CHAPTER IV
RESULTS AND DISCUSSION

4.1 PZC Result

Point of zero charge (PZC) is the pH where there is no net average charge at the shear plane, which also called as "isoelectric point (IEP)". Figure 4.1 shows the zeta potential of methyl palmitate as a function of equilibrium pH. The PZC value of methyl palmitate was approximately 2.2 which means that if solution pH is lower than 2.2, the charge on methyl palmitate surface becomes positive. On the other hand, if the solution pH is greater than 2.2, the surface of methyl palmitate has negative charge.

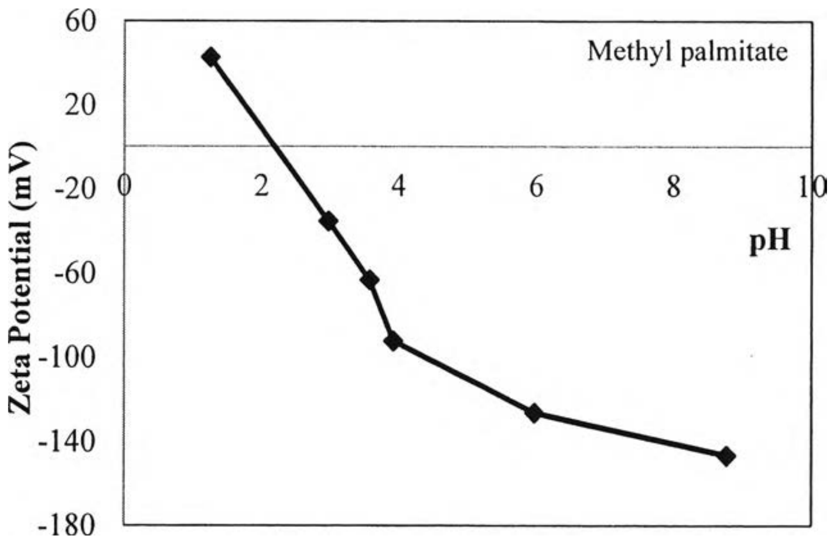

Figure 4.1 Zeta potential of methyl palmitate in de-ionized water at various pH values.

4.2 Zeta Potential Results

The zeta potential of methyl palmitate in an Alfoterra® C145-4(PO) solution becomes less negative as the Alfoterra® C145-4(PO) concentration increases, as shown in Figure 4.2. The result can be explained in that the higher the Alfoterra® C145-4(PO) concentration, the higher the Alfoterra® C145-4(PO) adsorption onto the methyl palmitate surface (heterogeneity surface). In general, the extended surfactant composes of anionic and nonionic part, the anionic part generally adsorbs onto the oil surface, resulting in higher negative of the zeta potential. Figure 4.2 shows that the zeta potential became less negative which can be explained in that it was resulted from the higher pH (pH ≈ 10) in solution that caused the more negatively charge onto the oil surface resulting in the higher amount of surfactant adsorption onto the oil surface. In this case, the surfactants adsorb head down onto the oil surface and the longer tail group can shield the negative charge of the oil surface resulting in less negative zeta potential.

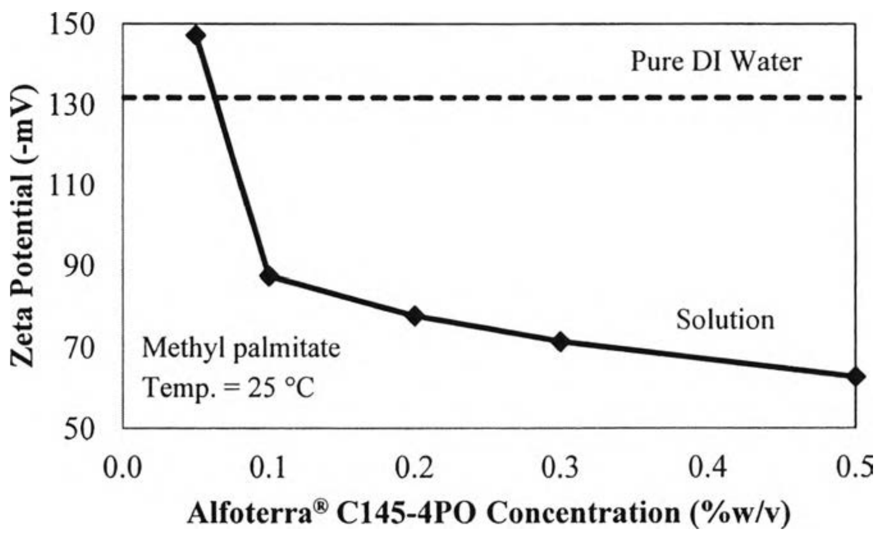

Figure 4.2 Zeta potential of methyl palmitate in Alfoterra® C145-4(PO) solutions at various concentrations.

Figure 4.3 shows the zeta potential of methyl palmitate in 0.1 %w/v Alfoterra® C145-4(PO) as a function of salinity. The zeta potential of methyl palmitate after adding electrolyte (NaCl) also had the similar trend as varying surfactant concentration. This was due to the counter ion effect that reduced the negatively charged of the oil surface. Therefore, the higher the salinity, the lower the negative zeta potential.

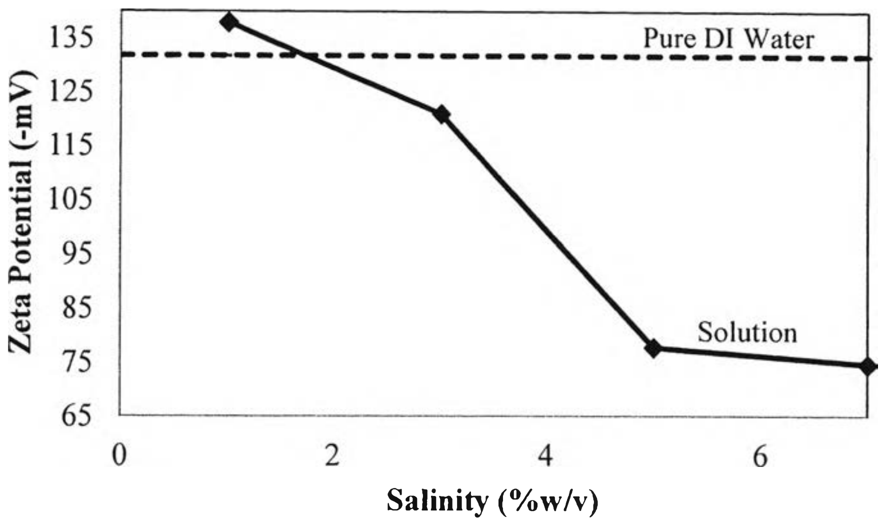

Figure 4.3 Zeta potential of methyl palmitate in 0.1 %w/v Alfoterra® C145-4(PO) solutions at various salinity.

4.3 Detergency Performance Results

Detergency performance of semi-solid oil removal depends on various variables such as surfactant concentration, salinity, washing temperature, and agitation speed. It can be investigated by three parameters; the percentage of detergency (%D) calculated from the change in reflectance, the amount of semi-solid oil removal, and the amount of semi-solid oil re-deposited.

4.3.1 Effect of Soiling Ratio of Dyed Oil to Dichloromethane and Soiling Time

In order to find the best condition that the dyed oil can absorb onto the fabric homogeneously, the soiling ratio of dyed oil to dichloromethane was varied from 1 to 3 to 1 to 8 and the soiling time was varied from 2 min to 10 min, respectively. The results showed that the ratio of dyed oil to dichloromethane of 1 to 8 and soiling time 5 min provided the best physical observation as shown in Figure 4.4 and 4.5. At that soiling condition, the average weight ratio of methyl palmitate to fabric (a polyester/cotton blend) was approximately 0.14.

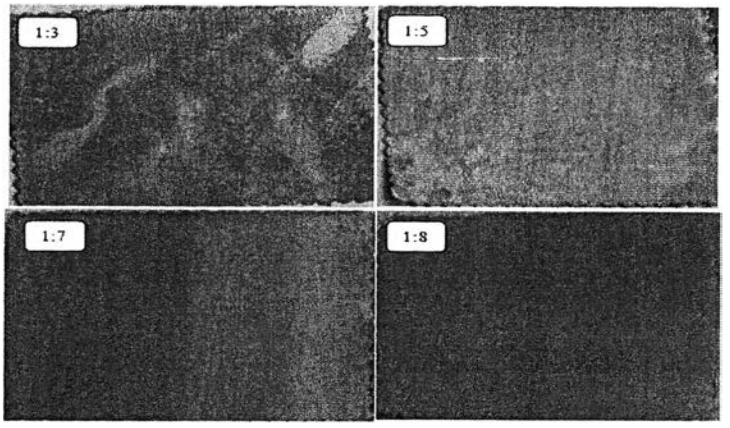

Figure 4.4 The soiled fabrics at different soiling ratio of dyed oil to dichloromethane.

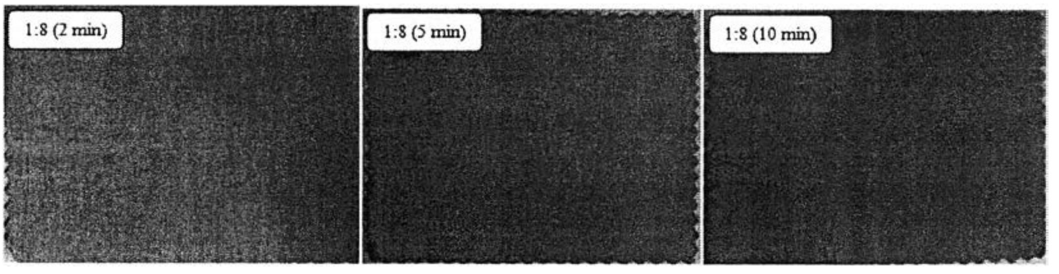

Figure 4.5 The soiled fabrics at different soiling time for 1 to 8 of dyed oil to dichloromethane ratio.

4.3.2 <u>Effect of Surfactant Concentration</u>

In this study, the different concentrations of Alfoterra® C145-4PO were varied from 0 %w/v (pure distilled water) to 2 %w/v. The experiments were carried out under constant washing temperature of 30 °C and agitation speed of 120 rpm. Figure 4.6 shows the percentage of detergency as a function of surfactant concentration. From this result, detergency (%) increased with an increasing in surfactant concentration until it reached the plateau at the Alfoterra® C145-4PO concentration approximately 0.3 %w/v. At this concentration, the maximum detergency of semi-solid oil removal was obtained at 24.77%.

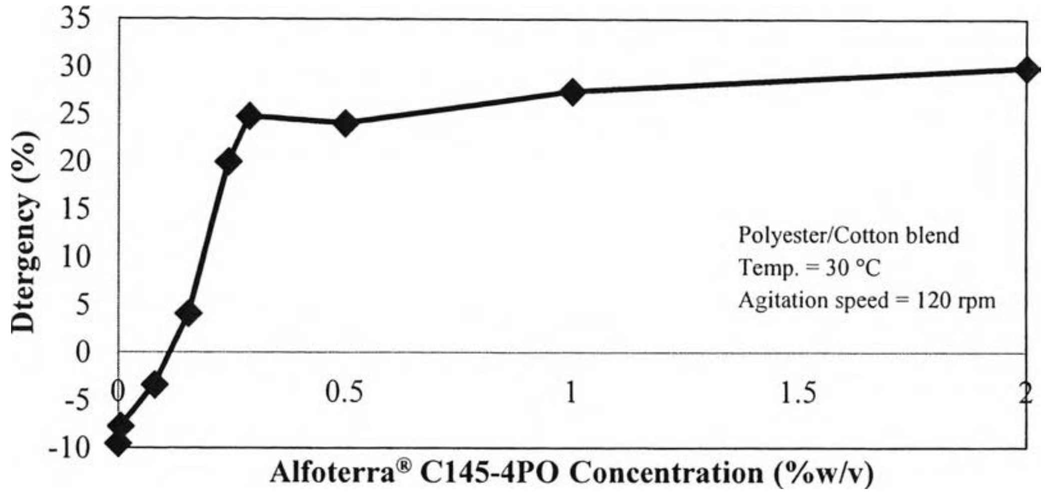

Figure 4.6 Detergency (%) of semi-solid oil at different surfactant concentrations.

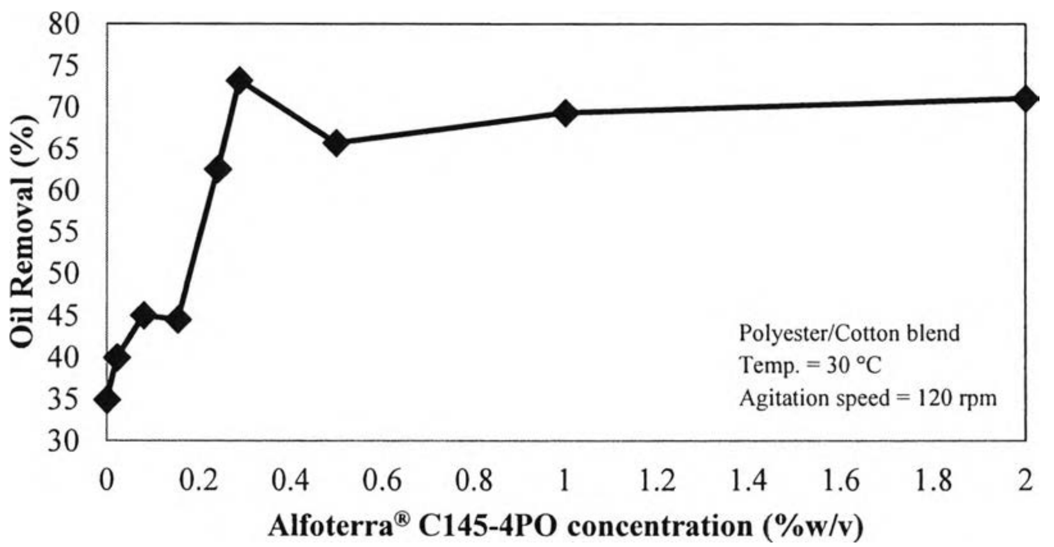

Figure 4.7 Semi-solid oil removal (%) at different surfactant concentrations.

Moreover, the cleaning efficiency of semi-solid oil can also be determined from the amount of attached semi-solid oil residue on the fabric in order to calculate the amount of semi-solid oil removal in terms of the percentage of semi-solid oil removal as shown in Figure 4.7. The result showed the similar trend as determining by the change in reflectance (detergency %). The percentage of semi-solid oil removal increased with an increasing in surfactant concentration and remained unchanged at Alfoterra® C145-4PO concentration around 0.3 %w/v which given 73.21% of semi-solid oil removal. The results can be described that the increase in surfactant concentration caused increasing in micelle concentration, which resulting in higher oil solubilization. In addition, the effect of oil re-deposition was also studied. Interestingly, the presence of surfactant was found to provide a significant reduction of oil re-deposition. The effect of surfactant concentration was found to give a slight improvement when it reached 0.1 %w/v.

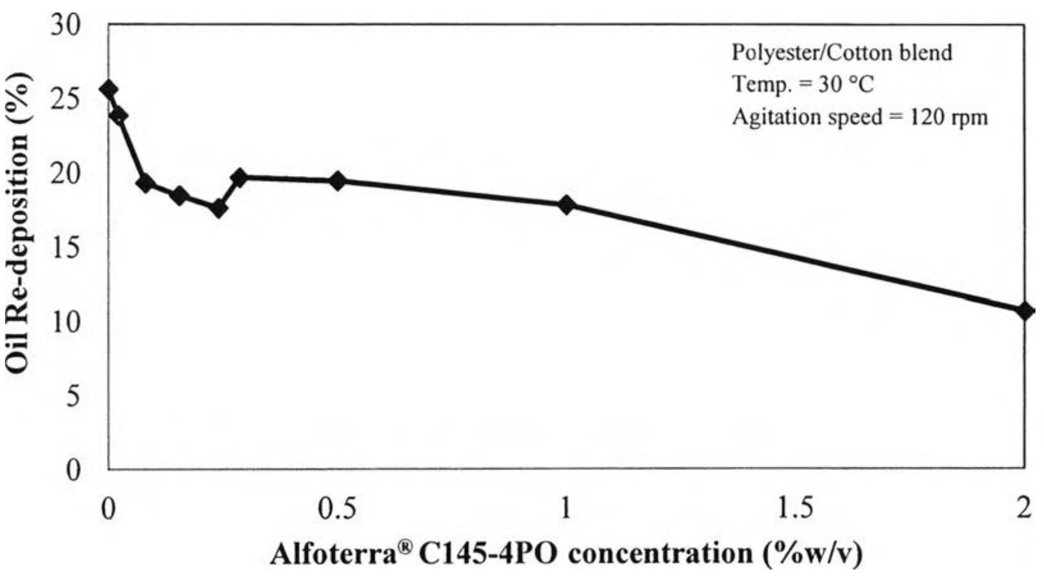

Figure 4.8 Semi-solid oil re-deposition (%) at different surfactant concentrations.

4.3.3 Effect of Salinity

Figure 4.9 shows the detergency (%) as a function of Alfoterra® C145-4PO concentration at various salinity and at constant washing temperature of 30 °C and an agitation speed of 120 rpm. The results showed that at salinity lower than 3 %w/v; the detergency (%) increased with increasing salinity. Once the salinity exceeded 3 %w/v; the detergency performance significantly decreased. This is because the addition of sodium chloride (NaCl) can reduce the electrostatic repulsion between the head groups of anionic surfactant, leading to the ease of micelle formation or higher micelle concentration. In contrast, too high salinity can increase in repulsion force between the head group of Alfoterra® C145-4PO, leading to increasing CMC (critical micelle concentration) and negative effect on micellization. The detergency (%) showed the negative results at very low surfactant concentration, because the soiled fabric exhibited the darker color after washing due to the lower of oil removal. Figure 4.10 shows semi-solid oil removal (%) as a function of surfactant concentration with different salinities, and at constant washing temperature of 30 °C and an agitation speed of 120 rpm. For any given sodium chloride (NaCl) concentration as well as without NaCl, the detergency performance increased with increasing surfactant concentration and with increasing salinity up to a certain level. It was found that without the addition of NaCl, a maximum detergency was achieved at 0.3 %w/v surfactant. The effect of NaCl concentration on detergency performance is also shown in Figure 4.10, the NaCl concentration of 3 %w/v provided the highest detergency performance at 0.1 %w/v of surfactant, thus, reducing the amount of surfactant usage. Additionally, it also shows the dynamic interfacial tension at different concentrations of surfactant under the 3 %w/v NaCl condition. The dynamic IFT decreased substantially with increasing surfactant concentration and reached the lowest IFT at 0.1 %w/v of surfactant. At this point, the oil removal (%) reached the highest corresponding to the lowest IFT. Therefore, the condition of 3 %w/v of NaCl and 0.1 %w/v of surfactant concentration were the optimum conditions which gave the maximum detergency and oil removal of 19.36% and 65.44%, respectively.

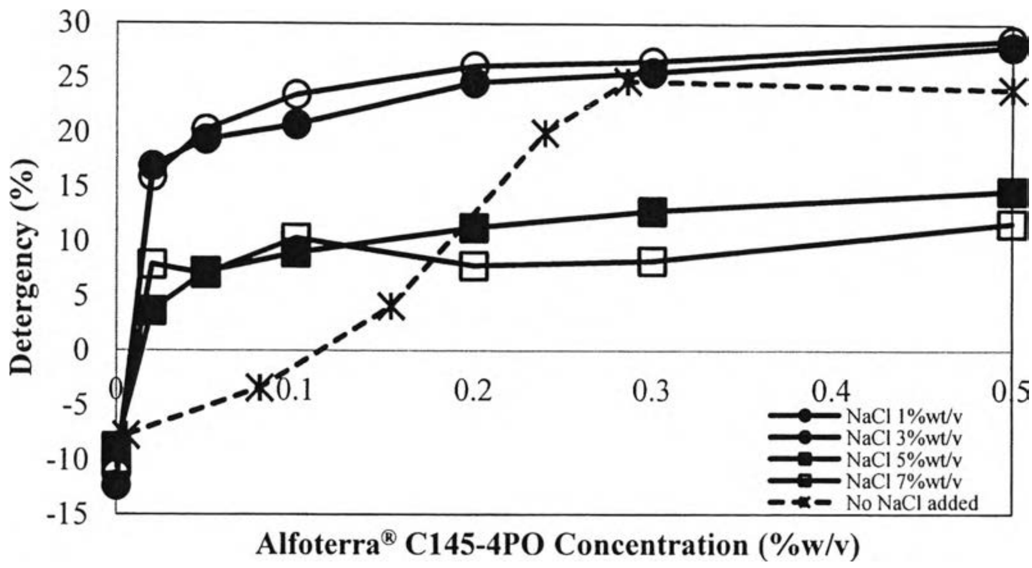

Figure 4.9 Detergency (%) of semi-solid oil at different salinities for any given surfactant concentrations under 30 °C of washing temperature and 120 rpm of agitation speed.

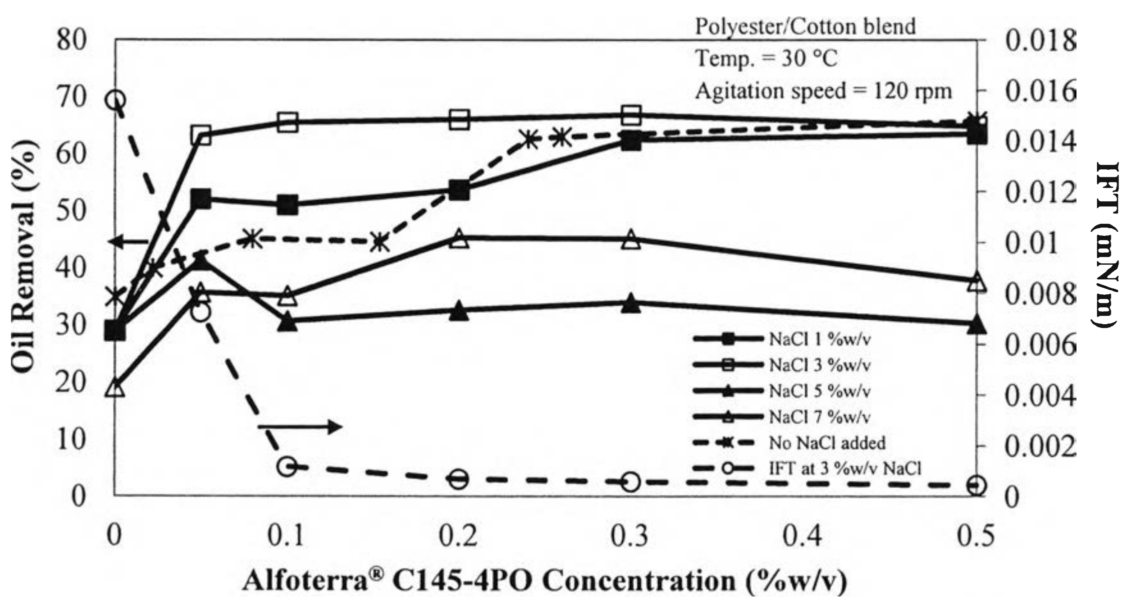

Figure 4.10 The correlation of semi-solid oil removal (%) and dynamic interfacial tension (IFT).

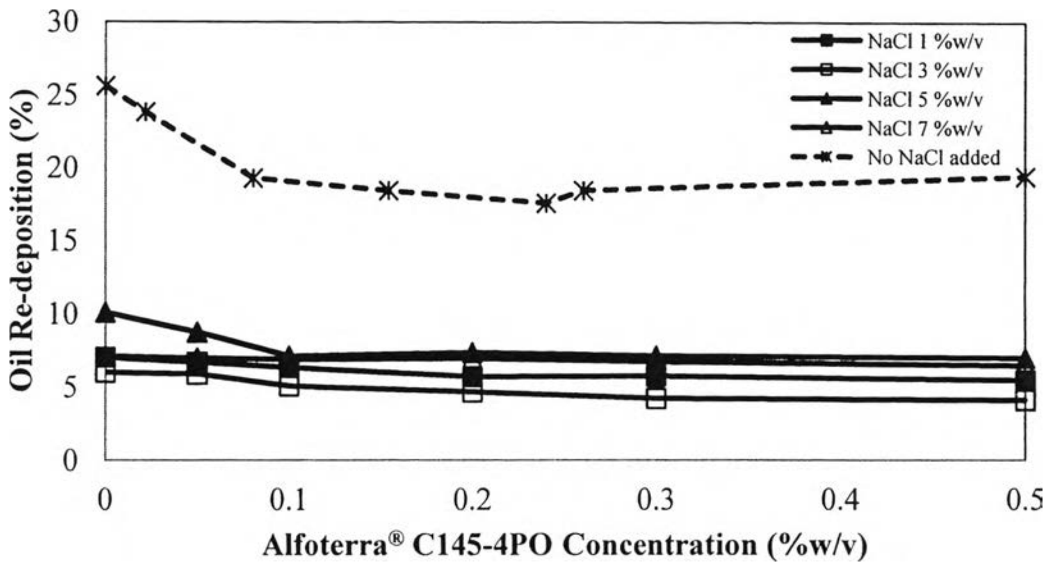

Figure 4.11 Re-deposition (%) of semi-solid oil at different salinities for any given surfactant concentrations under 30 °C of washing temperature and 120 rpm of agitation speed.

Figure 4.11 shows the effect NaCl concentrations on the oil re-deposition onto polyester/cotton blend fabric. Surprisingly, the addition of NaCl showed a significant effect on oil re-deposition. The optimum NaCl concentration of 3 %w/v provided the lowest oil re-deposition. Hence, 0.1 %w/v of Alfoterra® C145-4(PO) and 3 %w/v of NaCl were used as the selected formulation for investigation of temperature effect.

4.3.4 Effect of Washing Temperature on Detergency Performance

Temperature is also a variable that can affect the detergency performance. To understand this effect, the results of dynamic interfacial tension (IFT) at different temperatures were studied in order to compare with the semi-solid oil removal results, as shown in Figure 4.12.

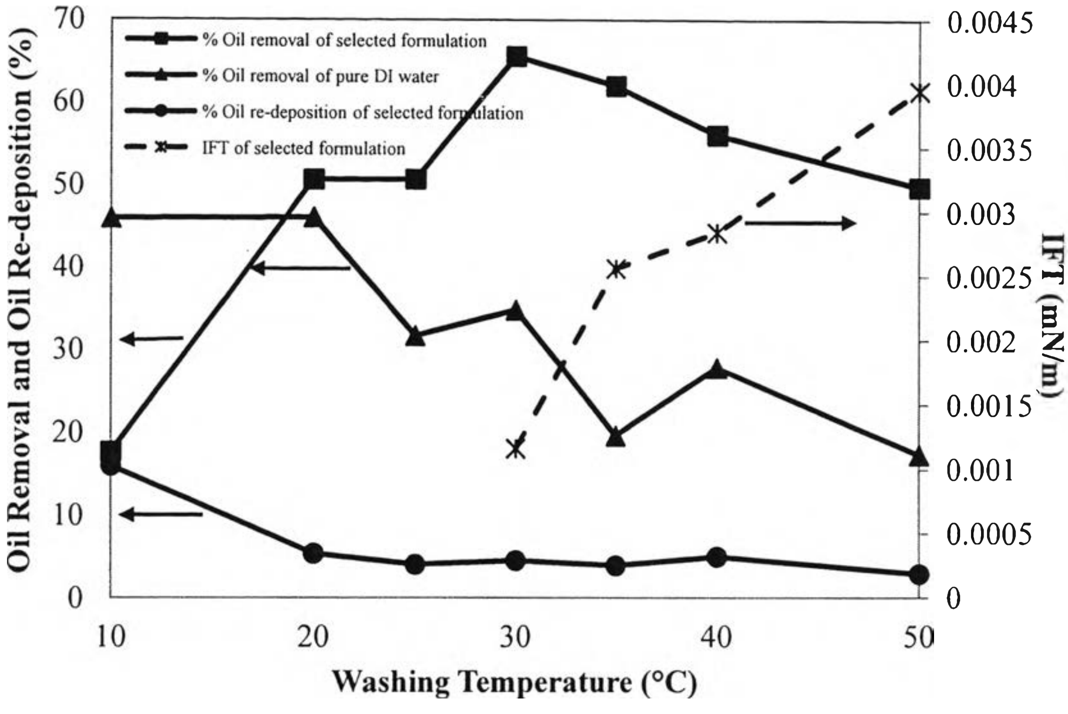

Figure 4.12 The correlation of semi-solid oil removal (%), semi-solid oil re-deposition (%), and dynamic interfacial tension (IFT) at different washing temperatures for our selected formulation and pure de-ionized water under 120 rpm of agitation speed using polyester/cotton blend fabric.

It should be mentioned that melting point of methyl palmitate is slightly lower than 30 °C and so the studied oil was in liquid when the washing temperature was controlled at 30 °C or higher, but it became solid with a temperature lower than 30 °C. From Figure 4.12, the oil removal increased with increasing washing temperature and reached a maximum at 30 °C. Beyond 30 °C, the oil removal decreased slightly with further increasing washing temperature. For washing temperature equaled to and higher than 30 °C, the methyl palmitate was in liquid form and thus the mechanism is liquid oil removal by the reduction of IFT. When the studied methyl palmitate became solid, the oil removal mechanism is dependent on the surfactant adsorption which provides the repulsion forces for the solid oil detachment. Interestingly, the solid oil removal was much higher for the case of surfactant-free system especially at a very low washing temperature of 10 °C.