

# DEODORIZING MORINDA CITRIFOLIA (MENGKUDU) STRONG ODOR JUICE BY $\beta$ -CYCLODEXTRIN-ORGANIC ACIDS INCLUSION

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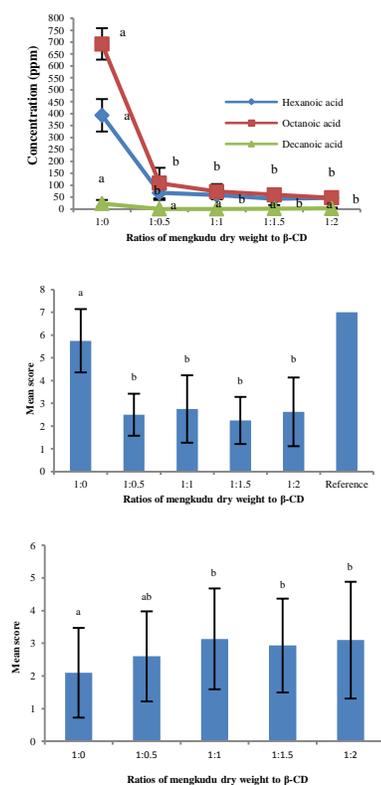
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## Graphical abstract



## Abstract

*Morinda citrifolia* (noni) which is locally known as *mengkudu* in Malaysia, is a small evergreen tree usually found growing in open coastal regions at sea level and in forest areas. It has been reported to have various therapeutic effects, including having anticancer activities, in clinical practices and laboratory animal models. However, consumers mostly avoid consuming *mengkudu* products due to *mengkudu*'s sensory properties such as a strong rancid-like odor that is released when the *mengkudu* fruit is fully ripe. Therefore, this study was conducted to determine the effectiveness of  $\beta$ -cyclodextrin in deodorizing the unpleasant odors in *mengkudu* juice which are mainly caused by medium chain fatty acids such as hexanoic acid, octanoic acid and decanoic acid. Initially, the optimal molar ratio for the encapsulation of hexanoic, octanoic and decanoic acid by  $\beta$ -cyclodextrin was constructed as a model system prior to the encapsulation of the juice. The formation of inclusion complex between all acids and  $\beta$ -cyclodextrin was verified by means of differential scanning calorimetry (DSC). Next, four dry weight ratios of *mengkudu* juice to  $\beta$ -cyclodextrin (1:0.5, 1:1, 1:1.5 and 1:2) were selected to determine the degree of the effectiveness of  $\beta$ -cyclodextrin in encapsulating unpleasant odors via gas chromatography-mass spectrometry (GC-MS). Based on the results, inclusion complex formation was confirmed by DSC through the disappearance of a melting point for pure acid, and shifting to a lower melting point from the pure  $\beta$ -cyclodextrin after the encapsulation process. Moreover, there were significant differences observed between hexanoic acid and octanoic acid content in the *mengkudu* juice before and after adding  $\beta$ -cyclodextrin ( $p < 0.05$ ). On the other hand, the results obtained from GC-MS and sensory evaluation had contributed to an optimum entrapment of fatty acids at the optimal dry weight ratio of 1:0.5 (dry weight of *mengkudu*:  $\beta$ -cyclodextrin). Hence, the ability of  $\beta$ -cyclodextrin as a masking agent has been proven to be able to reduce the odor-based fatty acids in *mengkudu* juice.

Keywords:  $\beta$ -cyclodextrin, *mengkudu* juice, fatty acids, encapsulation

## Abstrak

*Morinda citrifolia* (noni) dengan nama tempatannya di Malaysia iaitu mengkudu adalah tumbuhan hijau sepanjang musim yang tumbuh luas di kawasan perairan di aras laut dan kawasan hutan. Ianya dilaporkan secara klinikal dan model haiwan makmal iaitu mempunyai beberapa kesan terapeutik termasuklah di dalam merawat aktiviti sel. Walaubagaimanapun, kebanyakan para pengguna cuba mengelak untuk menggunakan sebarang produk mengkudu disebabkan oleh bau tengiknya yang kuat apabila buah masaknya digunakan untuk penyediaan perubatan (dalam bentuk jus). Oleh yang demikian, kajian ini dijalankan bagi menentukan keberkesanan ' $\beta$ -cyclodextrin' di dalam menyahbaukan bau kurang enak di dalam jus yang mana disebabkan oleh beberapa asid lemak rantai sederhana seperti 'hexanoic acid, octanoic acid' dan 'decanoic acid'. Permulaannya, nisbah molar optimum untuk pemerangkapan 'hexanoic, octanoic' dan 'decanoic acid' menggunakan ' $\beta$ -cyclodextrin' dibina sebagai model permulaan sebelum pemerangkapan asid organik menggunakan jus mengkudu. Pembentukan penjerapan kompleks di antara semua asid organik dan ' $\beta$ -cyclodextrin' disahkan melalui analisis 'differential scanning calorimetry' (DSC). Seterusnya, empat nisbah berat kering jus mengkudu kepada ' $\beta$ -cyclodextrin' (1:0.5, 1:1, 1:1.5 dan 1:2) disediakan dan dipilih untuk menentukan tahap keberkesanan pemerangkapan ' $\beta$ -cyclodextrin' terhadap proses penyahbau asid organik melalui analisis 'gas chromatography-mass spectrometry' (GC-MS). Berdasarkan kepada keputusan ujikaji, pembentukan penjerapan kompleks disahkan berlaku melalui analisis DSC apabila wujudnya kehilangan titik lebur bagi asid organik piawai dan perubahan titik lebur yang rendah bagi ' $\beta$ -cyclodextrin' selepas proses pemerangkapan berlaku. Sebagai tambahan, terdapat perubahan kandungan di antara 'hexanoic acid' dan 'octanoic acid' secara signifikan di dalam jus mengkudu sebelum dan selepas penambahan ' $\beta$ -cyclodextrin' ( $p < 0.05$ ). Selain daripada itu, keputusan yang diperolehi daripada analisis GC-MS dan penilaian sensori turut menyumbang kepada penentuan nisbah berat kering jus mengkudu kepada ' $\beta$ -cyclodextrin' dalam pemerangkapan asid-asid organik penyebab bau tengik secara optimum iaitu 1:0.5. Oleh yang demikian, keupayaan ' $\beta$ -cyclodextrin' sebagai agen pemerangkap bau telah terbukti berupaya menyerap beberapa asid lemak penyebab bau tengik jus mengkudu secara efektif.

**Kata kunci:**  $\beta$ -siklodekstrin, jus mengkudu, asid lemak, pemerangkapan

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## 1.0 INTRODUCTION

*Morinda citrifolia* which is known as *mengkudu* in Malaysia, is an evergreen tree under the family, *Rubiaceae* which is grown in tropical and sub-tropical areas. *Mengkudu* is native from Southeast Asia to Australia. Besides it is also planted in Polynesia, India, the Caribbean, as well as the Central and Northern part of America<sup>1</sup>. *Mengkudu* plants have been used by the Polynesians for more than 2000 years as a source of food and for their therapeutic functions [2, 3]. *Mengkudu* has been used traditionally as it is believed to possess some medicinal functions. *Mengkudu* fruit is used to treat a variety of health problems. It functions as an anti-microbial, anti-cancer, antioxidant, anti-inflammatory, as well as analgesics agent and in controlling cardiovascular activities [2]. There are about 160 phytochemical compounds that have been identified in *mengkudu*. Furthermore, phenolic compounds, organic acids and alkaloids are the main micronutrients in *mengkudu* [2, 4].

However, consumers still limit their consumption on *mengkudu* products due to *mengkudu*'s sensory properties such as a strong rancid-like odor which is

released when the *mengkudu* fruit is fully ripe [1, 5] which this is quite unfavorable. Based on the study conducted by Farine *et al.* [6], it is suggested that the volatile compounds in *mengkudu* are mainly 83% carboxylic acid, 5% alcohol and 3% ester. Besides, the volatile carboxyl acids are mainly contributed by 58% octanoic acid, 19% hexanoic acid and 2% decanoic acid. According to Norma *et al.* [7], medium chain fatty acids such as hexanoic acid (caproic acid), octanoic acid (caprylic acid) and decanoic acid (capric acid) are responsible in contributing to the unpleasant odor of *mengkudu*.

Cyclodextrin is an oligosaccharide which is made up of glycopyranose.  $\alpha$ -,  $\beta$ - and  $\gamma$ -Cyclodextrin are made up of 6 units, 7 units and 8 units of glycopyranose respectively. The  $\alpha$ -(1,4)-glycosidic bond is used to link the glucopyranose units. The hydrophobic cavity of the cyclodextrin enables it to encapsulate other molecules to form inclusion complex [8]. In food industry, cyclodextrin is used to protect the lipophilic food component which is sensitive to oxygen, light or heat; solubilize food coloring and vitamins; stabilize aroma, flavoring, vitamins and essential oils; mask unpleasant odor or flavor; and control the release of certain food

substances [9].  $\beta$ -Cyclodextrin is also an encapsulant that protects aroma or flavor during food processing. Besides,  $\beta$ -cyclodextrin is able to maintain and improve aroma quality and quantity to a higher level and for a longer period. According to Meier *et al.* [10],  $\beta$ -cyclodextrin is able to reduce the goaty flavor of goat milk which is mainly caused by fatty acids such as octanoic acid and decanoic acid. The maximum amount of incorporated acid in  $\beta$ -cyclodextrin according to DSC, occurs at the molar ratio ( $\beta$ -CD:acid) of 1:1 and 1:1.5 for decanoic acid and octanoic acid [15].

Therefore, the aim of this study is to determine the molar ratio of hexanoic acid, octanoic acid and decanoic acid incorporated in  $\beta$ -cyclodextrin in order to determine the effectiveness of  $\beta$ -cyclodextrin in encapsulating the unpleasant odor of *mengkudu* juice.

## 2.0 METHODOLOGY

### 2.1 Determination of Molar Ratio of Acid Incorporated in $\beta$ -Cyclodextrin

Hexanoic acid, octanoic acid and decanoic acid (0.05 M) were prepared by dissolving them in 100 ml ethanol respectively.  $\beta$ -Cyclodextrin solution (0.1 M) was prepared by dissolving it in isopropyl alcohol and distilled water (1:2 v/v) and diluting it based on the molar ratio of (acid: $\beta$ -Cyclodextrin) 1:0.5, 1:1, 1:1.5 and 1:2. The Bhandari *et al.* [11] method was used with some minor modifications. Acid solution was slowly added to the warm  $\beta$ -cyclodextrin solution at 55 °C. The mixture was stirred by using incubator shaker for 4 hours without heating. The final solution was cooled and refrigerated overnight at 4 °C with formed precipitates. The solution was centrifuged at 2000 rpm for 4 minutes at 4 °C. The acid content in 6 ml supernatant was extracted with 2 ml hexane and analyzed with gas chromatography-mass spectrometry (GC-MS). The formed precipitates were dried in the oven at 50 °C for 24 hours and kept in the desiccator prior to the component analysis.

### 2.2 Mengkudu Juice Extraction

Ripe *mengkudu* fruits (harvest maturity: stage 4 - week 15<sup>th</sup>) were obtained from Seksyen 2, Bangi, Selangor, Malaysia. The whole fruits were washed, weighed and cut into small pieces. The fruit pieces were added with distilled water at the ratio of 1:1 (w/v) and blended using a food blender. The blend was filtered using a cotton cloth and centrifuged at 4000 rpm for 25 minutes at 5 °C. The extracts were kept chilled at 4 °C prior to deodorizing mechanism and analysis.

### 2.3 Organic Acids Extraction

The liquid-liquid extraction of *mengkudu* juice organic acids was conducted using hexane with the mixing ratio

of 1.5:1 (previous study - data not shown). The extract was then analyzed using GC-MS to determine the volatile compounds (organic acids) in *mengkudu* juice ( $\beta$ -cyclodextrin free solution).

### 2.4 Mengkudu Moisture Content (Wet Basis)

The moisture content of *mengkudu* was determined by executing oven drying method. Crucible and 5 g of the *mengkudu* sample were weighed and dried in an oven at 105 °C overnight. The sample was weighed after drying to determine the moisture content.

### 2.5 Incorporation Ratio of Organic Acids in $\beta$ -Cyclodextrin

The best incorporated organic acids (hexanoic acid, octanoic acid and decanoic acid: 5 ml each) in  $\beta$ -cyclodextrin ratio were determined based on the Bhandari *et al.* [11] method (1:0.5, 1:1, 1:1.5 and 1:2). The highest amount of the organic acids adsorption determines the best ratio to be used prior to the *mengkudu* juice extract's organic acids adsorption study.

### 2.6 Gas Chromatography-Mass Spectrometry (GC-MS)

Standard curves were obtained by using 0.001 M, 0.005 M, 0.010 M, 0.015 M and 0.020 M of hexanoic acid, octanoic acid and decanoic acid. The hexane extract was injected into GC-MS for an analysis using Shimadzu GCMS-QP5050 (Shimadzu Japan). The column was HP5 (length 30 m x internal diameter 0.25 mm; film thickness 0.25  $\mu$ m). For all injections, the volatile extracts were used in a 100 split injection mode together with the helium carrier gas at a constant flow rate of 1 ml/min. The column oven was temperature-programmed to fluctuate from 80 °C (2 minutes initial hold) to 210 °C at 15 °C/min and then increase again to 250 °C at 20 °C/min and this was maintained for 3 minutes. The injector temperature was 250 °C. The detected temperature was 280 °C with the average mass of 50-450 units.

### 2.7 Differential Scanning Calorimetry (DSC)

Formation of inclusion complex was determined by using DSC. The pure acid samples,  $\beta$ -cyclodextrin sample and inclusion complex samples (6 mg) were weighed and analyzed using Mettler Toledo DSC 822 respectively. The study involved -20 to 250 °C for hexanoic acid complex, -10 to 250 °C for octanoic acid complex and 20 to 250 °C for decanoic acid complex. The operating circumstances were 10 °C/min heating rate and 50 ml/min nitrogen flow.

### 2.8 Sensory Evaluation

Hedonic test and descriptive test were carried out. For hedonic test, 30 consumer-type panelists from Universiti

Kebangsaan Malaysia (UKM) were involved. The panelists were made up of Malays, Indians and Chinese of males and females student and staff at the average age of 19-24. The panelists were required to evaluate their degree of liking of the aroma of the samples. The quantity for each sample was 4 ml per glass and 5 samples were served which included 4 samples with the addition of  $\beta$ -cyclodextrin, and a sample of original *mengkudu* juice. For a descriptive test, 8 trained panelists of the 4<sup>th</sup> year Food Science Program students in UKM, Malaysia were involved in evaluating the aroma intensity of the *mengkudu* juice with the addition of a different ratio of  $\beta$ -cyclodextrin. The quantity for each sample was 4 ml per glass. The glass with labeled R was the reference. The panelists were required to evaluate the R and evaluate the samples based on the R. For both tests, the glasses were kept sealed until the panelists were asked to sniff them. A mark was assigned for the intensity of off-flavour on a scale ranging from 0 to 7. The samples were randomized so that all possible serving combinations could occur and they were later presented to the panelists. Five samples were presented on a tray and the evaluation of the intensity of the aroma started from left to right.

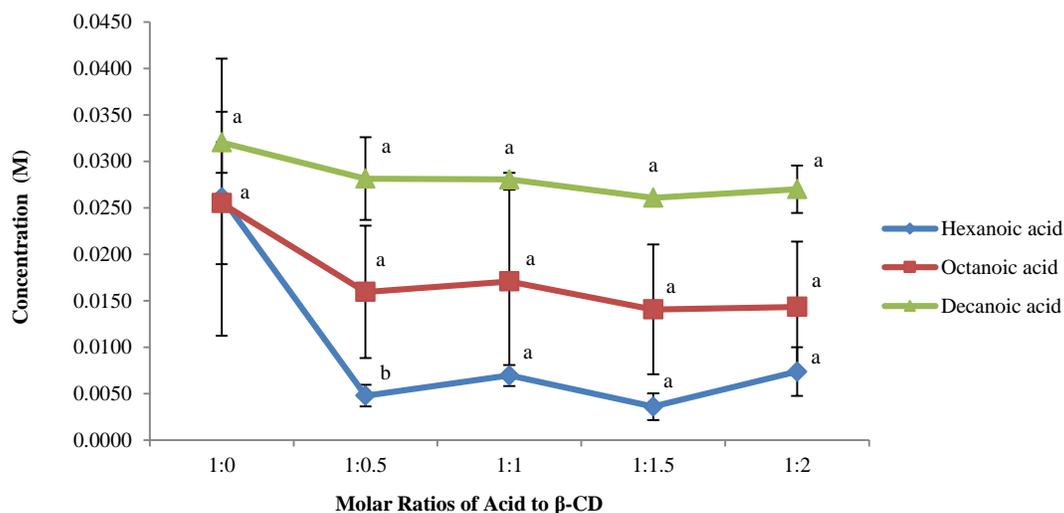
### 3.0 RESULTS AND DISCUSSION

#### 3.1 Molar Ratio of Acid Incorporated in $\beta$ -Cyclodextrin

According to Figure 1, there were no significant differences ( $p > 0.05$ ) between the acid concentrations

before and after adding  $\beta$ -cyclodextrin for hexanoic acid, octanoic acid and decanoic acid respectively. Furthermore, no significant differences were found in the acid concentration after the addition of  $\beta$ -cyclodextrin based on the molar ratio, 1:0.5, 1:1, 1:1.5 and 1:2 for the respective acid. The higher molar ratio of  $\beta$ -cyclodextrin used was not necessarily able to encapsulate acid more effectively. Hence, it proved that the encapsulation of acid did not necessarily happen at a higher molar ratio of  $\beta$ -cyclodextrin.

The cavity of  $\beta$ -cyclodextrin was estimated to have the same polarity as aqueous ethanol solution [12]. In this study, pure acids were dissolved in ethanol due to their low solubility properties in water. According to Ohashi *et al.* [13], a suitable quantity of ethanol can assist in the inclusion complex formation of d-limonene. However, excessive ethanol used might reduce the d-limonene complex formation as ethanol complex formation is increased. Therefore, a high quantity of ethanol used might prevent the desired guest molecules from being encapsulated by  $\beta$ -cyclodextrin in the formation of inclusion complexes. In this study, no significant differences were discovered in the concentration for the three types of acid before and after adding  $\beta$ -cyclodextrin. It might be due to the competition between the acids with the ethanol against the  $\beta$ -cyclodextrin cavity.



**Figure 1** Concentration of pure acids before and after adding  $\beta$ -cyclodextrin. a-b\* Different letters on the same line show significant difference between samples ( $n = 3$ )

### 3.2 Inclusion Complex Formation

In this study, the inclusion complex was prepared by executing co-precipitation method. The inclusion complex formed as white powder was analyzed by using DSC. DSC can be used to determine the melting point and crystallization point of a substance. It gives quantitative and qualitative information of a substance regarding the physical and chemical changes that involve endothermic and exothermic process. Based on the thermogram of inclusion complex, the temperature changes in inclusion complex compared to pure substances that this provides information about the changes in crystal lattice, melting point, boiling point or sublimation point [14]. In this study, the melting point of inclusion complex was used to determine the formation of inclusion complex by comparing the melting point of pure acid and  $\beta$ -cyclodextrin (Figure 2).

A sharp peak is presented in Figure 3 for pure guest molecules. When inclusion complex was formed, no energy absorption at the melting point of guest molecules was observed in the complex. According to Figure 4, the melting point for the inclusion complex was lower than the pure  $\beta$ -cyclodextrin and no melting point of the pure decanoic acid was observed in the inclusion

complex. It was due to the fact that the guest molecules were surrounded by  $\beta$ -cyclodextrin and were unable to interact with other guest molecules. Hence, there was no guest molecules' structure in crystalline that absorbed the energy [15].

The melting points of pure  $\beta$ -cyclodextrin, hexanoic acid, octanoic acid and decanoic acid were 114.86, -4.15, 16.37 and 32.71 °C respectively. Based on Table 1, all the inclusion complexes demonstrated a lower melting point than pure  $\beta$ -cyclodextrin and no melting point of hexanoic acid, octanoic acid and decanoic acid was observed in respective inclusion complexes. For octanoic acid, maximum encapsulation occurred at the molar ratio of 1:0.5 ( $p < 0.05$ ) with the melting point of 105.53 °C  $\pm$  0.16. According to Meier *et al.* (2001) [15], maximum encapsulation of octanoic acid based on DSC occurred at the molar ratio of 1:1.5 ( $\beta$ -CD:acid) which showed that one molar of  $\beta$ -cyclodextrin was able to encapsulate more than one molar of octanoic acid. The reason for the result of this study not to comply with the study conducted by Meier *et al.* [15] probably due to the incomplete co-precipitation process and a different molar ratio used in this study. However, this study revealed that more octanoic acid was encapsulated by  $\beta$ -cyclodextrin.

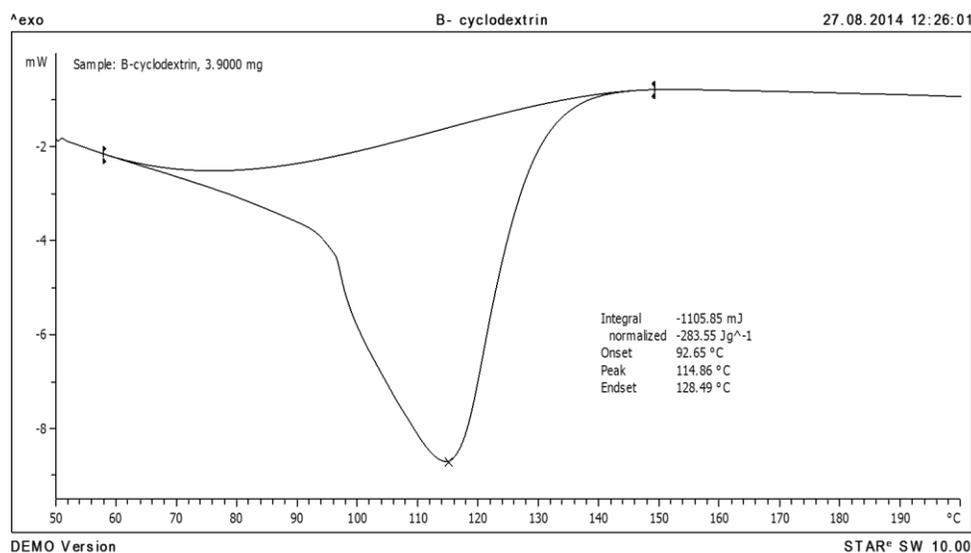


Figure 2 DSC thermogram for pure  $\beta$ -cyclodextrin

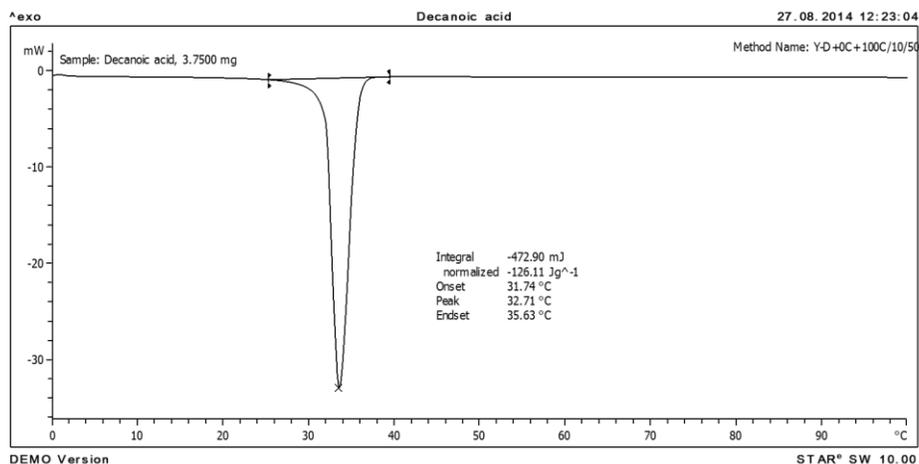


Figure 3 DSC thermogram for pure decanoic acid

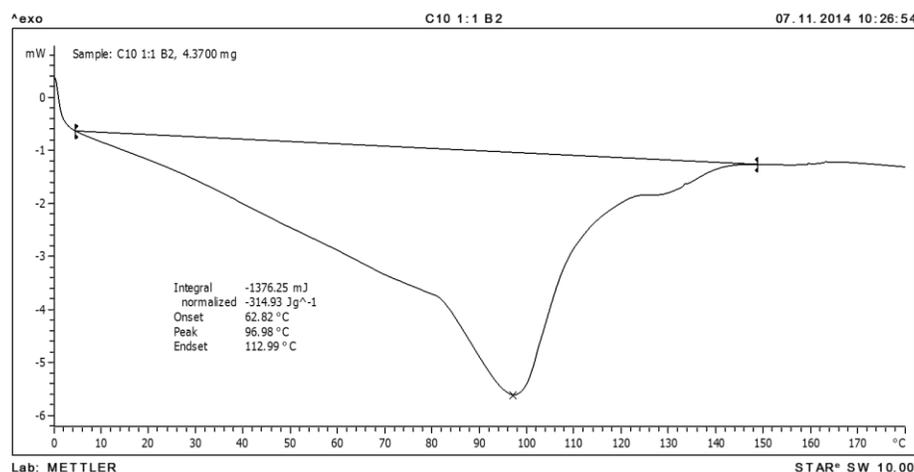


Figure 4 DSC thermogram for decanoic acid complex

Table 1 DSC results for  $\beta$ -cyclodextrin, pure acids and inclusion complexes

	Molar ratio (Acid: $\beta$ -CD)	Melting point (°C)
$\beta$ -CD		114.86
Hexanoic acid (C <sub>6</sub> )		-4.15
Octanoic acid (C <sub>8</sub> )		16.37
Decanoic acid (C <sub>10</sub> )		32.71
C <sub>6</sub> / $\beta$ -CD	1:0.5	110.57 $\pm$ 0.69 <sup>a</sup>
	1:1	110.67 $\pm$ 0.61 <sup>a</sup>
	1:1.5	112.40 $\pm$ 1.15 <sup>a</sup>
	1:2	110.05 $\pm$ 2.32 <sup>a</sup>
C <sub>8</sub> / $\beta$ -CD	1:0.5	105.53 $\pm$ 0.16 <sup>a</sup>
	1:1	108.77 $\pm$ 1.39 <sup>b</sup>
	1:1.5	109.60 $\pm$ 0.46 <sup>bc</sup>
	1:2	110.89 $\pm$ 0.21 <sup>bc</sup>
C <sub>10</sub> / $\beta$ -CD	1:0.5	105.73 $\pm$ 4.36 <sup>a</sup>
	1:1	98.93 $\pm$ 2.75 <sup>a</sup>
	1:1.5	106.96 $\pm$ 0.93 <sup>a</sup>
	1:2	107.97 $\pm$ 0.44 <sup>a</sup>

a-c\* Different letters in same group show significant difference between samples

In the formation of inclusion complex, most of the water molecules in the cavity will be replaced by acid molecules which weaken the bonding between the water molecules left in the cavity. Hence, the release of water molecules requires lower energy and it occurs at a lower temperature [16]. In this study, DSC results revealed the interaction between the pure acids with  $\beta$ -cyclodextrin in the formation of the inclusion complexes. Besides, a lower intensity of endothermic peak was observed in the inclusion complexes as compared to the  $\beta$ -cyclodextrin.

### 3.3 Availability of Volatile Acids

Table 2 shows the compositional profiles of all organic in mengkudu extract analyzed via GC-MS. Octanoic acid in mengkudu juice appeared to be the highest, and this was followed by hexanoic acid and decanoic acid. Such a result of this study apparently complied with the result of the study conducted by Farine *et al.*

[6] which reported that octanoic acid, hexanoic acid and decanoic acid were of 58%, 19% and 2% respectively in *mengkudu* juice. Besides, Pino *et al.* [17] has also reported that ripe *mengkudu* juice contained 72.29% of octanoic acid, 8.19% of hexanoic acid and 0.24% of decanoic acid.

### 3.4 Moisture Content of Mengkudu

The moisture content of the *mengkudu* studied was  $13.10 \pm 0.22\%$  (wet basis). According to Satwadhar *et al.*

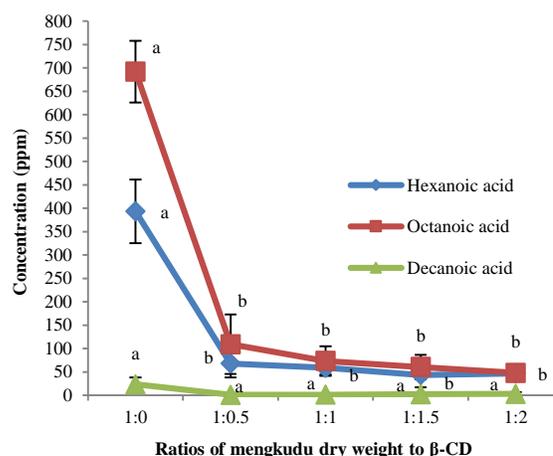
[18], a *mengkudu* fruit usually contains 91% of water compared to  $86.90 \pm 0.22\%$  of water, a finding discovered in this study. The differences were due to the different sources of the *mengkudu* used which could varied in many tropical countries. Based on the moisture content value, there was  $0.35 \pm 0.01$  g of dry weight in every 5 ml of the *mengkudu* juice.

**Table 2** Main acid components in *mengkudu* juice: (a) hexanoic acid (b) octanoic acid (c) decanoic acid

Component	Yield % (w/w)	Retention time
Octanoic acid	$70.33 \pm 0.23$	4.354 mins
Hexanoic acid	$9.25 \pm 0.66$	2.464 mins
Decanoic acid	$1.56 \pm 1.84$	6.133 mins
Unknown compounds	$18.22 \pm 1.53$	1.234 mins

### 3.5 Acids Encapsulation in Mengkudu Juice by $\beta$ -Cyclodextrin

The molar ratio of the acid incorporated in  $\beta$ -cyclodextrin for the *mengkudu* juice was determined based on the dry weight basis. The weights of  $\beta$ -cyclodextrin used were  $0.18 \pm 0.01$ ,  $0.35 \pm 0.01$ ,  $0.53 \pm 0.01$  and  $0.70 \pm 0.01$  g for the ratio of 1:0.5, 1:1, 1:1.5 and 1:2 respectively. Based on Figure 5, hexanoic acid and octanoic acid showed some significant differences ( $p < 0.05$ ) in the acid concentration after the addition of  $\beta$ -cyclodextrin when compared to the *mengkudu* juice without  $\beta$ -cyclodextrin. However, the concentration of decanoic acid showed no significant differences ( $p > 0.05$ ) after the addition of  $\beta$ -cyclodextrin. Octanoic acid concentration showed some decreases of  $-84.61 \pm 7.17$ ,  $-89.57 \pm 3.59$ ,  $-91.43 \pm 2.97$  and  $-93.02 \pm 1.88\%$  for the ratio of 1:0.5, 1:1, 1:1.5 and 1:2 respectively, where the negative symbol used signifies a decrease in the concentration of acid after being encapsulated. For hexanoic acid, the decreases of  $-83.14 \pm 4.74$ ,  $-85.13 \pm 1.06$ ,  $-89.41 \pm 4.88$  and  $-88.0 \pm 1.32\%$  in the concentration for the ratio of 1:0.5, 1:1, 1:1.5 and 1:2 were observed. At the ratio of 1:0.5, the percentages of the acid concentration reduction were  $-83.14 \pm 4.74\%$  and  $-84.61 \pm 7.17\%$  for hexanoic acid and octanoic acid respectively, where the octanoic acid presented a higher percentage in the acid concentration reduction. It might be due to the fact that the higher hydrophobicity of octanoic acid's molecules and its geometry with the  $\beta$ -cyclodextrin cavity had increased the encapsulation efficiency. However, the encapsulation of compounds into  $\beta$ -cyclodextrin cavity depends on the number of guest molecules which are able to bind with the cavity, hydrophobicity of the guest molecules and affinity binding base constant of the guest molecules [19].



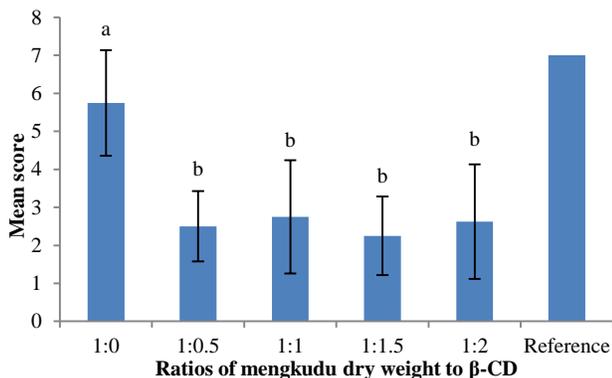
**Figure 5** Concentration of acids in *mengkudu* juice before and after adding  $\beta$ -cyclodextrin. a-b\* Different letters on the same line show significant differences between samples ( $n = 3$ )

### 3.6 Sensory Acceptance

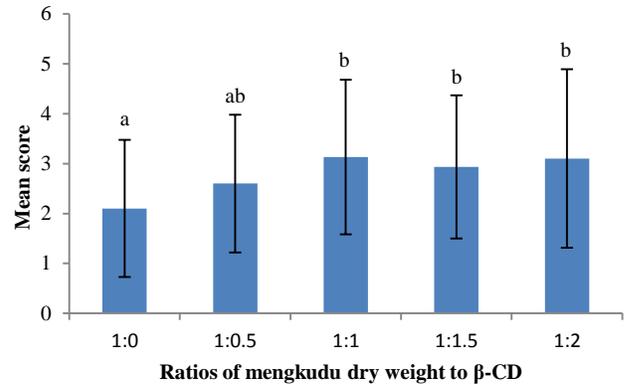
For the descriptive test, *mengkudu* juice was used as a reference sample (R) and it achieved the highest mean score, 7 which demonstrated the strongest intensity of the odor investigated (Figure 6). There was a slight difference in the mean score for 1:0 and R although both were the same sample. However, the mean score for the *mengkudu* juice without  $\beta$ -cyclodextrin as the control sample was  $5.75 \pm 1.39$  which indicated the highest mean score among the samples that this means it possessed the highest odor intensity when compared with the *mengkudu* juice treated with  $\beta$ -cyclodextrin. The mean scores for the ratio of 1:0.5, 1:1, 1:1.5 and 1:2 were  $2.50 \pm 0.93$ ,  $2.75 \pm 1.49$ ,  $2.25 \pm 1.04$  and  $2.63 \pm 1.51$  respectively. Sample 1:1.5 received the lowest mean score which this clearly implies it possessed the lowest odor intensity. The ANOVA and Duncan test

demonstrated that some significant differences ( $p < 0.05$ ) existed between the *mengkudu* juice before and after adding  $\beta$ -cyclodextrin. However, no significant differences were found between the samples with  $\beta$ -cyclodextrin added. The reason why all the panelists were unable to differentiate the odor intensity of the samples with  $\beta$ -cyclodextrin added could be due to their insensitivity in detecting the odor intensity. Besides, the adaptation involved for the odor intensity could have affected the performance of the panelists in their sensory evaluation.

For the hedonic test, the sample at the ratio, 1:1 achieved the highest mean score of  $3.13 \pm 1.55$  whereas the *mengkudu* juice without  $\beta$ -cyclodextrin as the control sample achieved the lowest mean score of  $2.10 \pm 1.37$  (Figure 7). The panelists presented the lowest degree of liking towards the *mengkudu* juice without  $\beta$ -cyclodextrin, whereas they preferred 1:1 sample the most. For samples of the ratio of 1:0.5, 1:1.5 and 1:2, the mean scores obtained were  $2.60 \pm 1.38$ ,  $2.93 \pm 1.44$  and  $3.10 \pm 1.79$  respectively. The panelists did not favor the *mengkudu* juice without  $\beta$ -cyclodextrin because of the presence of hexanoic acid, octanoic acid and decanoic acid. However, a higher mean score was obtained for the *mengkudu* juice treated with  $\beta$ -cyclodextrin that shows they were preferred the treated sample as compared to the others ( $p < 0.05$ ). The inclusion of  $\beta$ -cyclodextrin in the juice led to substantial encapsulation of hexanoic acid, octanoic acid and decanoic acid (the major organic acids to the unpleasant odor of *mengkudu* juice), thus reducing the odor intensity.



**Figure 6** Histogram of mean score  $\pm$  standard deviation for descriptive test. a-b\* Different letters show significant differences between samples ( $n = 3$ )



**Figure 7** Histogram of mean score  $\pm$  standard deviation for hedonic test. a-b\* Different letters show significant differences between samples ( $n = 3$ )

## 4.0 CONCLUSION

$\beta$ -cyclodextrin appeared to be effective in encapsulating hexanoic acid and octanoic acid in *mengkudu* juice ( $p < 0.05$ ) where the concentration of hexanoic acid and octanoic acid decreased by  $-83.14\% \pm 4.74$  and  $-84.61\% \pm 7.71$  respectively at the optimal ratio of 1:0.5. The inclusion method thus decreased the odor intensity with the optimal ratio of 1:0.5 (*mengkudu* dry weight:  $\beta$ -CD) but it did not deodorize the juice exhaustively. The kinetic  $\beta$ -cyclodextrin-organic acids adsorption study is required to identify the efficacy of the adsorption profiles as it becomes exhaustive. Moreover, the sensory evaluation conducted for the descriptive test revealed that the odor intensity was able to be reduced at the ratio of 1:0.5 ( $p < 0.05$ ). In fact, the Hedonic test managed to discover that the degree of liking for the *mengkudu* juice with  $\beta$ -cyclodextrin were substantially accepted as compared to the *mengkudu* juice without  $\beta$ -cyclodextrin ( $p < 0.05$ ) which seems to provide further proof on its potential to be used as a pretreatment material against strong odors.

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