

Determination of critical micelle concentration (CMC) of oleyl mannoside

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Abstract— The critical micelle concentration (CMC) of nonionic surfactant, oleyl mannoside, ManC18:1 was determined by surface tension method. This surfactant with oleyl alkyl chains and sugar-based head groups was prepared in various concentration. The result is then compared with the series of nonionic surfactants n-alkyl α -D-mannopyranosides (C_nMan) with different alkyl chain length (n = 6, 7, 8, 9, 10, 12, 14) have been prepared by the Zhang et. al. The hydrophobic alkyl chain length affects their HLB number, water solubility and surface tension. The results showed that the increasing in alkyl chain length will decrease the surface tension, HLB number as well as the solubility in water. In addition, their emulsifying properties depended on the alkyl chain length and the corresponding oil/water system.

Keywords— alkyl glycoside, surface tension, HLB number, CMC, oleyl mannoside

I. INTRODUCTION

Surfactants are amphiphilic molecules possessing polar (hydrophilic) and nonpolar (hydrophobic) domains that make them important in technology as well as in academic purposes. Surfactants are widely used in biochemistry and pharmaceutical applications such as micellar catalysis of reactions, drug-delivery vehicles and so on. These applications of surfactants are due to their unique molecular assemblies called micelles [1]. Micelles are formed by the interaction between the hydrophilic parts and water molecules by reducing interactions of the hydrophobic part with water molecules [2]. The surfactant monomers will self-aggregate to form micelle when it reaches certain concentration. This concentration is called critical micelle concentration (CMC). The surfactants can be classified into four major types which are anionic, cationic, nonionic and zwitterionic or amphoteric surfactant based on their charges of their polar head groups. The hydrophobic groups can be different with one another due to their length, containing at least eight carbon atoms and can have unsaturated double or triple bonds [3].

Among these surfactants, nonionic surfactants are the most common type of surface active agent used in drug delivery system due to their stability, compatibility and

toxicity [4]. In addition, nonionic surfactants are more cheaper compared to other phospholipids and most of them are relatively non-toxic because these surfactants do not release ions into the surrounding fluid [5][6]. The used of nonionic surfactant as drug delivery vesicle is called niosome. Niosome is mainly composed by nonionic surfactant which is more advantageous compared to liposome thus overcoming the problems associated with liposomes [7]. The drugs will be entrapped in the bilayers of niosome that consist both hydrophilic at the inner and outer surfaces with sandwiched lipophilic area in between [7]. The drug will be transported and penetrated into the human cell. The penetration will be recognized by the cell which allow the vesicle drug penetrate into the cell. Therefore, the hydrophobic part plays important role as cell recognition in order to penetrate into the cell.

Among the nonionic surfactant, glycoside is one of the recent developments of drug delivery system that promising some benefits [5]. In this research, alkyl glycoside as simple glycolipid systems with alkyl chain as hydrophobic part and a hydrophilic sugar headgroup is used to investigate their phase behavior [8]. Alkyl glycosides derived from oleyl mannoside, ManC18:1 was synthesized. ManC18:1 is a biosurfactant that produced from living cell which contains 18 carbons unsaturated hydrocarbon chain and sugar-based head group. The head group which is mannoside is act as cell recognition in drug delivery system. The monomer will self-aggregate to form niosome. Thus, the presence of polymer micelle plays an important role in drug delivery system. The present of micelles can be determined through CMC as reported in most literatures [9].

The technique used to determine the CMC of ManC18:1 in this research was surface tension analysis. The experiment is then compared with the result obtained from the experiment of C_nMan which represent 1,2-trans n-alkyl α -D-mannopyranoside. As the concentration of surfactant increases, the surface tension decreases until constant reading achieved. The sharp changes in the graph of surface tension versus log concentration indicates the CMC value. Moreover, the research includes the determination of hydrophilic-lipophilic balance (HLB), solubility and the chain length. These parameters will affect the entrapment efficiency of drug [4] and also the surface tension of water.

II. METHODOLOGY

A. Materials

ManC 18:1 (pure and technical), distilled water, ethanol.

The pure and technical sample were synthesized by three steps; peracetylation, glycosylation and deacetylation [5]. The different between pure and technical samples is their glycosylation method. For technical sample, the glycosylation method is done to remove any impurities in the pure sample.

B. Methods

Preparation of stock solution

An aqueous solution of ManC18:1 was prepared by diluting 10 mg of ManC18:1 with distilled water. The desired concentrations were adjusted by mixing the stock solution with water in 25 mL volumetric flask. The sample then transferred to a vial for measurement of surface tension

Evaluation of surface tension

The surface tension of solution was determined using du Nouy ring method using KSV Sigma 702 tensiometer. Temperature was controlled with water circulating system. The results were the average of three measurements. The sample in glass container was placed inside a sample holder and let to equilibrate for 10 minutes until the desired temperature of sample was achieved. Before each measurement, the platinum ring was cleaned and heated with Bunsen burner. The CMC values were determined from the intersection of two linear graph of surface tension vs logarithms of surfactant concentration plots. The CMC values are expressed in mol/L.

III. RESULTS AND DISCUSSION

Evaluation of the surface tension of the surfactants

The surface tension of ManC18:1 solution was determined at 30°C and the relationship between surface tension vs concentration were shown in Fig. 1. However, the surface tension of pure ManC18:1 was not measured due to the low water solubility.

The technical sample of ManC18:1 is soluble in water compared to the pure one. The technical sample was produced by the removal of the surface-active impurities from the original solution. There are some undissolved particles of pure sample present when mix with water. In can be said that there might be some properties that enhance the solubility of the technical sample.

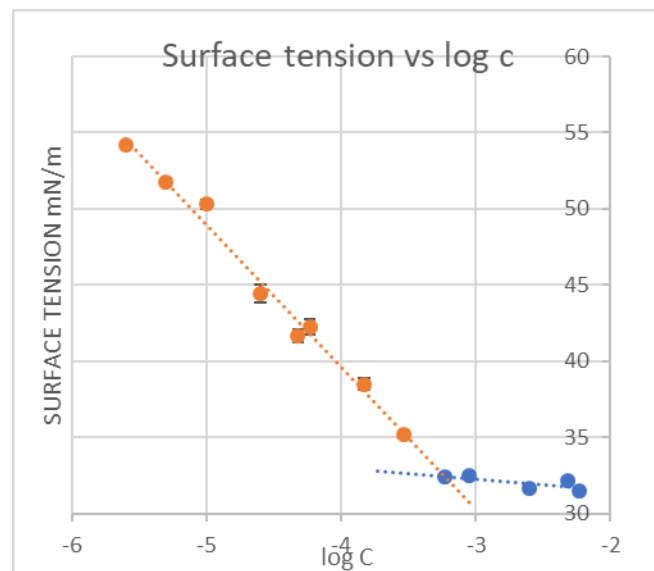


Figure 1 surface tension vs log concentration of ManC18:1 solution

From the graph, the CMC value obtained was 3.98×10^{-4} mol/L and γ_{CMC} was 32 mN/m at 30°C. This result is compared with the experiment conducted by Zhang et al. (2018) by using series of non ionic surfactants C_n Man with different alkyl chain length ($n = 6, 7, 8, 9$). The results were shown in schematic diagram in Fig.2 and summarized in Table 1. However, the other C_n Man was not studied due to extremely low water solubility and high Kraft temperature [10].

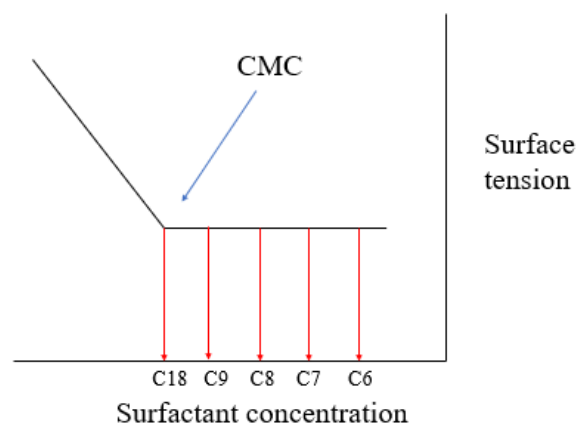


Figure 2 schematic diagram shows how the alkyl chain of the surfactants lower the CMC values.

Table 1: C_n Man at the air-aqueous solution interface at 25°C [10]

C_n Man	6	7	8	9	18
CMC (mol/L)	0.072	0.031	0.012	0.004	0.0004
γ_{CMC} (mN/m)	34.93	31.75	30.69	30.69	32.00

Both experiments showed that the surface tension of C_n Man solutions decreased when the concentration increased. At low concentration which is below the CMC, the surface tension decreases as the concentration of the surfactant increases until the CMC is obtained. At this point, the surface tension is at minimum and the surface becomes saturated with the monomers. The constant values of the surface tension indicate the formation of micelles [2]. According to Chakraborty et. al (2010), at low concentration, surfactant monomers obstruct intermolecular hydrogen forces between water molecules at the air/ solution interface. This decreases the interfacial tension (γ) gradually with increasing surfactant concentration till the air/solution interface becomes saturated with the surfactant molecules [1]. Beyond complete interfacial saturation, surfactants self-assemble to form micelles. The tensiometric profile thus decreases up to complete interfacial saturation and remains unaltered thereafter. Fig. 3 below shows the formation of micelles in water [11].

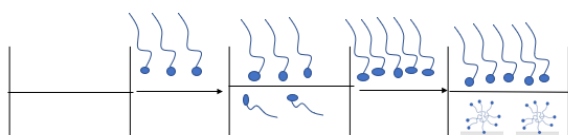


Figure 3 micelle formation

Furthermore, the alkyl chain length on the hydrophobic part influence the value of CMC. As the number of alkyl chain length increase, the values of CMC decrease as well as the surface tension. This result may be due to the attractive force occurred in the air-aqueous solution and air-aqueous interface [10]. The force presents in the air-aqueous solution between glycoside molecule and water molecules while the other force that occurred at the interface is between alkyl group and water molecules. Therefore, with increasing in alkyl chain length both forces increase in the solution and at the interface. Increasing in the surfactant chain length increased the interfacial area [12] since there were more hydrocarbon units requiring contact with the solution [13].

Hydrophilic-lipophilic balance (HLB) number

HLB system is used to determine the solubility and behavior of a surfactant. HLB number is one of the important elements in nonionic surfactants as they do not dissociate when dissolved in water [14]. Low HLB number indicates the lipophilic surfactant while high HLB number considered as hydrophilic surfactant. Hydrophilic surfactants which is soluble in water are good stabilizers for oil- in-water (o/w) emulsions. However, for lipophilic surfactants with low water solubility are good stabilizers for water-in-oil (w/o) emulsions [15]. Griffin's HLB number has been established and frequently used empirical parameter for the classification of nonionic surfactants. It was defined as [16]:

$$HLB = 20 \times M_h/M$$

M_h = molecular weight of the hydrophilic head group of the surfactant molecule

M = molecular mass of the complete molecule

From the equation below, the HLB number for ManC 18:1 is 9. Thus, according to the HLB ranges, this nonionic surfactant can be applied as oil-in-water emulsifier[16]. From the C_n Man experiment, the HLB number decreased gradually with the increase in the number of alkyl carbon numbers and tabulated in Table 2 and illustrated in Fig. 4 below.

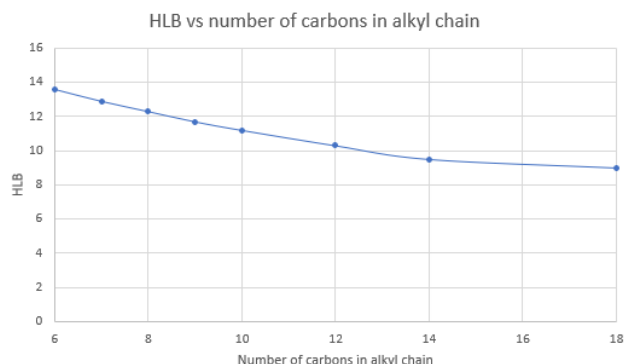


Figure 4 HLB vs alkyl chain

Table 2 HLB of C_n Man [10]

C_n Man	HLB
6	13.6
7	12.9
8	12.3
9	11.7
10	11.2
12	10.3
14	9.5
18	9.0

IV. CONCLUSION

In general, the surface activity for the above mentioned nonionic ecofriendly sugar-based surfactants strongly depends on their flexible alkyl chain length. In this study, their surface tension, HLB number and solubility. The results showed that all of parameters decreased gradually with increasing the alkyl chain length. Moreover, their emulsifying properties depended on their alkyl chain length and specific oil/water system in the details. Such sustainable tailor-made surfactants would be expected to have potential application in the field of fine chemicals, biochemical reagents, pharmacy, detergents and biochemistry research in the future.

For the C_{18} Man technical-grade surfactant, the solubility is higher compared to the pure one. This might be some properties presence in the surfactant that increase its solubility. Thus, as recommendation the GCMS method can be used to determine every molecule present in the surfactant for future study.

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