COMPUTER AIDED DESIGN OF MOLECULAR IMPRINTED POLYMER FOR SELECTIVE RECOGNITION OF CAPSAICIN

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ABSTRACT

Searching capsaicin-like molecule as an alternative dummy template has been conducted for the synthesis of Molecularly Imprinted Polymer (MIP) of capsaicin. Dummy template should be applied because synthesis of capsaicin practically has a problem due to its structure containing double bond at the aliphatic chains. Virtual searching was done using an online chemical database of ChemDB containing 5 million commercial molecules. Capsaicin structure was converted into SMILES code and then it was run on ChemDB with molecular similarity threshold of 0.5. There were 69 chemical structures obtained as the output and pseudocapsaicin was practically selected as the dummy template. Experimental result from the prediction evaluation showed that the use of capsaicin as template and pseudocapsaicin as dummy template produced MIPs that have separation factor of 1.28 and 1.25 respectively. It is suggested to choose pseudocapsaicin as dummy template for the synthesis MIP of capsaicin instead of using capsaicin molecule.

Keywords: *capsaicin; molecular imprinted polymer; chemical database; molecular similarity; dummy template*

ABSTRAK

Pencarian molekul serupa capsaicin sebagai templat pengganti telah dilakukan untuk sintesis polimer tercetak molekul (MIP) capsaicin. Templat dami harus digunakan mengingat sintesis capsaicin secara praktis memiliki masalah pada tahapan polimerisasi karena keberadaan ikatan rangkap pada rantai alifatisnya. Pencarian dilakukan secara maya berdasarkan analisis kemiripan molecular dengan menggunakan database ChemDB secara online yang memiliki 5 juta data senyawa komersial. Struktur capsaicin diubah menjadi kode SMILES kemudian dijalankan pada ambang nilai kemiripan sebesar 0,5. Terdapat 69 struktur kimia sebagai output dan pseudocapsaicin terpilih sebagai kandidat templat dami. Data eksperimen untuk evaluasi menunjukkan bahwa MIP yang disintesis dengan capsaicin sebagai templat dan pseudocapsaicin sebagai templat dami memiliki faktor pencetakkan masing-masing 1,28 dan 1,25. Hal ini menunjukkan bahwa pseudocapsaicin lebih cocok digunakan sebagai templat dami daripada capsaicin sendiri.

Kata Kunci: *capsaicin; polimer tercetak molekul; database kimia; keserupaan molekul; templat dami*

INTRODUCTION

Capsaicinoid compounds are chemicals responsible for the hot, spicy flavor presented by many varieties of chili and peppers. Nowadays, they are used in many products such as spicy food, pharmaceuticals or self-defense products. Consumption of capsaicinoid would cause side effect because its toxicity and effects on the nervous system [1]. Side effect of capsaicinoids compounds can give elicits intense physiological responses that include coughing and gagging, disorientation, erythema, lacrimation, temporary blindness, and intense pain [2]. Therefore, it is important to establish a selective and practicable technique for fast detection of capsaicinoid because of the increasing demand by consumers for capsaicinoid products.

Present methods for analysis capsaicinoid are gas chromatography [3], reversed-phase high-performance liquid chromatography (HPLC) [4], micellar electrokinetic chromatography (MEKC) [5], HPLC coupled with mass spectrometry [6], and capillary electrophoresis [7]. However, all these methods, sometimes give several problems such as detection limits, very laborious, lengthy analysis, expensive or the requirement of tedious pretreatment. Therefore rapid and low cost analysis is needed to

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determine capsaicinoid with easy, rapid and sensitive procedure. Nowadays sensitive determination of capsaicin using Quartz Crystal Microbalance (QCM) has been a popular method. This technique is very sensitive and capable of sensing a change of mass within the nanogram of the sample. It has been applied in many areas such as analysis of glucose [8], 8-hydroxy-2-deoxyguanosine [9], lysozyme [10], etc. QCM utilizes the piezoelectric properties of quartz crystals to measure changes in the attached surface mass [11] and usually based on a sensor that can be developed by immobilizing a novel material selective to the template. This selective material that has had much attention is Molecular Imprinted Polymer (MIP).

MIP can mimic the behavior (in terms of binding) of naturally occurring receptor sites to recognize a target compound specifically [12]. MIP is synthesized by polymerization of monomer, crosslinker, initiator and a suitable template with some common procedures. A template molecules is needed to prepare MIP by interaction with the polymer network via ionic, covalent or hydrogen bonding interactions. Then the template is removed after polymerization resulting in the polymer with cavity that has the ability to recognize the template with a high degree of selectivity. To produce MIP of capsaicin, we should apply capsaicin in a system of pre-complexation between capsaicin, monomer, crosslinker and solvent, then adding by radical donor agent to initiate polymerization [11]. However, in the aliphatic chain of capsaicin structure (Fig. 1), there is a double bond similar to the structure of common monomers or crosslinkers. Consequently, it may be attacked by initiator agents into radical species similar to monomer and crosslinker molecules [12]. Therefore capsaicin is normally bound covalently to the polymer structure and it would not be easily released from the structure of polymer. The tailored process is not successful using this process and the obtained MIP has no selectivity and specificity towards capsaicin. For this reason, it is urgent to find an alternative molecule as the dummy template to prepare selective and sensitive MIP for capsaicin.

Dummy template is very useful to act as a real template. Several papers have reported the use of dummy template for the synthesis of MIP, although some results are good [14-16] but many others give low binding of MIP to the target [17-18]. Searching for dummy template can be determined directly using the analogue molecules, but it is not effective. Ideally dummy template should have similar physical and chemical properties as target. In this case, we may apply a systematic analysis namely molecular similarity technique which is commonly utilized in drug design methodology [19-20]. Using this technique, many success stories in finding new drugs have been achieved using combination of molecular similarity and Quantitative Structure-Activity Relationships (QSAR) [21-23]. Molecular similarity is searched from the database and based on molecular weight, structural, steric, liphophilicity and electronic properties. Development of molecular similarity, especially for drug design areas, has been discussed intensively in several publications [24-27]. ChemDB application, which is an online tool supported with large commercial chemical database, has been commonly used for molecular similarity analysis in drugs design area [28]. Here we have tried this tool in MIP area. This method actually has been successfully applied to find a dummy template for sinensetin that has problem to supply the stock due to limited availability and very expensive [29]. This paper reports a study of the use of ChemDB tool for molecular similarity analysis of capsaicin to find a suitable dummy template in MIP applications. Confirmation of this selection is proven by experimental synthesis of the MIP using capsaicin and dummy template obtained from molecular similarity analysis.

EXPERIMENTAL SECTION

Materials

The chemicals used in this study were capsaicin, methacrylic acid, ethylene glycol dimethacrylate and benzoyl peroxide purchased from Fluka. Other chemicals were pseudocapsaicin (Sigma), acetonitrile (Fischer), acetic acid and methanol (Merck). All the chemicals were of analytical grade and used as received. Nitrogen gas was purchased from local supplier.

Instrumentation

ChemDB was used to analyse molecular similarity analysis by accessing online on the website: http://cdb.ics.uci.edu/cgibin/ChemicalSearchWeb.psp. Several apparatus used in the synthesis of MIP were mortar grinder, sieve shaker, water bath, soxhlet extraction apparatus and others. Confirmations of the binding of template in MIP were monitored using Hitachi U-2000 UV-Vis Spectrophotometer.

Methods

Selection of dummy template

The procedure of selection was simplified as follows using input files based on SMILES code (Simplified Molecular Input Files Entry String) of capsaicin. SMILES code of capsaicin is c1c(OC)c(O)ccc1CNC(=O)CCCCC=CC(C)C. Similarity option was set with similarity score threshold of 0.5. We used four parameters to cut off molecular similarity

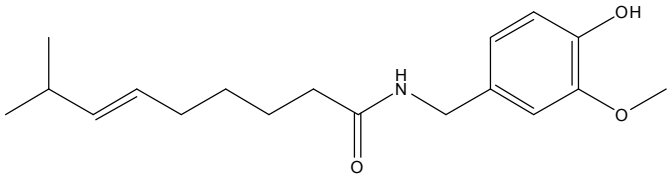


Fig 1. Structure of capsaicin

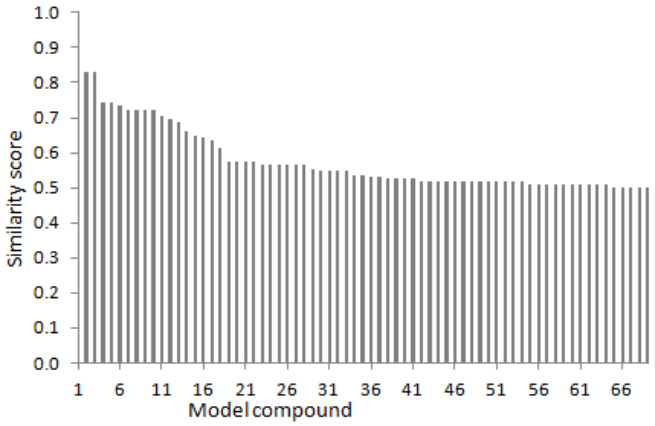


Fig 2. The value of similarity score generated by ChemDB associated to capsaicin molecule

including molecular weight (MW), number of rotatable bonds, number of hydrogen donor atoms and calculated log P (XlogP). The two first parameters represented steric descriptors, the third was assumed to represent electronic descriptor and the last represented liphophilic descriptor.

By running the input file, then ChemDB tool started to search the target from the database available in the server by exploring of approximately 5 millions commercially available molecules from the electronic catalogs of over 150 chemical vendors. The output of the analysis was a display of the molecular sketch together with the values of the four parameters that has been selected in the order of the similarity score.

Synthesis and binding testing of MIP

The MIPs were synthesized based on a procedure reported by Tan et al. [31] with little modification. Two different MIPs were synthesized using the template of capsaicin as a real template and other selected capsaicinoid as dummy template. Template compound of 0.1 mmol was placed into glass tubes filled with 5 mL of acetonitrile and then methacrylic acid (2 mmol), ethylene glycol dimethacrylate (10 mmol), benzoyl peroxide (10 mg) were added. The mixtures were shaken for homogeneity and purged with N_2 for 15 min to remove oxygen so that it would not inhibit the polymerization process. Then, the tubes was sealed and kept in a thermostat bath at 60–70 °C for 8 h. After the polymerization, a white bulk polymer was obtained. The resulting polymer was ground using mortar grinder. In order to remove the template from polymer matrix, the polymer was washed, first using mixture of methanol-acetic acid (9:1 v/v) for 3 h and then with acetonitrile for another 1 h. The solvent was separated from the washed polymers by filtration. The procedure was repeated for five times. Fine particles remained were collected and dried to constant weight.

In order to verify that binding of analytes was due to molecular recognition and not due to non-specific binding, control polymer was prepared. The third polymer was made by similar procedure with the absence of template and this polymer was termed as Non Imprinted Polymer (NIP).

Binding capacities of the polymers were determined via batch adsorption studies. Dried polymer 50 mg was added to 50 mL capsaicin solution in acetonitrile so that the concentration of the solution was 100 mg/L. The solution was stirred slowly for 4 h at a room temperature and then the solution was filtered. Concentration of capsaicin in initial and final solutions was determined by using UV-Spectrophotometer at 280 nm.

Batch binding analysis was conducted to evaluate properties of synthesized polymers. The polymer particles (50 mg) were placed in a screw cap test tube and mixed with 3 mL known concentration of capsaicin solution. The test tube was shaken at a room temperature using orbital shaker. After 24 h, the mixture was filtrated and the final concentration of capsaicin in solution was checked using UV-Spectrophotometer at 280 nm. The amount of capsaicin bound to polymer (Q) was calculated using Eq. (1).

$$Q(mg_{capsaicin} / g_{MIP}) = \frac{V_s(C_i - C_f)}{m_{MIP}} \quad (1)$$

where V_s, m_{MIP}, C_i and C_f represent the volume of test solution (mL), mass of dried polymer (g), initial capsaicin solution concentration (mg/mL) and final capsaicin solution concentration at equilibrium, respectively. Imprinting Factor (IF) was determined by Eq. (2).

$$IF = \frac{Q_{MIP}}{Q_{NIP}} \quad (2)$$

where Q_{MIP} and Q_{NIP} are total binding amount of capsaicin in MIP and NIP, respectively. For each polymer, binding experiment was carried out and repeated for three times.

RESULT AND DISCUSSION

In the process of MIP synthesis, the role of template molecules is very important because it is expected to produce the imprinted pores in the polymer. It has been reported in almost all publications

Table 1. The range value of the descriptors resulted from ChemDB associated to capsaicin structure

Criteria	MW	Rotatable Bonds	H-Bond Donors	XLogP
Minimum value	221.3	4	1	0.35
Maximum value	705.3	31	4	9.70
Average	348.2	12.1	2.2	4.44
Capsaicin (target)	305.4	10	2	4.58

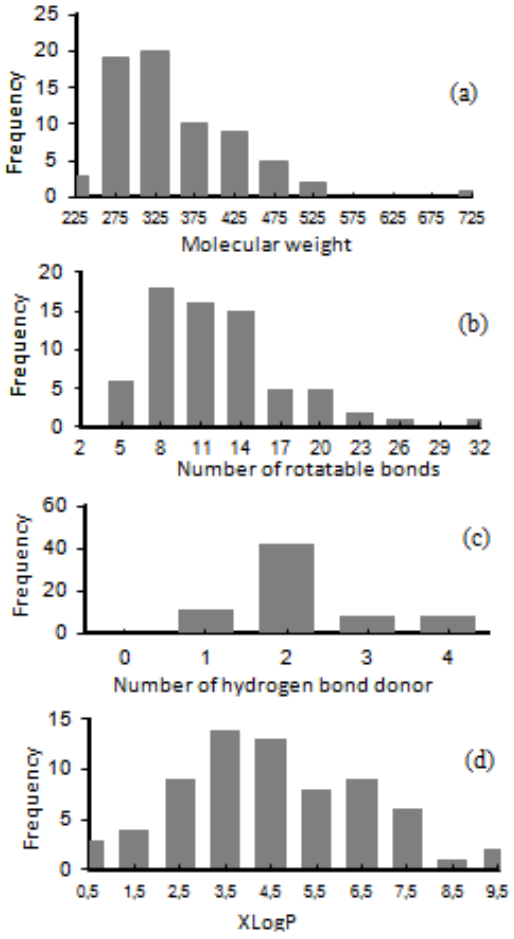


Fig 3. Histogram of descriptors used for molecular similarity analysis

of MIP that the imprinted pores gave significant differences in size and shape properties between MIP and NIP as control polymer [12]. Therefore, the availability of a template should be a must or a suitable dummy template should be selected similarly. In the case of capsaicin template where theoretically its structure is possible to induce problem during polymerization, capsaicin should be changed with other similar molecules to act as the template. Finding dummy template of capsaicin is very challenge and here we report the computer aided process for selecting a suitable dummy template of capsaicin based on molecular similarity using ChemDB tool.

Molecular Similarity Analysis

Molecular similarity analysis of capsaicin on ChemDB is relatively simple but very important step. After running the input file using SMILES code of capsaicin, the result that immediately can be obtained shows a list of 69 molecular models that are similar to capsaicin and can be selected as dummy template.

In Fig. 2, we can see the value of similarity score of the molecular models resulted by ChemDB. When the threshold of similarity score is set at 0.5, sixty nine molecular models have the score that meet the criteria. Similarity score closed to 1 indicates that the model is very much similar to capsaicin. The less value of similarity score gives rise to the less association molecularly. Close examination of Fig. 2 reveals that actually there are several pairs of molecular models giving same values of similarity score. These molecular models are mostly the isomer form of each other.

In our analysis, we used four descriptors selected to resemble capsaicin molecularly. They are molecular weight (MW), number of rotatable bonds (Rotatable Bonds), number of hydrogen donor atoms (H-Bond Donors) and calculated log P (XlogP). Table 1 summarizes the range of the descriptor values for 69 model compounds resulted from ChemDB associated to capsaicin structure. The value of each descriptor for the target molecule (capsaicin) is also given in Table 1 for the purpose of comparison. The histograms of each descriptor are given in Fig. 3.

MW is a steric parameter that represents the size and atomic variety available in the structure [19]. The higher value of MW relates to the more complex of a molecular structure or a structure that contains atoms with high value of atomic weight. The data showed that a range value of MW is large from 221.30 up to 705.03. MW of capsaicin itself is 348.21 and it relates that the most models also have MW close to this value in the range of 300-350 (Fig. 3(a)). However MW data could not be used as single descriptor because it gives a bias prediction especially for molecules containing heavy atoms like halogen in the aliphatic sites. Selection of model as dummy templates of capsaicin with higher MW value tends to produce MIP with low selectivity to capsaicin and thus it has less imprinting efficiency [31]

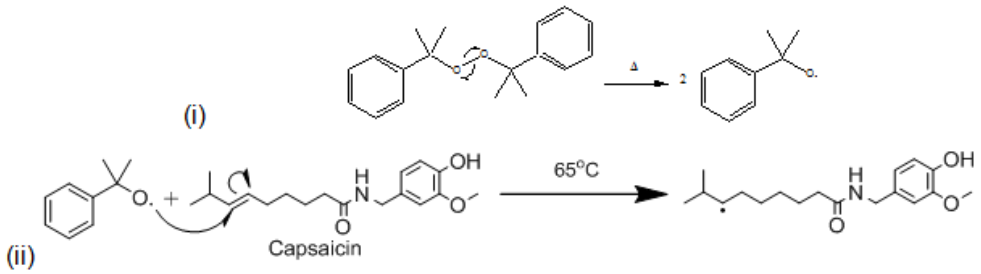


Fig 4. Mechanism of the reaction of capsaicin with monomer/crosslinker (i) Radical formation was initiated by benzoyl chloride (ii) Capsaicin is reacted into radical species

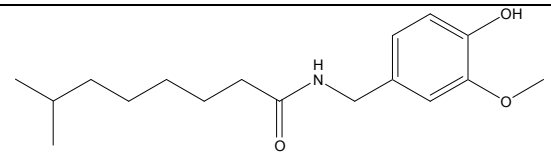
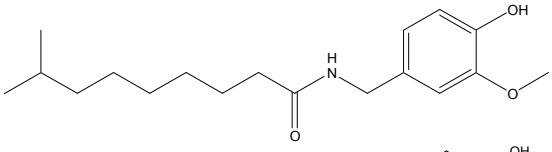
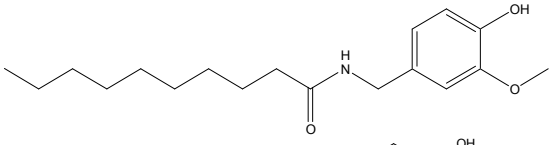
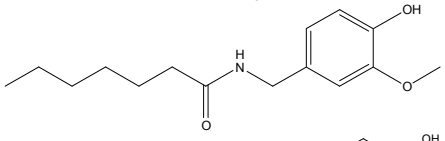
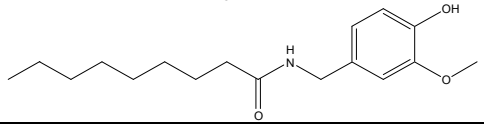
From the output of analysis, there are several models containing halogen atoms, i.e no 22 (chlorine) and 56 (bromine). Although very similar to capsaicin, model no 29 also can give bias data because it contains S atom to replace O atom in capsaicin. The orbital of S atom is different from that of O atom, therefore it generates different effect especially in the size of the MIP's pores and the orientation of pore related to the geometrical structure of aliphatic chain. MW data could also gives rise to bias data especially those containing cyclic site bounded to the aliphatic site such as model no 30, 31, 32, 37, 39, 61 and 68. The existence of cyclic site makes a larger pore size during polymerization. In fact, capsaicin has an aliphatic side chains, therefore the use of molecular model using cyclic chain may result in different size of the pore in the obtained MIP. The application of larger atom and cyclic chain in dummy template causes the resulted MIP which has lower efficiency and selectivity to the capsaicin.

Number of rotatable bonds also represents a steric descriptor and it shows a quantity of non cyclic single bond available in the structure of molecules [19]. Fig. 3(b) shows that the magnitude of descriptors with higher frequency lies between 7 and 12. This value strongly relates to the number of rotatable bond on capsaicin e.g. 10. As can be seen in Fig.1, capsaicin structure contains several rotatable bonds in the side chain of capsaicinoid. The availability of double bond in the aliphatic chain of the compounds should be avoided because it can be attacked by initiator agents during earlier polymerization steps [12]. Therefore, the role of this descriptor is very important as guidance in the selection of the model because changing a double bond into a single bond results in the increase of one rotatable bond from 10 to 11.

The number of hydrogen donor atom represents the availability of functional sites in the molecule, especially the sites with high possibilities to give difference electronegativity between two poles [19]. Examples of these functional sites are hydroxyl groups, amine, carboxylic acid, etc. In our study, the value of the descriptor is influenced mainly by hydroxyl sites as can be seen from 69 models which contain mainly amine and hydroxyl sites. Fig. 3(c) shows a distribution of model related to the number of hydrogen donor atom. Almost of the models have two hydrogen donor atoms. It can be understood easily if we see the structure of capsaicin (Fig. 1) on the hydrophilic site that gives contribution to this descriptor [3]. Amine contributes one hydrogen donor atom because it is always available in the side chain of capsaicinoid compounds. The other contribution comes from the hydroxyl sites available on phenyl ring or in the top of alkyl chain. If the number of hydrogen donor atom is zero, it means that the model does not contain hydroxyl sites. But in capsaicinoid compounds it is not the case because the compounds always contain amine sites and contribute one value to this descriptor. The majority of proposed models contains two hydrogen donor atoms. They are 42 models with such criteria and are assumed that their structure contains one amine site and one hydroxyl site.

XlogP descriptor represents liphophylicity parameters [19]. This descriptor is very useful to measure similarity with regard to the application in MIP synthesis especially for selection of the porogenic solvent. From the result (Table 1), XlogP for 69 models are varied from 0.35 to 9.70 with the average value of 4.44. From Fig. 3(d), it can be seen that the XlogP distribution is mainly on 3-5 and it indicates that the models with this value may have relatively non polar property [32]. Therefore in the synthesis of MIP using this model compound as a dummy template, it can be done using non polar solvent like hexane, benzene, carbon tetrachloride or others. Actually the usage of these non polar solvents with large size molecular volume is disadvantageous because it gives effect on the change in pore size. Therefore selection of semi polar solvent like tetrahydrofuran is preferable. Moreover, additional treatment during solvation of the template, for example, by additional process such as heating or sonification treatment is also advisable.

Table 2. Dummy template model for capsaicin resulted from ChemDB analysis

Similarity score	Structure	IUPAC, systematic and common name	Compound code
0.830		7-Methyl-octanoic acid-4hydroxy-3-methoxy benzylamide 7-Methyl-N-vanillyl-octamide Nordihydrocapsaicin	2
0.830		8-Methyl-nonanoic acid-4hydroxy-3-methoxy benzylamide 8-Methyl-N-vanillyl-nonamide Dihydrocapsaicin	3
0.720		Decanoic acid-4hydroxy-3-methoxy-benzylamide N-vanillyl-decamide	8
0.720		Heptanoic acid-4hydroxy-3-methoxy benzylamide N-vanillyl-heptamide	9
0.720		Nonanoic acid-4hydroxy-3-methoxy benzylamide Pseudocapsaicin	10

Selection of Dummy Template

The models resulted from ChemDB analysis of dummy template for capsaicin actually still contains double bond in the aliphatic chain similar to capsaicin, so they are not suitable to be chosen as template. Fig. 4 shows a mechanism explaining that the reaction of capsaicin with monomer/crosslinker into capsaicin radical will be affected by initiator [12]. The radical species then react easily with monomer/crosslinker molecules during propagation step of polymerization reaction, therefore the template will bind covalently in the polymer structure.

From 69 models, 31 models that contain double bond was removed out because they react with initiator during polymerization and bound covalently in the structure of polymer. Availability of the double bonds in capsaicinoid models resulted by ChemDB are characteristically found in two parts of the molecule, i.e. one is in aliphatic section and the other is in the amide section. The rest of the models are compounds with aliphatic chain existing as single bond. Quantitatively this single bond has been represented by rotatable bond descriptors which has higher value compared to those with double bond.

Selection of model as dummy template for capsaicin was then continued by exclusion of the structures containing more than one cyclic part. Capsaicin has only one cyclic vanilly ring chain. However ChemDB has suggested several models with more than one cyclic chain. They exist as an aliphatic ring or aromatic ring bound to liphophylic site of capsaicinoid. From 69 models, we could exclude 21 models that do not follow these criteria.

Selection for the rest of the model becomes easier and it was done based on the value of the similarity score as well as the structure of aliphatic chain. We now have 5 models i.e. no 2, 3, 8, 9 and 10 which are relatively good for dummy templates of capsaicin. Similarity score of the first two models is high i.e. 0.830 and for the last three models is 0.720. The five selected models are given in Table 2 along with their IUPAC and common names of each structure.

Based on the final selected dummy template obtained from the analysis, we have synthesized and evaluated two kinds of MIPs prepared using capsaicin as template and pseudocapsaicin as dummy template. Evaluation of the binding performance for both MIPs have proven our theory that capsaicin is not suitable to be used as template. The possible mechanisms to represents MIP synthesis using capsaicin (a) and pseudocapsaicin (b) are given in Fig. 5. It clearly shows that the preparation using pseudocapsaicin as a dummy template finally gives a cavity in the polymer (Fig. 5(b)) by releasing the template from the polymer because the template molecule is bound via weak interaction of hydrogen bond (non covalent bond). In

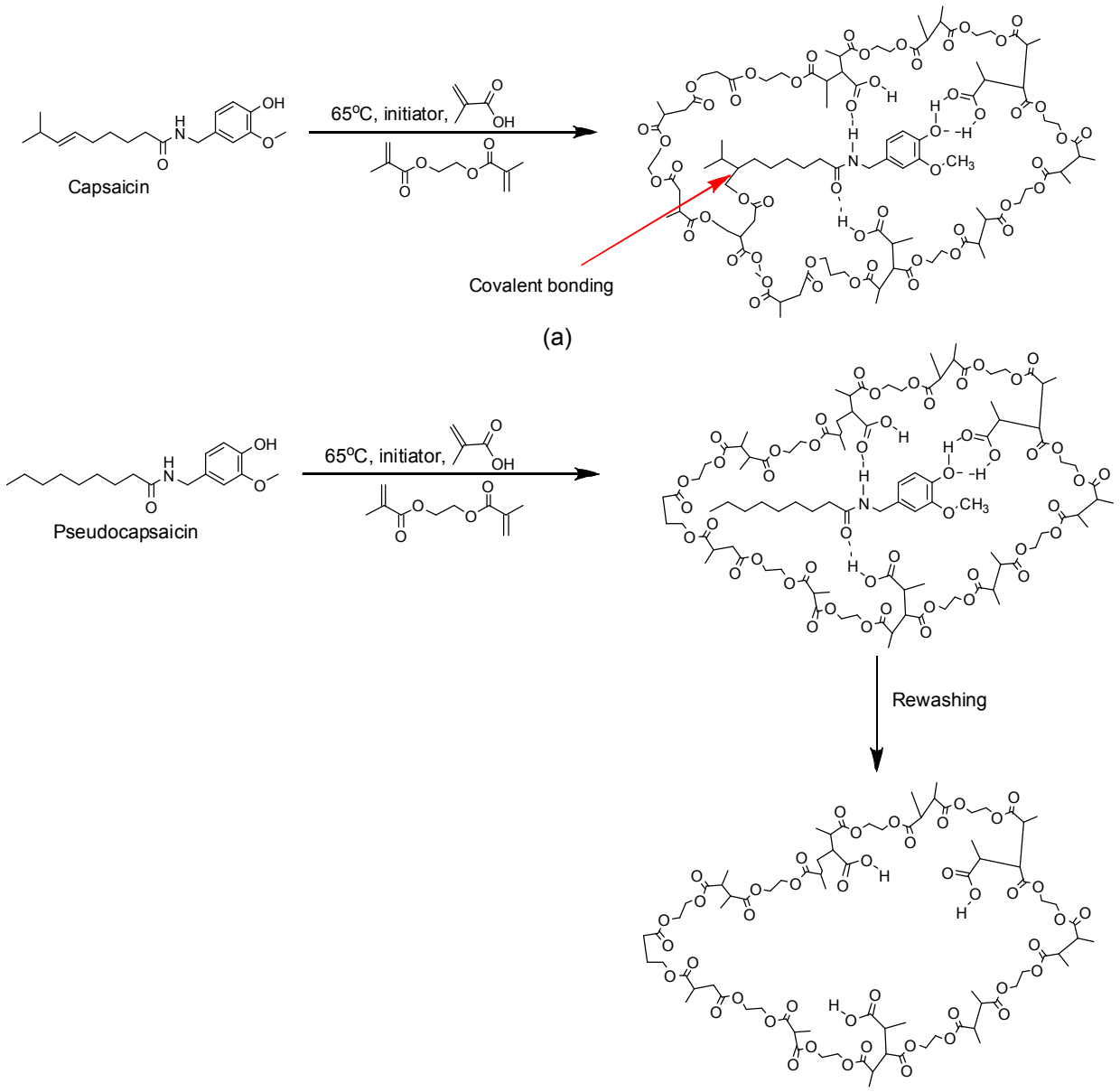


Fig 5. Scheme of the polymerization step using (a) capsaicin as template and (b) pseudocapsaicin as dummy template

Table 3. Total amount of capsaicin bound to polymer (Q) and imprinting factor (IF) of the MIP

Polymer	Q_{MIP} (mg/g)	Q_{NIP} (mg/g)	IF = Q_{MIP}/Q_{NIP}
MIP_{cap}	0.466 ± 0.003	0.372 ± 0.040	1.25
MIP_{pc}	0.475 ± 0.003		1.28

contrast, Fig. 5(a) illustrates a different effect on the polymer structure if capsaicin is used as template. Capsaicin is bound covalently to the structure of polymer and therefore it needs high energy to break the bond, consequently it is not easy to release template molecule from the polymer. As a result, there is no cavity obtained by molecular imprinting.

Synthesis and Batch Binding Analysis of MIP

Batch binding analysis in this experiment was performed to evaluate the recognition ability and capability of the prepared polymers synthesized using real template (MIP_{cap}) and dummy template (MIP_{pc}).

Table 3 shows the binding capacities for the two MIPs compared to that of NIP.

Table 3 gives the binding amount (Q) for all MIP. It is clearly showing that the Q values for MIP synthesized using capsaicin is smaller than the Q for MIP synthesized using pseudocapsaicin as dummy template. This indicates that MIP_{pc} has higher binding affinity towards capsaicin compared to MIP_{cap}. This may be due to higher number of cavity that can be formed if dummy template is used during polymerization.

The IF value is almost similar because it is only modified parameter of binding quality value of MIP resulted by similar procedure of the synthesis. The IF value for MIP is ideally greater than 1 and here we confirm that both MIPs have IF value > 1. Although NIP is made by polymerization without template, but the binding test shows that it has ability to adsorb capsaicin. Actually, NIP polymer also has pore and active surface that contains active site resulted by monomer. However the form and size of the pores in NIP is also relatively different from those of MIP. The form of pore in MIP is relatively uniform/regular and resemble to the form of molecular structure of the template, while in NIP it is not. During polymerization, template is trapped in the polymer structure via non covalent interaction, after washing process, the template then be released out and created molecular cavity in the polymer. Therefore Q value for MIP is always larger than Q value for NIP or IF value is always greater than 1.

Comparison between the IF value suggests that IF of MIP_{pc} is relatively greater than that of MIP_{cap}. This is probably due to the fact that capsaicin has been bound strongly via covalent bond to the structure of polymer. The slightly different effect shown in MIP_{pc}, may be due to fact that pseudocapsaicin is only trapped via non covalent interaction in the structure of polymer. So during the washing process some are released out leaving a template cavity, whereas capsaicin is more difficult to release because it is covalently bound to polymer. Fig 4 shows different mechanism of MIP's formation between the use of capsaicin as template and pseudocapsaicin as dummy template. From the above explanation we may suggest that synthesis of MIP for capsaicin is more preferable to use dummy template such as pseudocapsaicin rather than using capsaicin itself.

Furthermore, the similar work has been reported by Sun et al. [12] about MIP for capsaicin. They reported several treatment and optimized using design of experiment (DoE) technique with $L_9(3^4)$ orthogonal test. Using capsaicin as template, they reported that MIP has the apparent absorbent of capsaicin that is varied from 12.56 until 28.26 mg/g. As the control they synthesized NIP, i.e. polymer prepared using the same procedure but without template, by using this NIP, its apparent absorbent is 9.40 mg/g. This indicates that imprinting factor value of the MIP using capsaicin as the template is in the range of 1.3 to 3 [12]. However, we do not have enough information from his work to compare with those of pseudocapsaicin as dummy template. Nevertheless, similar to our result that the sorption of capsaicin is observed on both MIPs and NIP. Therefore, we assumed that the sorption of capsaicin in the polymers occurs in the micropores and mesopores rather than in the cavity produced by molecular imprinting process.

For the application of MIP for capsaicin in sensing material on QCM, we also suggest to use pseudocapsaicin as dummy template. Thin film of MIP can be coated before polymerization initiate by photon radiation or thermal aided process. After releasing template, the thin film of MIP will have recognizing cavity site that is selective to capsaicin even though it has been actually tailored using pseudocapsaicin.

CONCLUSION

It has been demonstrated that pseudocapsaicin can be selected as a dummy template for capsaicin during the synthesis process of molecular imprinted polymer (MIP) for sensing materials using QCM application. From the binding test result, it has been observed that MIP prepared using dummy template is able to give higher binding affinity toward capsaicin rather than MIP produced using capsaicin molecule as template. Therefore, for the MIP of capsaicin, it is suggested to use pseudocapsaicin as a template during polymerization rather than using capsaicin molecule.

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