CHAPTER IV
RESULTS AND DISCUSSION

4.1 Contact Angle Measurement

In this study, contact angle measurement was used to verify the antifoaming mechanism of calcium soap precipitate in the SDS solution.

Figure 4.1 shows the contact angle of water and SDS solution of varying concentration on calcium soap surface with chain length C_{12}-C_{22}. It can be seen that the contact angle increases with increase in chain length of calcium soap. For all calcium soaps, the contact angle decreases with increase in SDS concentration and it becomes constant above the CMC which is about 8 mM. It is interesting to note that calcium soap with chain length C_{22} is the only soap that has a contact angle greater than 90° when water is used.

From these results, calcium soap C_{22} (CaC_{22}) has higher hydrophobicity than calcium soap C_{18} (CaC_{18}), calcium soap C_{14} (CaC_{14}), and calcium soap C_{12} (CaC_{12}), respectively. It can be explained by the number of carbon atom in hydrocarbon chain of calcium soap in Table 4.1.

Table 4.1 The number of carbon atom per molecule of calcium soap.

Calcium soap	Number of carbon atom
CaC_{12}	24
CaC_{14}	28
CaC_{18}	36
CaC_{22}	44

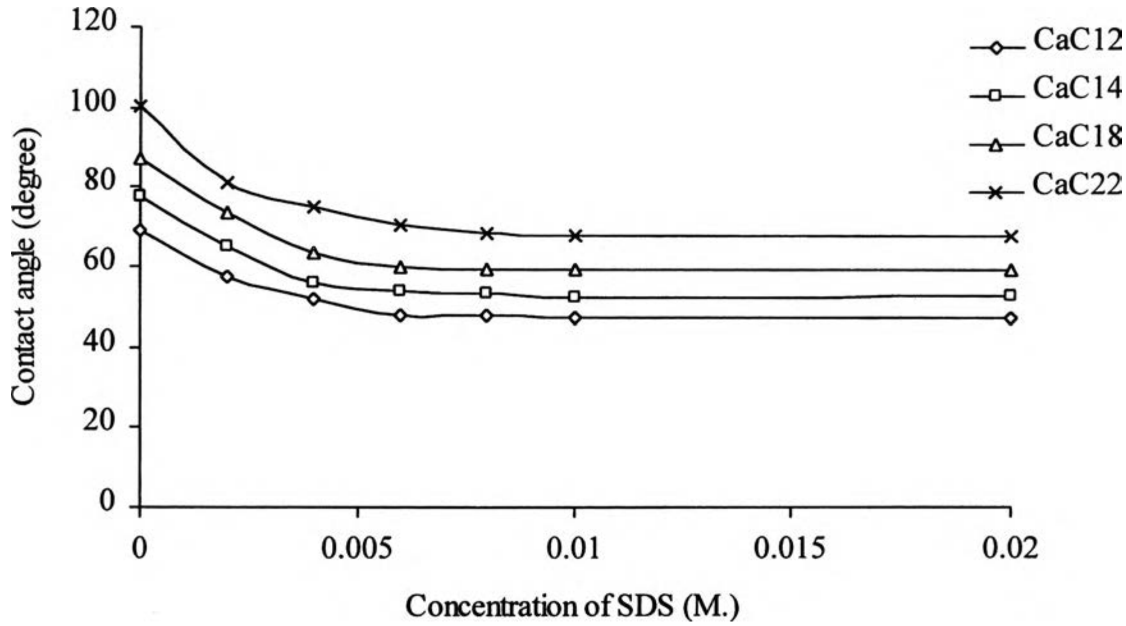

Figure 4.1 The contact angle of SDS solution of varying concentration on calcium soap surface.

In the earlier studies, there was a tendency to try and emphasize the importance of wetting by showing that an increase in contact angle can cause an increase in antifoaming action (Pugh, 1996).

4.2 Foaming Properties of SDS Solution in the Presence of Calcium Soaps

Figure 4.2 shows the change in foam height with time using Ross-Miles foam test. The results show that there is not much difference in foamability in the presence of different soaps but there are differences in foam stability.

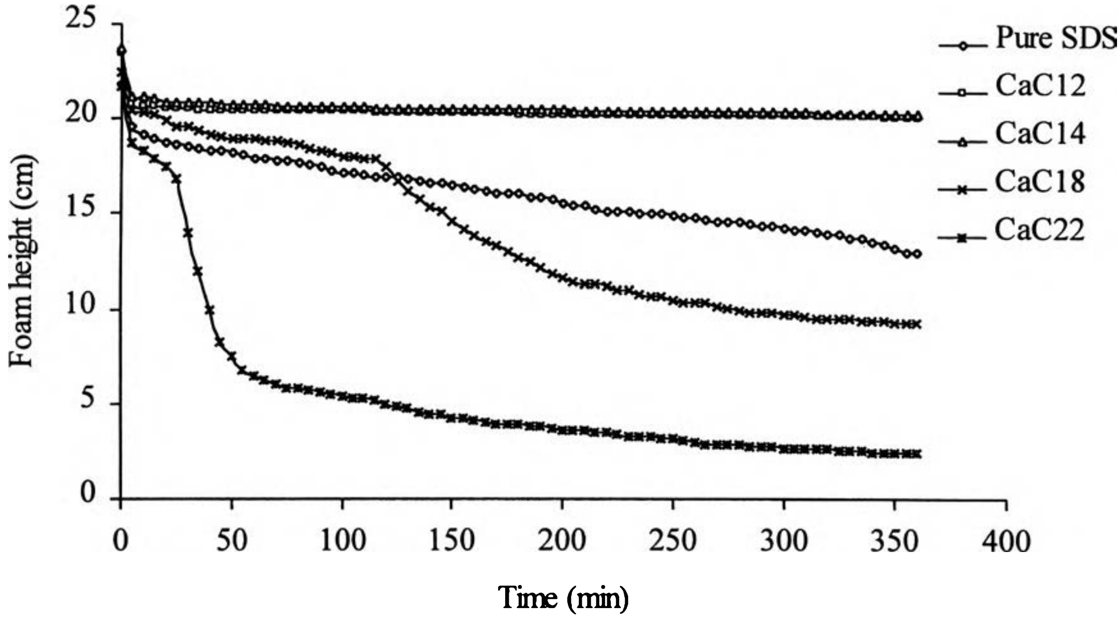

Figure 4.2 The change in foam height with time using the Ross-Miles foam test.

– In the case of pure SDS solution, there is a significant decrease of foam height at the first 5 minutes followed by a gradual decrease from a foam height of 19.6 cm down to 13 cm. in 360 minutes.

– In the case of calcium soaps C_{12} and C_{14}, there is a slight initial decrease of foam height after the first 5 minutes. The foam then remains stable at approximately 20 cm which is higher than the foam height of pure SDS all through the experiment time of 360 minutes. The results show that calcium soaps C_{12} and C_{14} have a stabilizing effect on the foam stability.

– In the case of calcium soap C_{22}, there is an initial drop in foam height after 25 minutes. The foam height then decreases sharply from 16.8 cm at 25 minutes to 6 cm at 70 minutes. After this, there is a gradual decrease down to 2.4 cm after 360 minutes. The results show that calcium soap C_{22} has a destabilizing effect on foam stability.

– In the case of calcium soap C_{18}, the results are intermediate between the short chain length (C_{12} and C_{14}) and the long chain length (C_{22})

soaps. The foam stability was relatively stable until 120 minutes. It then decreases sharply down to 11.6 cm at 200 minutes. After this, the foam decreases gradually to 9.4 cm at 360 minutes. The results show that calcium soap C_{18} has the stabilizing effect on foam stability during the first 120 minutes and it shows the destabilizing effect after 120 minutes.

From these results, we found that foam stability depends on the hydrophobicity of calcium soap precipitate. Calcium soap C_{22} which has a contact angle greater than 90^{o} shows the destabilizing effect on foam stability. The results support the bridging-dewetting antifoaming mechanism.

4.3 The Effect of Particle Size of Calcium Soap on the Foaming Properties of SDS Solution

The change in foam height of SDS solution with time by Ross-Miles method is shown in Figure 4.3 and Figure 4.4. From these figures, we found that the results are not much different. It can be seen that calcium soap C_{12} and C_{14} have a stabilizing effect on foam stability compared with the pure SDS solution. On the other hand, only calcium soap C_{22} has a destabilizing effect on foam stability. For CaC_{18}, it shows both a stabilizing and destabilizing effect on foam stability.

We can conclude from these results that there is no effect of particle size of calcium soaps on the foamability and foam stability of SDS.

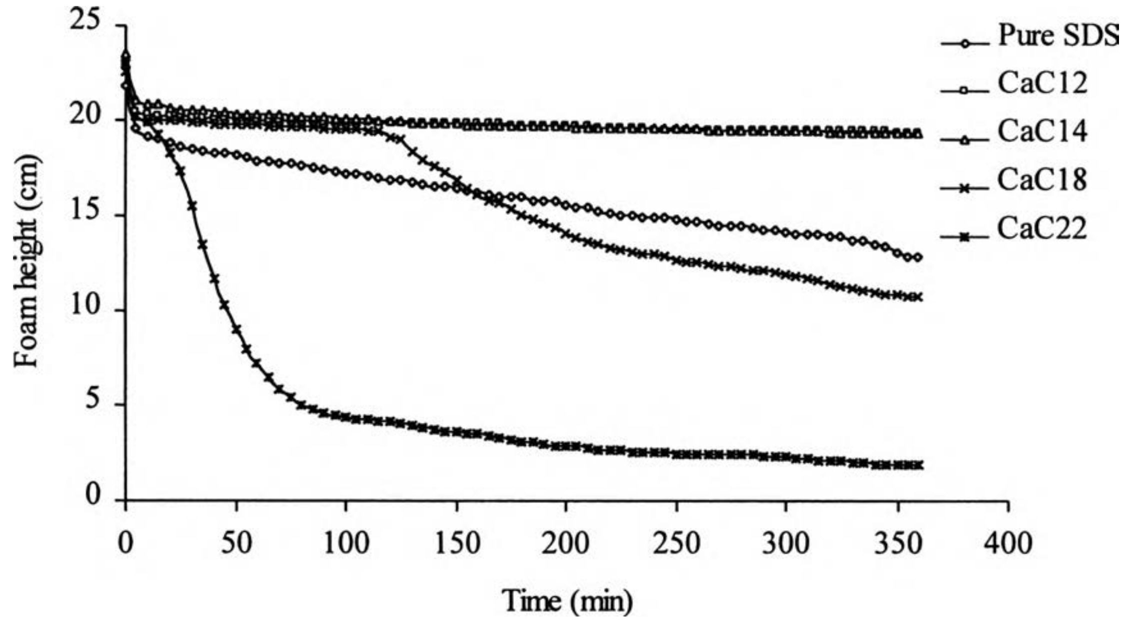

Figure 4.3 The change in foam height with time of sodium dodecyl sulfate solution in the presence of calcium soap which has the particle size in the range of < 212 μm.

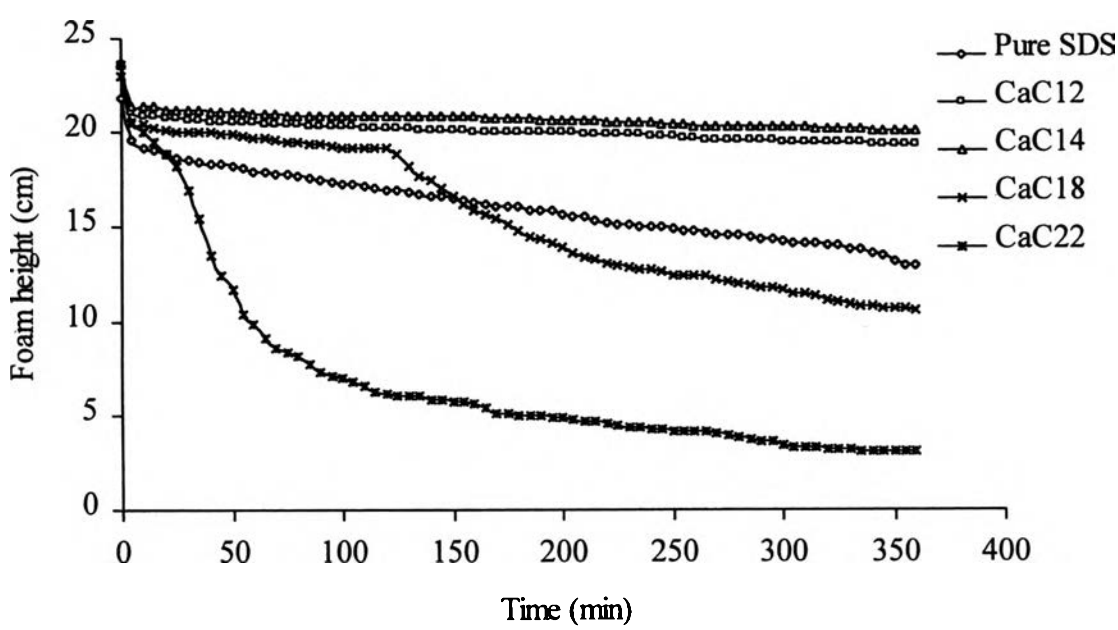

Figure 4.4 The change in foam height with time of sodium dodecyl sulfate solution in the presence of calcium soap which has the particle size in the range of 212-425 μm.

4.4 The Effect of Concentration of Calcium Soap on the Foaming Properties of SDS Solution

Figure 4.5 shows the foamability and foam stability of SDS solution in the presence of CaC_{14}. It can be seen that the results are not much different for both concentrations of calcium soap. The initial foam height (foamability) is about 24 cm. For the foam stability, the foam height slightly decreases after the first 5 minutes. It then becomes constant at approximately 20 cm throughout the experiment.

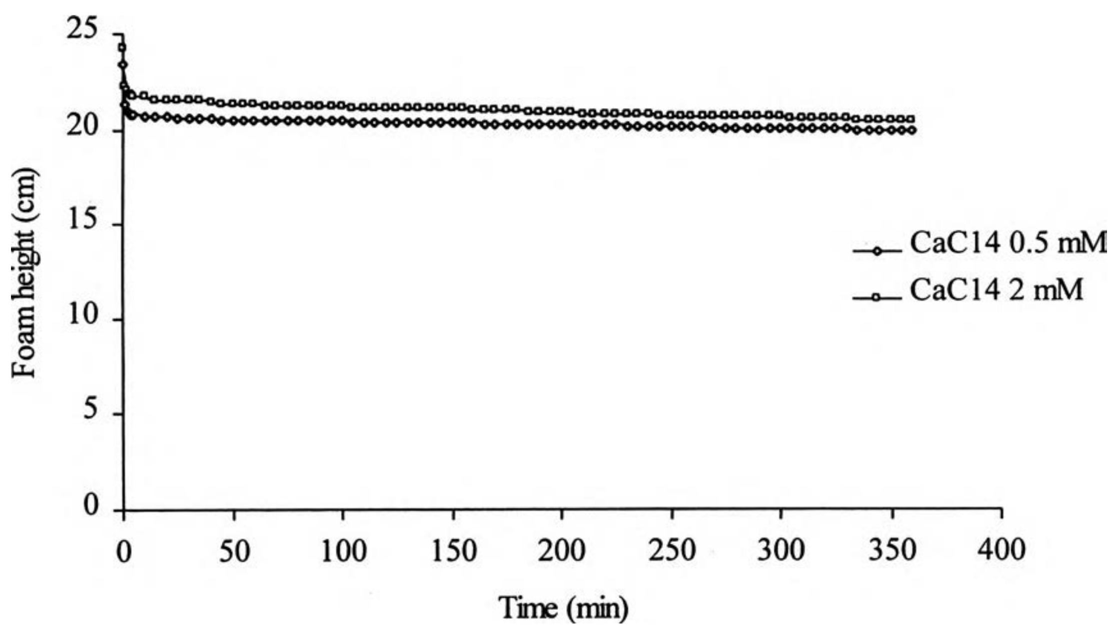

Figure 4.5 The change in foam height with time of SDS solution in the presence of varying concentration of CaC_{14}.

The change in foam height with time of SDS solution of varying concentration of CaC_{22} was shown in Figure 4.6. The results are almost the same for both concentrations of soap, 0.5 mM and 2 mM. The foam height decreases sharply from 24 cm at initial to 5 cm after the first 30 minutes.

Then, there is a gradual decrease down to 2 cm after 100 minutes. After that, the foam height remains constant through the experiment time of 360 minutes.

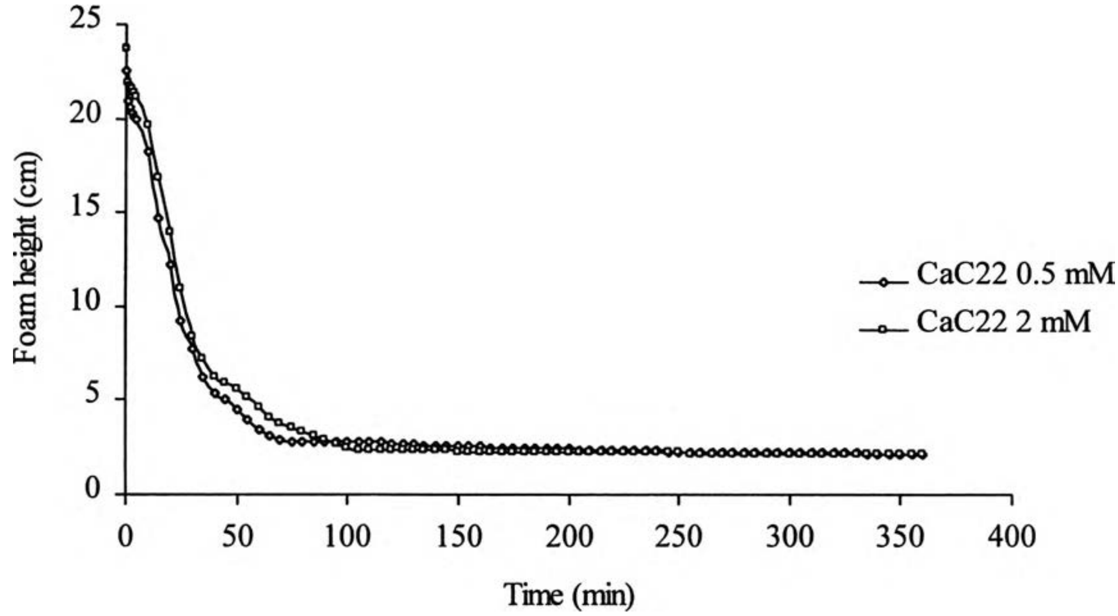

Figure 4.6 The change in foam height with time of SDS solution in the presence of varying concentration of CaC_{22}.

We found from these results that the calcium soap concentration, which is above the solubility limit, has no effect on both foamability and foam stability of SDS solution.

4.5 The Effect of Hardness Tolerance on the Foaming Properties of SDS Solution in the Presence of Calcium Soaps

An important characteristic of anionic surfactants is their tendency to precipitate from hard water. Precipitation of anionic surfactants can inhibit their use in many applications and can affect formulation compositions substantially (Rodriguez, 1998).

Figure 4.7 shows the effect of $CaCl_2$ on the foamability and foam stability of SDS solution. Calcium soap was not presented in this experiment. In the preparation of test solution, it was found that there was a lot of precipitate occurred in the solution, especially for $CaCl_2$ at concentration 5 mM. It can be postulated from Figure 2.7 that the concentrations of SDS and $CaCl_2$ in this experiment are in the precipitation phase boundary so calcium dodecyl sulfate can easily precipitate out from the solution.

For the SDS solution in the presence of $CaCl_2$ at 2 mM, there is not much difference in foamability, which is at approximately 23 cm the same as that of pure SDS, but there is difference in foam stability. The foam height dramatically decreases from the initial to 5 cm after 25 minutes. After this, there is a gradual decrease down to 2 cm after 150 minutes and it remains constant throughout the experiment time of 360 minutes.

For the SDS solution in the presence of $CaCl_2$ at 5 mM, there is the effect on both foamability and foam stability of the solution. The initial foam height drops from 23 cm to 14.9 cm. For the foam stability, the foam height significantly decreases down from 14.9 cm to 3.5 after 15 minutes and it then decreases gradually to about 2 cm after 90 minutes. After this, it remains stable throughout the experiment.

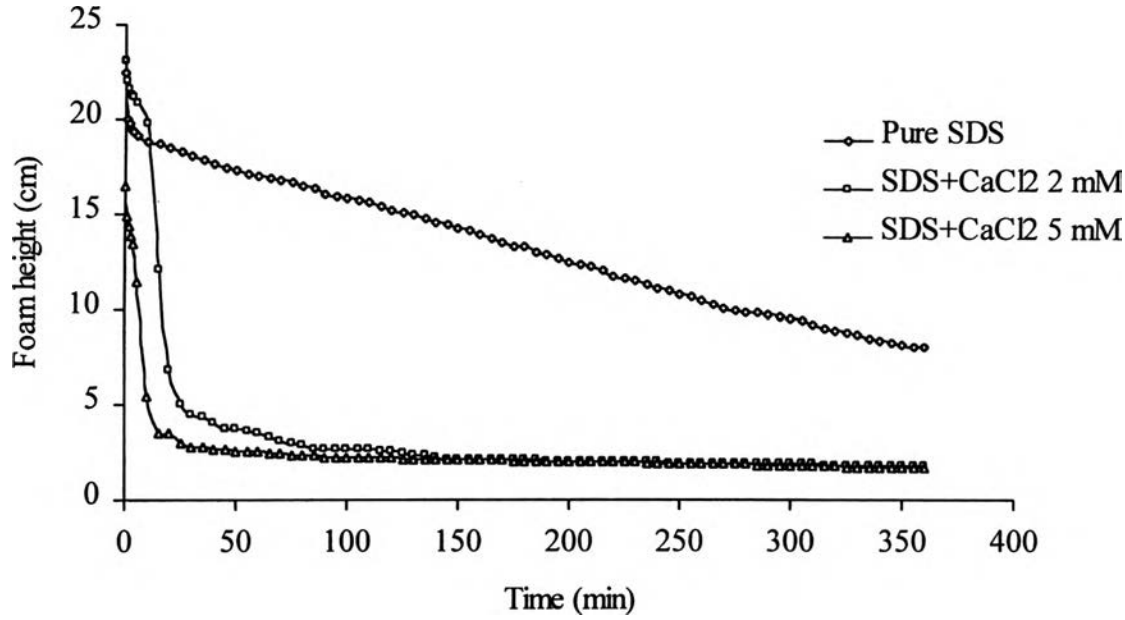

Figure 4.7 The effect of hardness tolerance on the foaming properties of pure SDS solution.

The effect of hardness tolerance on the foaming properties of SDS in the presence of CaC_{14} is shown in Figure 4.8. It can be seen from the results that there is not much difference in the foaming properties in the presence of $CaCl_2$ at 2 mM. The initial foam height is still about 23 cm which is almost the same as that of pure SDS and SDS+CaC_{14} in deionized water. For the foam stability, the foam height drops gradually to 20.2 after the first 5 minutes and it slowly decreases to 18.4 cm after 360 minutes. From these results, CaC_{14} still has the stabilizing effect on the SDS solution.

For the solution which was composed of SDS, CaC_{14}, and $CaCl_2$ at 5 mM, there is a sharp decrease in foamability from about 23 cm to 10.5 cm. For the foam stability, the foam height gradually decreases from 10.5 cm initially to 6.7 cm after the first 5 minutes. After this, it decreases slightly down to 5.3 cm. at 360 minutes.

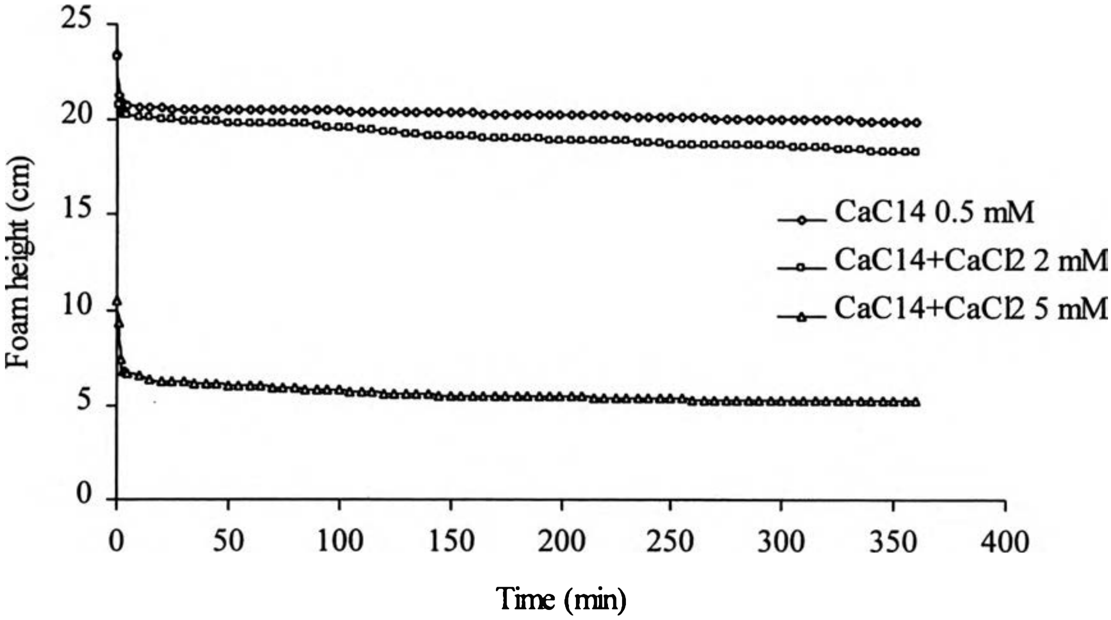

Figure 4.8 The effect of hardness tolerance on the foaming properties of SDS solution in the presence of CaC_{14}.

Figure 4.9 shows the effect of hardness tolerance on the foaming properties of SDS solution in the presence of CaC_{22}. It can be seen that the results of SDS+CaC_{22} in deionized water are almost the same as that of SDS+CaC_{22}+$CaCl_2$ 2 mM. The initial foam height is 22 cm and it then drops significantly down to about 3.5 at 50 minutes. Next, there is a gradual decrease down to 3.1 at 90 minutes. The foam height then decreases slowly to 2 at 360 minutes.

For the test solution in which $CaCl_2$ at 5 mM was present, there is a sharp decrease in foamability to 10.8 cm. For the foam stability, it decreases dramatically down to 2.5 after 25 minutes. The foam height then drops slowly down to 1.8 cm. at 360 minutes.

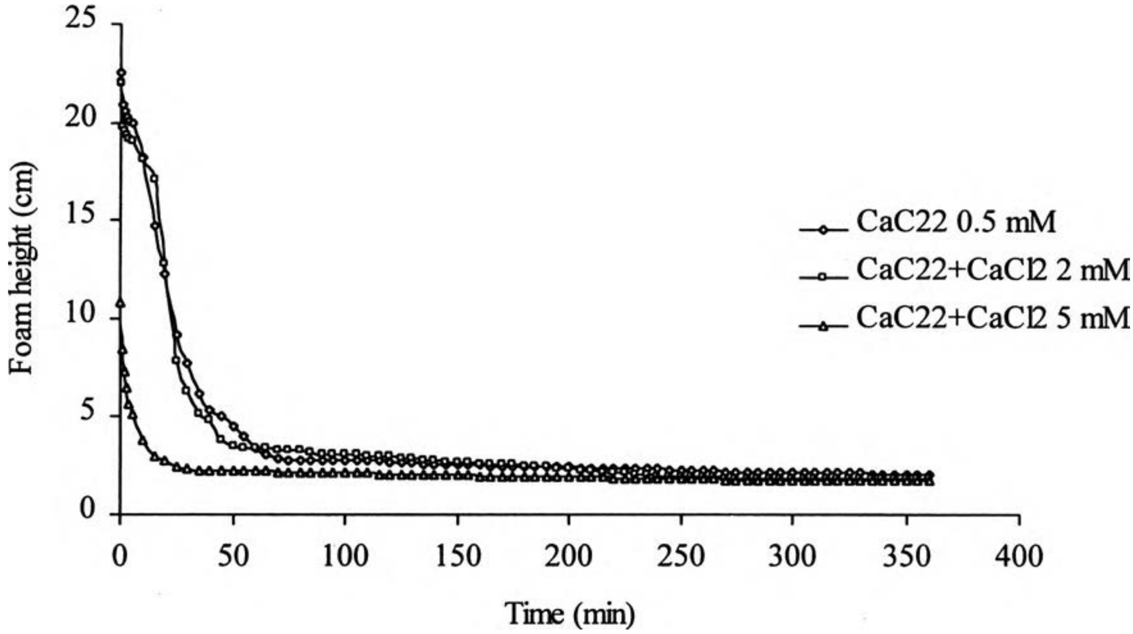

Figure 4.9 The effect of hardness tolerance on the foaming properties of SDS solution in the presence of CaC_{22}.

4.6 The Effect of $NaHCO_3$ on the Foaming Properties of SDS Solution in the Presence of Calcium Soaps

Alkaline is generally added to a detergent formulation. It is therefore of interest to study the effect of added alkaline on the foaming properties of the surfactant solution.

Possible reactions occurring in these systems are represented by the following equations:

$$NaHCO_3\,(s) \longleftrightarrow Na^+\,(aq) + HCO_3^-\,(aq) \qquad (4.1)$$

$$\tfrac{1}{2}\,CaC_{14}\,(s) \longleftrightarrow \tfrac{1}{2}\,Ca^{2+}\,(aq) + C_{14}^-\,(aq) \qquad (4.2)$$

$$Na^+ (aq) + C_{14}^- (aq) \longleftrightarrow NaC_{14} (s) \quad (4.3)$$

The sodium soap may occur from the equations above as evidenced by the cloudy solution after stirring for 12 hours. In this case, the amount of calcium soap (CaC_{14} and CaC_{22}) in the solid form should decrease.

Figure 4.10 shows the change in foam height with time of SDS solution in the presence of CaC_{14} and $NaHCO_3$. From the results, we found that $NaHCO_3$ at concentrations 50 and 100 ppm have no effect on both foamability and foam stability of SDS solution. The results are almost the same for all. The initial foam height is about 24 cm. Then, there is a gradual decrease down to 21 cm after the first 5 minutes and it is relatively stable throughout the experiment time of 360 minutes.

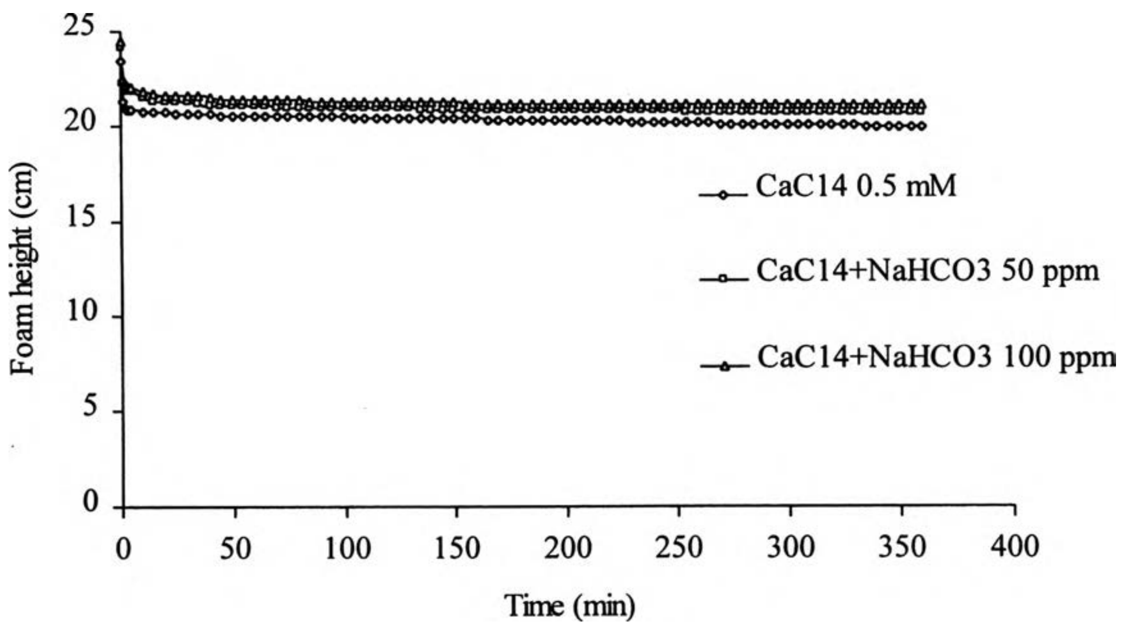

Figure 4.10 The effect of $NaHCO_3$ on the foaming properties of SDS solution in the presence of CaC_{14}.

The effect of $NaHCO_3$ on the foaming properties of SDS in the presence of CaC_{22} was shown in Figure 4.11. It can be seen from the results that $NaHCO_3$ has the effect on only the foam stability. The antifoaming behavior of CaC_{22} was reduced by added $NaHCO_3$. The stabilizing effect of the test solutions is in the order: SDS+CaC_{22}+$NaHCO_3$100 ppm > SDS+CaC_{22}+$NaHCO_3$50 ppm > SDS+CaC_{22}. It can be explained by the decrease in concentration of CaC_{22} which acts as the antifoamer in the solution.

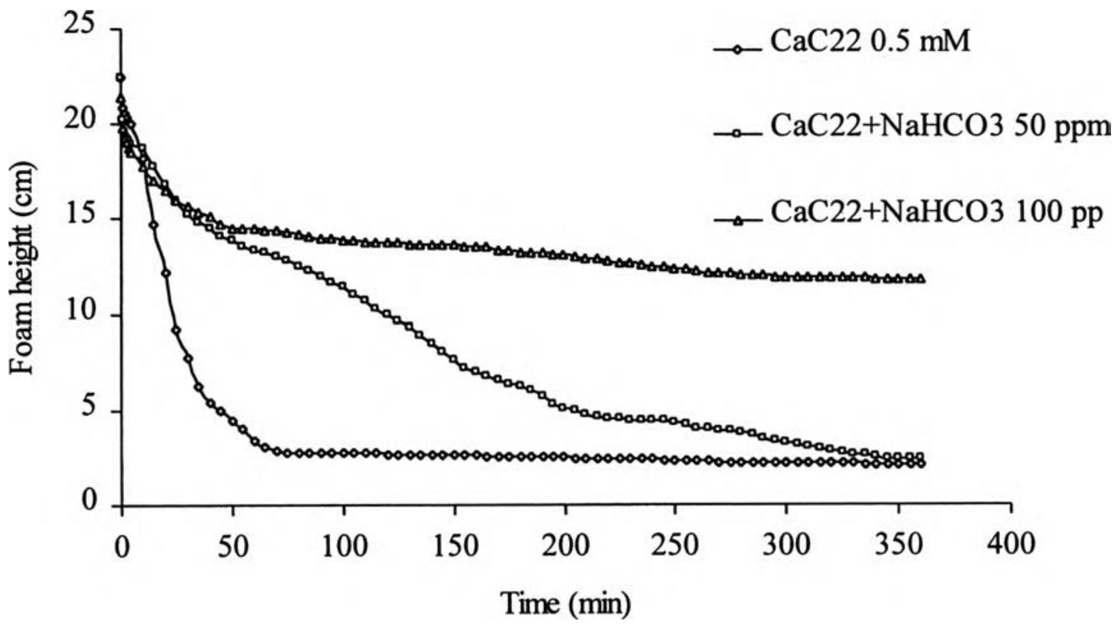

Figure 4.11 The effect of $NaHCO_3$ on the foaming properties of SDS solution in the presence of CaC_{22}.