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COMPARISON OF ESTERIFICATION AND TRANSESTERIFICATION METHOD IN SYNTHESIS OF OCTYL P-METHOXYCINNAMATE (OPMC) FROM *KAEMPFERIA GALANGA* L. RHIZOME

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ABSTRACT

Octyl p-methoxycinnamate (OPMC) is a cinnamic acid derivative that is often used for sunscreens in cosmetics. OPMC can be synthesized from ethyl p-methoxycinnamate (EPMC) as main contain in *kaempferia galanga* L. rhizome. The purpose of this study is to compare the synthesize of OPMC from natural EPMC by esterification and transesterification method. The first step is the extraction of EPMC from *kaempferia galanga* L. rhizome by maceration method (29,76%). In the esterification method, EPMC was hydrolysis into 4-methoxycinnamic acid (4-MCA) (72%) then reacted with octanol in different reaction time ((2,3,4,5,6 h). In the transesterification method, EPMC directly reacted with octanol in different reaction time (2,3,4,5,6 h). The OPMC synthesis results were identified with TLC, FTIR spectrophotometry, and gas chromatography-mass spectrometry (GC-MS). The identification results show that OPMC can be synthesized by both of method with optimum reaction time for esterification method is 3 hours and for transesterification method is 5 hours.

Keywords: esterification, ethyl p-methoxycinnamate, octyl p-methoxycinnamate, transesterification, 4-methoxycinnamic acid

INTRODUCTION

Octyl p-methoxycinnamate (OPMC) is one of an active compound as a sunscreen.[1-2] It is cinnamate acid derivative that can be synthesized by reacting ethyl p-methoxycinnamate (EPMC) and octanol.[3] EPMC as starting material can be obtained by synthesis or isolation from the plant. Recently, the development of sunscreen product from *kaempferia galanga* L. was increased since EPMC is a main content *kaempferia galanga* L. rhizome.[4-5] Sunscreen compound from natural EPMC is safer and cheaper compare to synthetic one, especially for sensitive skin.[6] In vitro study show that natural EPMC from *kaempferia galanga* L. rhizome can be classified as UV B sunscreen[7] similar with OPMC.[8-9]OPMC can be synthesized by esterification or transesterification method. Esterification is ester formation reaction from carboxylic acid with catalysis, meanwhile, transesterification is ester formation reaction from another ester compound.[10-12] EPMC is an ester compound and cinnamate group[13] that can be used as starting material to OPMC synthesis. In the esterification method, EPMC was hydrolyzed into 4-methoxycinnamic acid (4-MCA), a carboxylic acid compound, then reacted with n-octanol in acid condition. The yield was obtained 53.98% with optimum time is 4 hour[14] and 71.60% with an optimum time of 3 hours.[15] In transesterification, EPMC as ester compound directly reacted with n-octanol in acid condition. In this study, OPMC will be synthesized using both of method. The aim of this research is to compare these methods to determine which one is more effective for OPMC synthesis from natural EPMC.

EXPERIMENTAL

All chemicals used were of analytical grade and used without further purification. All solution was made using aquadestilata. Ethanol 96%, ethanol 70%, hydrochloride acid, n-octanol, sodium hydroxide, n-

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hexane, ethyl acetate were purchased from Merck. *Kaempferia galangal* L. rhizome was collected from a locally grown garden in Sumedang, West Java, Indonesia. Its plants were authenticated in the Herbarium, Biological Department, Faculty of Mathematical and Science (No. 336/HB/0/2016). Octyl p-methoxycinnamate (OPMC) standard was obtained from PT. Tissan Pandica.

Extraction EPMC from Kaempferia galangal L. rhizome

The *Kaempferia galangal* L. rhizome was collected, washed, and rinsed with tap water. The rhizomes were chopped into 2-3 mm and dried at room temperature for 7 days until the light brown color was obtained. The rhizomes are made into powder then approximately 2 kg of powder was extracted with 70% ethanol for 72 hours. The extract was concentrated under reduced pressure in a rotary vacuum evaporator. The concentrated extract was cooled in the refrigerator until the crystal of ethyl p-methoxycinnamate (EPMC) was formed. The crystal of EPMC was filtered and purified by recrystallization method using ethanol (yield 29.76%). The EPMC was characterized by organoleptic, melting point apparatus, thin layer chromatography (TLC), and Fourier Transform Infrared (FTIR).

Synthesis of OPMC by Esterification Method

In the esterification method, EPMC was hydrolyzed into 4-methoxycinnamic acid (4-MCA) then reacted with n-octanol to get OPMC. Hydrolysis was done by reacting 0.0374 mol of NaOH in ethanol then 0.024 mol of EPMC was added. The temperature of the reaction was kept at 60-70°C for 3 hours. The white colloids were dissolved with 200 ml of aquadest and acidified by HCl 15% until pH 4. The white precipitate was filtered and rinsed with water. The crystal of 4-methoxycinnamic acid was purified by recrystallization using ethanol (yield 72%). The 4-methoxycinnamic acid was characterized by organoleptic, thin layer chromatography (TLC), and Fourier Transform Infra Red (FTIR). Then, 1 mmol of 4-methoxycinnamic acid, n-octanol (10 ml) and HCl (0.5 ml) was mixed and refluxed on the temperature 110-140°C for the variation of reflux time on 2, 3, 4, 5, and 6 hours. The OPMC was characterized by thin layer chromatography (TLC), Fourier Transform Infra Red (FTIR), and Gas Chromatography-Mass Spectrometry (GC-MS).

Synthesis of OPMC by Transesterification Method

In transesterification method, EPMC (1 mmol), n-octanol (7 ml), and HCl (0.5 ml) were mixed and refluxed on the temperature 150-160°C for the variation of time 3, 4, 5, and 6 hours. The OPMC was characterized by thin layer chromatography (TLC), Fourier Transform Infra Red (FTIR), and Gas Chromatography-Mass Spectrometry (GC-MS).

RESULTS AND DISCUSSION

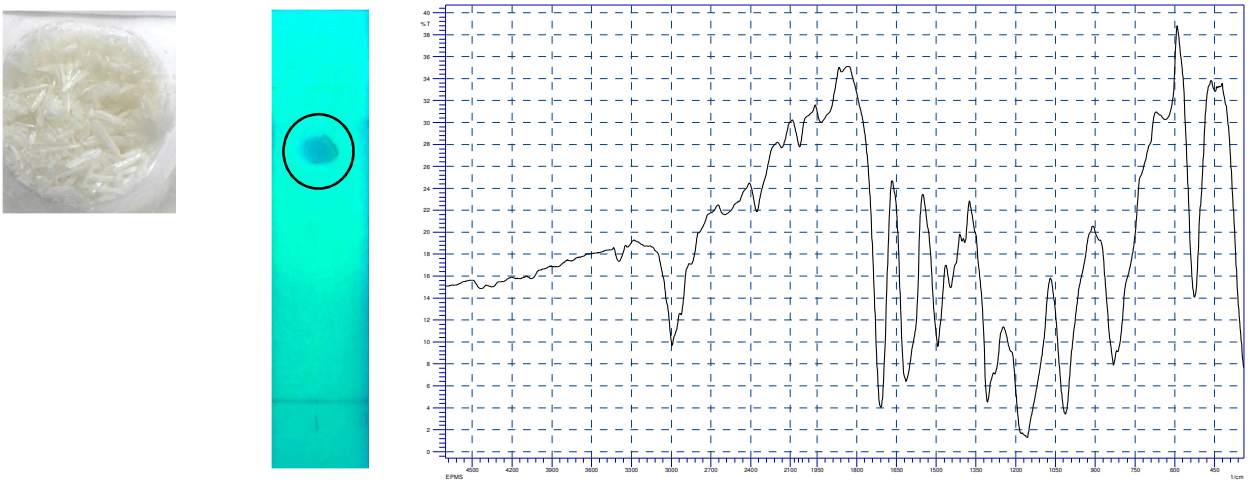
Extraction EPMC from *Kaempferia galanga L. rhizome*

Identification and characterization of EPMC are shown in Fig.-1. Visually, the crystal of EPMC (Fig.-1a) is white color, long crystalline form, and smells typical of *Kaempferia galanga* L. The melting point of EPMC is 47.7 – 48°C.[3] The yield of EPMC was obtained at 29.76 %. Figure-1b shows that only one spot was observed in TLC using n-hexane: ethyl acetate (7.5:2.5) with Rf value is 0.71.[3] It indicates that only one compound in the result of extraction. The EPMC compound was confirmed by data on IR spectral transmission bands of that presented in Fig.-1c. The IR spectra are interpreted by observing the following banding patterns: stretching bands at 3007-3045 cm^{-1} indicate the presence of aromatic C-H groups. The peak between 2979-2842 cm^{-1} and 1629-1573 cm^{-1} also show the aromatic C-H aliphatic and C=C groups, respectively. A peak of the para-substituted aromatic is observed around 829 cm^{-1}. A peak on the 1704 cm^{-1} is specific for carbonyl group and between 1367-1321 cm^{-1} showed C-O groups.

Synthesis of OPMC by Esterification Method

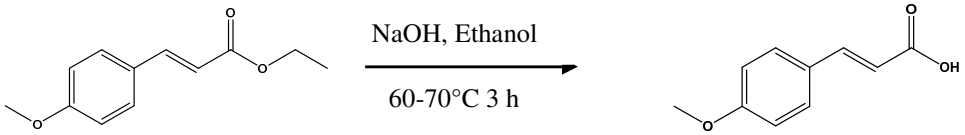
In this method, EPMC was hydrolyzed into 4-methoxycinnamic acid (4-MCA) using NaOH as a base catalysis and ethanol as a solvent. Hydrolysis reaction was initiated by protonation on carbonyl group. This protonation causes polarization on carbonyl group and makes this group more electrophilic and nucleophilic group will attach to the group.[16] The hydrolysis schematic of EPMC is shown in Fig.-2. The white crystal of 4-MCA was obtained after recrystallization with yield 72% (Fig.-3a). The 4-MCA compound was confirmed by TLC and IR spectra (Fig.-3b and 3c). The TLC analysis indicates that the hydrolysis process

of EPMC is done and 4-MCA was formed. It is marked by that only one spot in TLC. The characterization of IR spectra is observed the following banding patterns, stretching bands at 3100-3200 cm^{-1} specific for O-H bond in the carboxylic group. The peak between 2979-2842 cm^{-1} and 1590 cm^{-1} also show the aromatic C-H aliphatic and C=C groups, respectively. A peak of the para-substituted aromatic is observed around 840 cm^{-1}. A peak on the 1680 cm^{-1} is specific for carbonyl group.



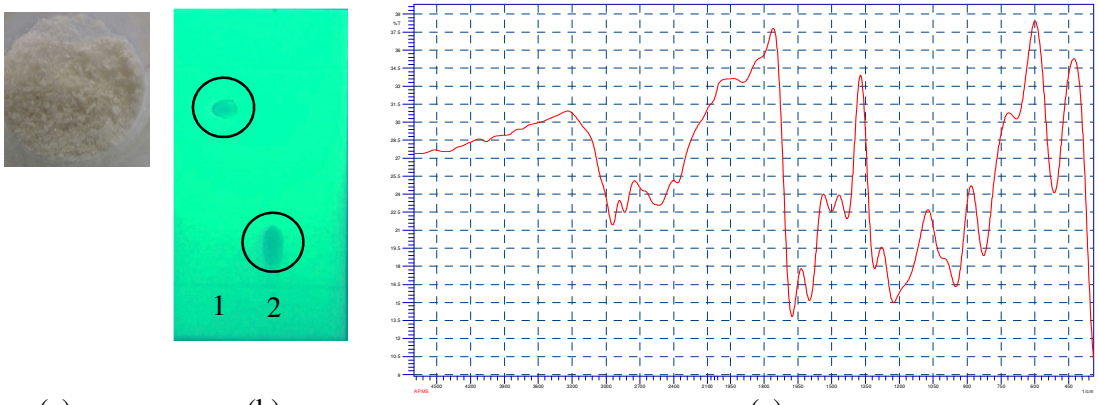
(a) (b) (c)

Fig.-1: Identification of Ethyl p-methoxycinnamate (EPMC). (a) The crystal of EPMC. (b) Chromatogram of crystal of ethyl p-methoxycinnamate (EPMC) using n-hexane:ethyl acetate (7.5:2.5) as eluent under UV 254 nm. (c) Infrared spectra of the EPMC.



ethyl p-methoxycinnamate (EPMC) 4-methoxycinnamic acid

Fig.-2: Hydrolysis of ethyl p-methoxycinnamate (EPMC) to 4-methoxycinnamic acid (4-MCA)

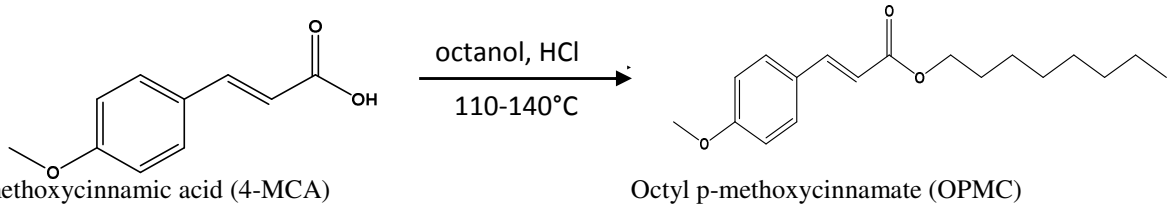


(a) (b) (c)

Fig.-3: Identification of 4-methoxycinnamic acid (4-MCA). (a) The crystal of 4-MCA. (b) Chromatogram of crystal of 4-MCA [2] and EPMC [1] using n-hexane:ethyl acetate (7.5:2.5) as eluent under UV 254 nm. (c) Infrared spectra of the 4-MCA.

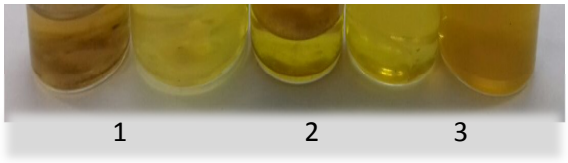
Synthesis of OPMC by esterification method is reacting 4-MCA as a carboxylic acid compound with octanol in acid catalysis (Fig.-4). The mixture of the compound was refluxed in different reaction time. Heating is an important process in an esterification reaction to increase the reaction rate and improve the yield. The each of OPMC in different reaction time (2, 3, 4, 5, and 6 hours) was identification and

characterization. Visually, the OPMC is a yellow viscous liquid (Fig.-5a). To ensure the OPMC was formed, TLC analysis was observed compared to the OPMC standard. As shown in Fig.-5b, the spot of OPMC synthesis in 3 hours give the similar Rf value with the OPMC standard. This is also confirmed by similar IR spectra as shown in Table-1. Identification by Mass spectrometry show that OPMS has a fragmentation in 290 $(M)^+$; 178 $(M - CH2{=}C_6H_{13})^+$; 161 $(M - O\text{-}Octyl)^+$; 133 $(M - COO\text{-}Octyl)^+$; 77 $(C_6H_5^+ + H^+)$. This indicates that OPMC was formed.

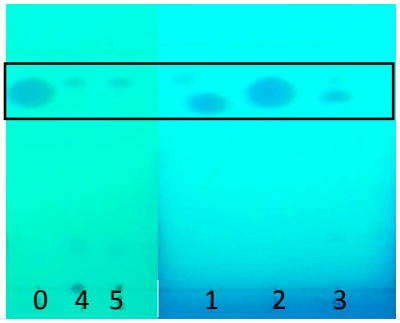


4-methoxycinnamic acid (4-MCA) Octyl p-methoxycinnamate (OPMC)

Fig.-4: Synthesis of Octyl p-methoxycinnamate (OPMC)



(a)



(b)

Fig.-5: Identification of Octyl p-methoxycinnamate (OPMC) by esterification method. (a) The yellow viscous liquid of OPMC. (b) Chromatogram of OPMC standard (0) and OPMC on different time reaction of synthesis using n-hexan:ethyl acetate (7.5:2.5) as eluent under UV 254 nm.
[0] OPMC standard, Rf 0.82; [1] 2 h, Rf 0.81; [2] 3 h, Rf 0.82; [3] 4 h, Rf 0.84; [4] 5 h, Rf 0.85; [5] 6 h, Rf 0.86.

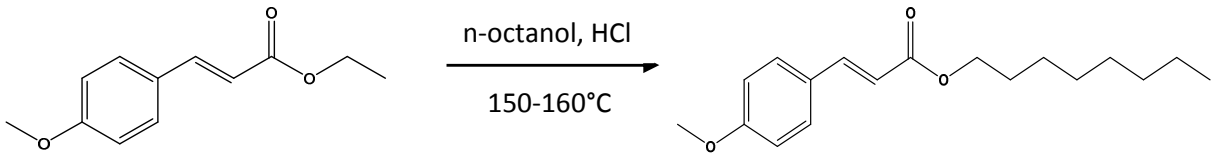
Table-1: IR Spectra Transmission Bands of OPMC by Esterification Method

Reaction time (hours)	Groups/IR band (cm^{-1})						
	C-H aryl	C-H aliphatic	C=O	C=C aryl	C-O	C-O aryl	Para position in aromatic
OPMC Standard	3007-3045	2979-2824	1710	1620	1340	1290	840
2	3000-3020	2910-3000	1680	1560	1350	1200	810
3	3000-3020	2900-3000	1710	1590	1380	1200	800
4	3000-3030	2980-3000	1680	1530	1330	1180	790
5	3000-3010	2800-3000	1650	1470	1360	1170	750
6	3000-3020	2910-3000	1650	1500	1360	1050	750

Synthesis of OPMC by Transesterification Method

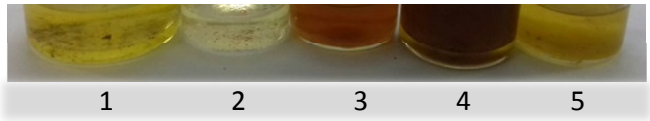
In the transesterification method, EPMC is directly reacting with octanol and HCl in different reaction time. Transesterification reaction is the ester formation reaction from another ester compound by exchange of alkoxy groups. Similar to the esterification method, this method needs catalysis to increase the reaction rate. The EPMC as an ester compound was reacted with octanol in acid catalysis in different reaction time (Fig.-6). The yellow viscous liquid of OPMC was Identification and characterization of OPMC by TLC and IR spectra as shown in Figure 7. TLC analysis in Figure 7(b) show that OPMS in 5 hours reaction has the nearest Rf value with the OPMC standard. The IR spectra also describe that OPMC in 5 hours reaction has the similar spectra with the OPMC standard. As shown in Table 2, the OPMC in 5 hours has the stretching

bands at 3000-3050 cm^{-1} show the C-H aryl. The peak between 2979-3000 cm^{-1} and 1610 cm^{-1} also show the aromatic C-H aliphatic and C=C aryl, respectively, and peak on 1680 cm^{-1} is specific for carbonyl group. Identification also confirmed by Mass spectrometry that shows the OPMC synthesis has a molecular weight of 290.

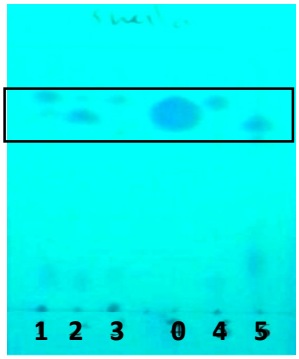


ethyl p-methoxycinnamate (EPMC) Octyl p-methoxycinnamate (OPMC)

Fig.-6: Synthesis of Octyl p-methoxycinnamate (OPMC) by a transesterification method



(a)



(b)

Fig.-7: Identification of Octyl p-methoxycinnamate (OPMC) by transesterification method. (a) The yellow viscous liquid of OPMC. (b) Chromatogram of OPMC standard (0) and OPMC on different time reaction of synthesis using n-hexan:ethyl acetate (7.5:2.5) as eluent under UV 254 nm.
[0] OPMC standard, Rf 0.82; [1] 2 h, Rf 0.84; [2] 3 h, Rf 0.81; [3] 4 h, Rf 0.84; [4] 5 h, Rf 0.83; [5] 6 h, Rf 0.81.

Table-2: IR Spectra Transmission Bands of OPMC by a Transesterification Method

Reaction time (hours)	Groups/IR band (cm^{-1})						
	C-H aryl	C-H aliphatic	C=O	C=C aryl	C-O	C-O aryl	Para position in aromatic
OPMC Standard	3007-3045	2979-2824	1710	1620	1340	1290	840
2	3000-3020	2910-3000	1680	1560	1350	1200	810
3	3000-3020	2900-3000	1650	1590	1380	1200	800
4	3000-3030	2980-3000	1680	1530	1330	1180	790
5	3000-3050	2980-3000	1710	1610	1350	1210	810
6	3000-3040	2910-3000	1650	1500	1360	1050	750

CONCLUSION

Octyl p-methoxycinnamate (OPMC) can be a synthesis in two ways, esterification and transesterification method. In the esterification method, EPMC must be hydrolyzed into 4-MCA then reacted with octanol. The optimum condition by esterification method is refluxed for 3 hours to get OPMC. In transesterification method just need one step reaction between EPMC and octanol with the optimum time reaction is 5 hours. This OPMC were characterized by TLC, FTIR and GC-MS. It has the similar Rf value with the standard that is 0.82 and has the similar spectra of FTIR. Identification by Mass spectrometry was confirmed that OPMC was formed with fragmentation in 290 $(M)^+$.

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