Bioactive Flavonoid Compounds from Spearmint (Mentha spicata L.) Leaves by Using Response Surface Methodology, Food and Bioprocess Technology, 5, 912–920.

Design Expert 6.0.6, 2005, Stat-Ease, US.

Gomes P.B. Mata V.G., Rodrigues A.E., 2007, Production of rose geranium oil using supercritical fluid extraction, The Journal of Supercritical Fluids, 41, 50–60.

Junior M.R.M., Leite,A.V., Dragano N.R.V., 2014, Supercritical Fluid Extraction and Stabilisation of Phenolic Compounds From Natural Sources – Review (Supercritical Extraction and Stabilisation of Phenolic Compounds), The Open Chemical Engineering Journal, 5, 51–60.

Jusoh Y.M.M., Orsat V., Gariepy Y., Raghavan V., 2017, Optimisation of radio frequency assisted extraction of apple peel extract: Total phenolic contents and antioxidant activity, Chemical Engineering Transactions, 56, 1153–1158.

Sampath P.D. Vijayaraghavan K., 2007, Cardioprotective effect of α-mangostin, a xanthone derivative from Mangosteen on tissue defense system against isoproterenol-induced myocardial infarction in rats, Journal of Biochemical and Molecular Toxicology, 21, 336–339.

Yodhnu S., Sirikatitham A., Wattanapiromsakul C., 2009, Validation of LC for the determination of alpha-mangostin in mangosteen peel extract: a tool for quality assessment of Garcinia mangostana L., Journal of chromatographic science, 47, 185–189.

Zaidul I.S.M. Norulaini N.A N., Omar A.K.M., Sato Y., Smith R.L., 2007, Separation of palm kernel oil from palm kernel with supercritical carbon dioxide using pressure swing technique, Journal of Food Engineering, 81, 419–428.

Zarena A.S., Sachindra N.M., Udaya Sankar K., 2012, Optimisation of ethanol modified supercritical carbon dioxide on the extract yield and antioxidant activity from Garcinia mangostana L., Food Chemistry, 130, 203–208.

Zarena, A.S., Udaya Sankar K., 2011, Xanthones enriched extracts from mangosteen pericarp obtained by supercritical carbon dioxide process, Separation and Purification Technology, 80, 172–178.