CHAPTER IV
RESULTS AND DISCUSSIONS

4.1 Phase behavior study

4.1.1 Investigation microemulsion system

The first objective of this study is to investigate the surfactant systems able to form microemulsions with the selected vegetable oils in order to extract the oil from their oil seeds. To understand the microemulsion system, phase behavior studies was firstly need to be conducted. In this study, two vegetable oils, soybean oil and palm kernel oil, were selected. The first oil contains highly unsaturated fatty acids while the second oil contains mainly saturated fatty acids.

For the phase behavior study, only the surfactant system for palm kernel oil was investigated. For the soybean oil the selected surfactant system from previous study by Kongkleaw et al. (2006) was used for the second part experiment on oil extraction and oil quality. The surfactant system for soybean oil extraction was a mixture of 0.1% Alfoterra145-5PO (Branched alcohol propoxylated sulfate, sodium salt) and 3% Comperlan KD (Coconut fatty acid diethanolamine), which provided the highest efficiency for soybean oil extraction in the previous work. (Kongkleaw et al., 2006)

For palm kernel oil (PKO), even though it is different in composition as compared to soybean oil, the major components are still triglyceride and triacylglycerols containing fatty acids, thus, the mixed surfactant system of Alfoterra and Comperlan KD was also used in this study. This is because mixtures of nonionic surfactant and anionic surfactant have been revealed on their ability to form microemulsions with long chain fatty acid (Tongcumpou et al., 2003). Recently, extended surfactant was reported to enhance microemulsion formation of vegetable oil as well as reducing interfacial tension down to ultralow values (Witthayapanyanon, et al., 2007). A mixture of nonionic and anionic surfactant has an advantage in terms of increasing electrostatic interaction between mixed micelle due to the incorporation of charged surfactant. In addition, the relative hydrophilic-lipophilic balance (HLB) of the mixed surfactant system is the optimum in the midst the three phase region when the microemulsion exists with excess water and oil

phases. This leads the system to reach maximum solubilization and ultralow interfacial tensions of microemulsion system (Kunieda et al., 1998). Furthermore, the mixed non ionic surfactant and anionic surfactant decreased the tendency of non ionic presented in oil phase. (Bourrel and Schechter, 1988).

The phase behavior study of PKO was carried out by varying the concentrations of extended anionic surfactant in the system of mixed Alfoterra145-5PO and Comperlan KD. Additional to previous work, in this study Alfoterra5-8PO was also investigated for microemulsion system since it is expected that the longer propoxylated (PO) group would affect phase behavior of microemulsion formation. By nature, the extended surfactants are surfactants in which groups of intermediate polarity, such as polypropyleneoxides or copolymers of propyleneoxides and ethylenoxide, are inserted between the hydrocarbon tail and hydrophilic head group. According to the unique structure of this class of surfactant, the surfactant is stretched out further into both oil and water phases and also providing a smoother transition between the hydrophilic and hydrophobic regions of the interface which provides more suitable for solubilizing hydrophilic and hydrophobic molecules. In addition, several papers have demonstrated the benefit of using extended surfactants to enhance oil solubilization of microemulsion with highly hydrophobic oils, as well as triglyceride and vegetable oil (Minana-perez, et al., 1995, Huang, Lips, and Co.C., 2004 and Childs, et al., 2005).

To determine the phase transition, visual observation of the phase change and interfacial tension are normally used. In this work, the phase transition of the microemulsion system did not clearly observed due to solubilization of PKO which is the very long chain unsaturated fatty acid (C12 is mainly fatty acid composition) was very small and thus the volume of the phase change cannot be noticed. Another unique property of microemulsion is the ultralow interfacial tension, thus the interfacial tension of the system was measured to determine phase transition for this study. Interfacial tension of the oil and surfactant aqueous phase would be one of the key parameters to influence the oil extraction from their seeds.

4.1.2 Interfacial tension between mixed surfactant and vegetable oils

One of the most special and useful properties of microemulsion is the typically ultra low interfacial tension produced at liquid-liquid interfaces. Interfacial tension (IFT) between oil and water is related to free energy difference of the interfacial film at the planar interface separating the bulk phase and the curved interface of microemulsion droplet. (Acosta et al., 2003). The interfacial tension achieves a minimum, and often a very low value for Winsor type III systems, where there is a coexistence of three phases; microemulsion, water and oil. This state was later realized to represent so called balanced conditions with zero spontaneous of the surfactant film separating water and oil domains. Whenever interfacial tension increases strongly on the side of the balance point that means there is change from a three phase to a two phase system.

In this experiment, the interfacial tension was measured between the surfactant solution and PKO with salinity scan from 0 to 20% (wt) NaCl The IFT was measured immediately after injecting 1-3 μL of oil phase into the spinning drop tube containing the mixed surfactant inside and measured IFT until the machine give the constant value. Two types of extended anionic surfactant; Alfoterra145-5PO and Alfoterra5-8PO with various concentrations from 0.1% to 0.3% of anionic surfactant were selected to mix with 3% nonionic surfactant.

The interfacial tensions of the salinity scan systems for the mixtures of 3 % Comperlan KD and Alfoterra145-5PO and Alfoterra5-8PO at different concentrations (0.1%, 0.2% and 0.3% by weight) were measured as the results shown in Table 4.1. Figure 4.1 and 4.2 demonstrate the correlation between interfacial tension and at different salinity for all systems. The results show that both extended anionic surfactants mixing with nonionic surfactant in salinity scans systems generate microemulsion phase transition as demonstrated by IFT values. The IFT values of systems with different salt concentration varied in the range from lower than 1 mN/m to 10^{-3} mN/m. In the range of 10^{-2}–10^{-3}mN/m for vegetable oil could be considered as ultra low IFT. This would indicates that microemulsion formation in these two systems of mix surfactants with palm kernel oil; 0.1%-0.3% Alfoterra145-5PO + 3% Comperlan KD and 0.1%-0.3% Alfoterra5-8PO + 3% Comperlan KD were occurred.

Table 4.1 Interfacial tensions of the systems of mixed surfactant of 3% Comperlan KD and Alfoterra145-5PO and 5-8PO at different concentrations.

%NaCl	IFT (mN/m)					
	0.1% Alfoterra		0.2% Alfoterra		0.3% Alfoterra	
	AF-5PO	AF-8PO	AF-5PO	AF-8PO	AF-5PO	AF-8PO
0	0.6110	0.3503	0.3214	0.2710	0.3400	0.2265
1	0.0971	0.1039	0.0853	0.0653	0.0942	0.0715
2.5	0.0667	0.0828	0.0737	0.0582	0.0724	0.0525
5	0.0620	0.0552	0.0397	0.0357	0.0459	0.0415
7.5	0.0408	0.0458	0.0167	0.0275	0.0241	0.0326
10	0.0374	0.0358	0.0149	0.0223	0.0181	0.0205
12.5	0.0244	0.4870	0.0124	0.0107	0.0191	0.0173
15	0.0251	0.6411	0.0239	0.0152	0.0110	0.0101
17.5	0.0196	0.6608	0.0260	0.0160	0.0158	0.0120
20	0.0851	0.8342	0.0530	0.0242	0.0194	0.1210

From the graphs in Figure 4.1 and 4.2, almost cases the IFT values decrease as the salinity increase as expected because adding salt can promote the formation of middle phase microemulsion due to the reduction repulsive force between the ionic charge of surfactants at their head group (Tongcumpou et al., 2003). When sodium chloride concentration increases, the aggregation numbers increases. Subsequently, the solubilization of oil into the inner core of micelles may increase. Likewise, an increase in salinity enhances the phase transition of Winsor Type I microemulsion toward Winsor Type III microemulsion. From these data of IFT values, it may be assumed that Type III microemulsion occur at only 1% NaCl was added for all concentrations of both Alfoterra 145-5PO and 5-8PO due to the drop of IFT values for one magnitude from the systems without salt.

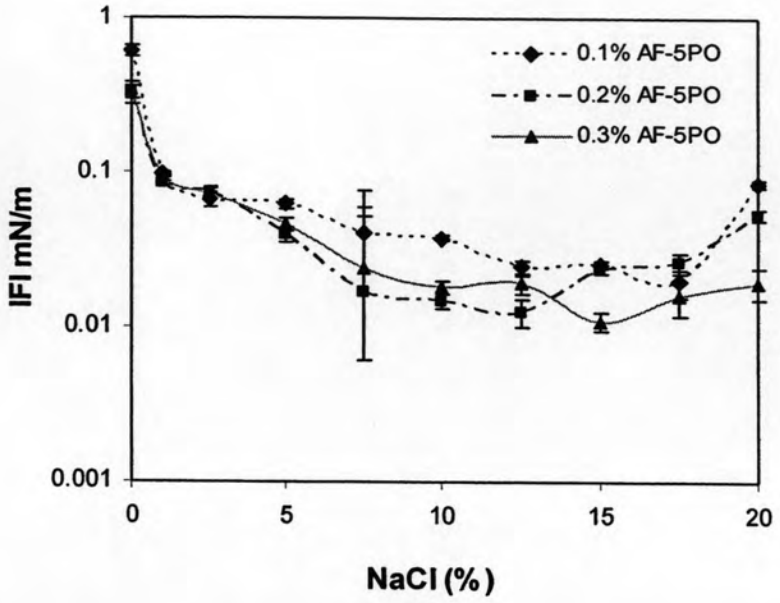
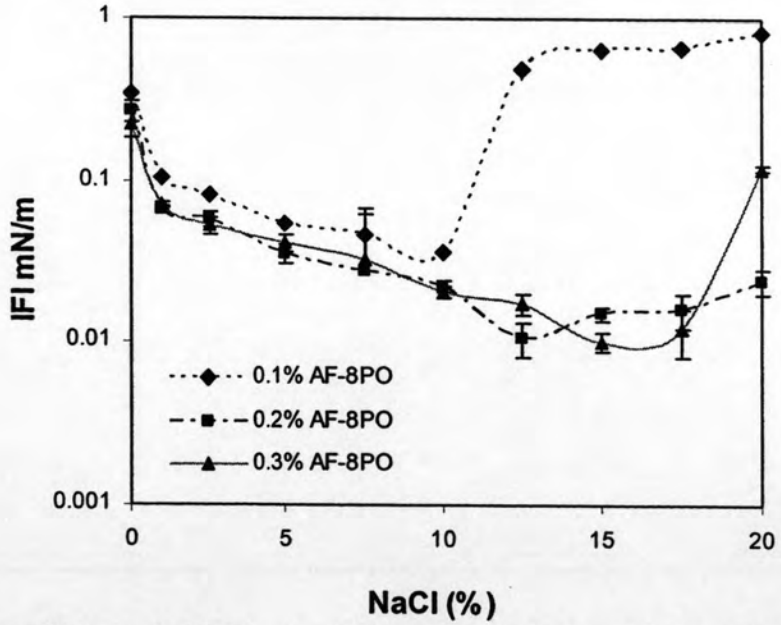


Figure 4.1 Logarithm scale plot between interfacial tension and the mixed surfactant system at 0.1%, 0.2% and 0.3% Alfoterra145-5PO respectively and 3% Comperlan KD with palm kernel oil at different NaCl concentrations.



Fiqure 4.2 Logarithm scale plot between interfacial tension and the mixed surfactant system at 0.1%, 0.2% and 0.3% Alfoterra 5-8PO respectively and 3% Comperlan KD with palm kernel oil at different NaCl concentration.

Decreasing of IFT relates to hydrphile-lipophile balance (HLB) of the system (Holmberg et al., 2003). The HLB is the parameter that shows the partitioning of surfactant between oil and water phase relative to surfactant hydrophobicity. When decreasing HLB the surfactant moves from the water phase to oil phase since the surfactant system becomes more hydrophobic. The further increase in salinity results in an increase of IFT indicating that the phase transition form Winsor Type III to Type II occurs. For the effect of concentration of extended anionic surfactant shows in same trend for both Alfoterra145-5PO and Alfoterra5-8PO as mentioned earlier. Increase of the concentration of Alfoterra from 0.1 to 0.3% resulted to IFT decreasing gradually because the higher concentration of an extended anionic surfactant enhanced affinity of oil to solubilize in micelle. It was expected that as compared Alfoterra145-5PO and5-8PO, the Alfoterra with 8PO may exhibit more hydrophobicity to the system than the one with 5PO; hence it may needs less salt to transition from Type III microemulsion to Type II microemulsion. This seems to be correct if we consider the comparison for the systems of 3% Comperlan KD mixed with 0.1% and 0.3% Alfoterra145-5PO or 5-8PO but it cannot be observed for the systems of 3% Comperlan KD mixed with 0.2% Alfoterra145-5PO or 5-8PO. In addition, when we compare among the system of mixed of Comperlan KD with Alfoterra at different concentration, the result did not show the trend that the higher concentration the Alfoterra-8PO, the higher the salt concentration is needed for phase transition. These confusing results may be explained by the fact that an extended surfactant, especially the ones with PO group as internal linker can exhibit both hydrophobicity and lipophilicity from its nature.

Therefore, from the phase study, the mixed system of 0.1% Alfoterra145-5PO and 3% Comperlan KD and the mixed system of 0.1% Alfoterra5-8PO and 3% Comperlan KD were selected for further experiments because the both systems achieved ultra interfacial tension while contained less of anionic extended surfactant concentration. At 0.1% Alfoterra145-5PO and 3% Comperlan KD, the IFT reached the minimum point at 17.5% NaCl. However from 10% to 17.5% NaCl, the IFT does not decrease significantly from 0.0375 mN/m to 0.0196 mN/m. While at 0.1% Alfoterra5-8PO and 3% Comperlan KD, the IFT reached the minimum point at 10 % NaCl, IFT 0.0358 mN/m. (All IFT data were showed in Table A-1 to Table A-6 in the Appendix A).

This work aims to propose the microemulsions system as extraction process since the microemulsions have their unique properties on ultra low interfacial tension which is expected to promote the oil to be detached from its vegetable oilseeds. From the phase behavior study in the previous section, the selected mixed surfactant system were used for palm kernel oil extraction experiment. In the second part of experiment on oil extraction, the selected surfactant systems with different salinities were applied for extraction palm kernel oil from seeds. The parameters to determine the optimum condition of the extraction are yield of the extracted oil and oil quality while the variables of the study were salinity, grain size, contact time and palm kernel seed loading. The experimental data and calculation method for palm kernel oil extraction were showed in Appendix B.

Similar to palm kernel oil, soybean oil extraction were carried out to examine the oil quality, the optimum condition from previous study was used for extraction and collected the extracted oil for oil quality study. The conditions of experiments for soybean oil extraction are also shown in Appendix B in Table B-1.

4.2 Vegetable oil extraction

4.2.1 Palm kernel oil extraction by selected surfactant at different salinity scan.

In this section, the experiments were conducted in order to find the optimum free oil phase from the two selected systems at different salinity from 0-20%. The palm kernel seeds were varied in 3 sizes following the standard of the vegetable oil seed size used foe soy bean extraction in the US. There are coarse size: larger than 35 mesh (>0.425 mm), fine size: 35- 65 Mesh (0.212-0.425 mm) and very fine size less than 65 mesh (<0.212 mm). The experiment was conducted by adding 10 ml of the mix surfactant system into the tube and homogenous mixed with 1 g of ground palm kernel for each size with vortex mixer for 30 seconds. The system was then continuously shake for 30 minutes and centrifuged for 15 minutes to separate the free oil phase. The volume of free oil phase can be measured in order to find the extraction efficiency. The results showed both of selected surfactant systems were found that to be able to extract palm kernel oil from palm kernel seed. The results were shown in Figure 4.3.

Figures 4.3 and 4.4, show the same trend in extraction efficiency, the largest. grain size (>0.425 mm) resulted the lowest efficiency while for the other two sizes 0.212 – 0.425 mm and smaller than 0.212 mm exhibited the extraction efficiency insignificantly different. This can be explained by the reason that the smaller size of ground seeds, the larger the surface area and hence it can enhance capability of surfactant monomer to interact with the surface. Subsequently, the interfacial tensions reduce and led oil to be detached. However, the indifference of extraction efficiency between smallest sizes (<0.212 mm) and the middle size (0.212-0.425 mm) may be because too small size, even though providing more surface area, but affect on phase separation and hence provide similar yield as the middle size did. Therefore, it can be concluded that the middle range 35 – 65 mesh (0.212 – 0.425 mm) is the most appropriate grain size since the smaller size needs more energy for its grinding process.

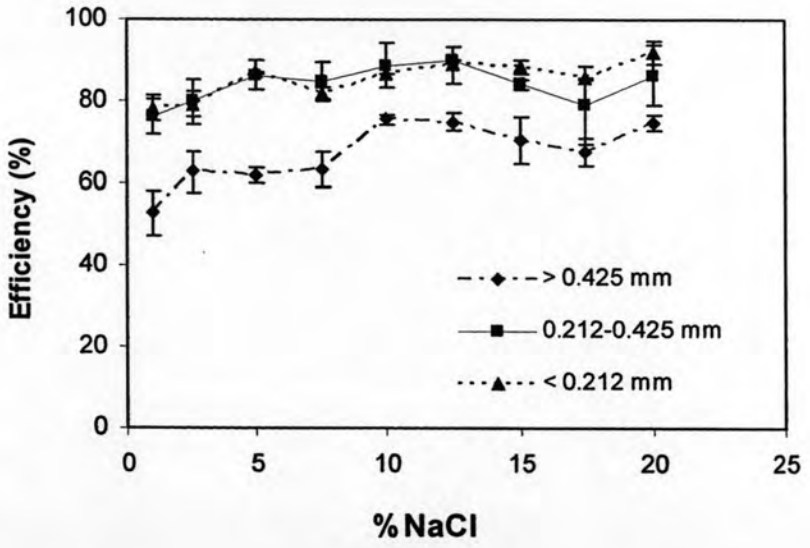


Figure 4.3 Relationship between efficiency extraction of palm kernel oil (%) at different grain sizes by the system of mixed 0.1% Alfoterra145-5PO and 3% Comperlan KD at various salinities.

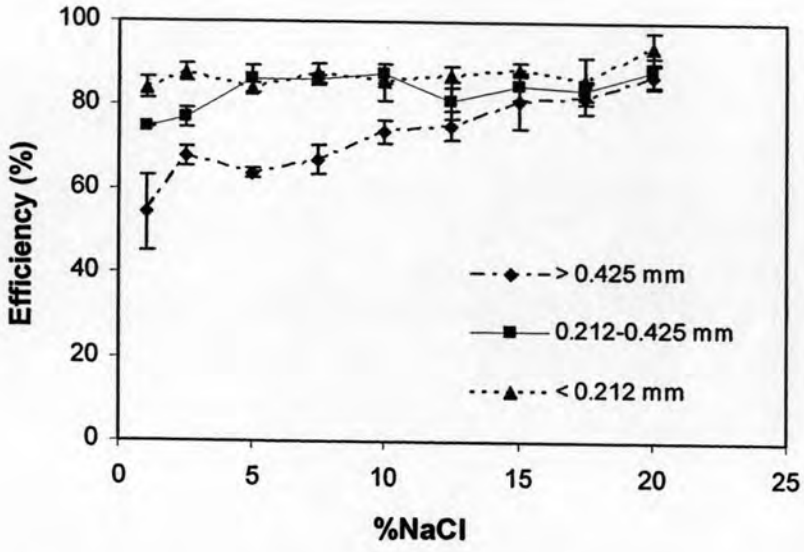


Figure 4.4 Relationship between efficiency extraction of palm kernel oil (%) and grain size by the system of mixed 0.1% Alfoterra5-8PO and 3% Comperlan KD at various salinities.

To determine the optimum salinity for the both surfactant systems of mixed Comperlan KD with Alfoterra145-5PO and Alfoterra5-8PO, the plot between %NaCl vs IFT values and oil extraction efficiency were drawn (see Figure 4.5). It is expected that at a higher salinity, the IFT of the system should be lower and oil subsequently may be extracted at the higher yield. However, if we consider for the IFT values for both system A (3% Comperlan KD and 0.1% Alfoterra145-5PO) and system B (3% Comperlan KD and 0.1% Alfoterra5-8PO), it seems that the both systems may reach microemulsion Type III at 1%NaCl and transition to Type II at around 20% and 10% NaCl for system A and system B, respectively. This is quite reasonable since Alfoterra5-8PO is more hydrophobic than Alfoterra145-5PO as discussion earlier. However, the oil extraction efficiency for both systems does not express correlation between IFT and the efficiency obviously, only at very low salinity that the efficiency is higher when the salt is increased. This may be concluded that IFT is not the only parameter governing the oil seed extraction. As compared to detergency process, Tongcumpou et al. (2005) revealed that for removing oil from fabric surface, mechanical force and other interaction such as

such as solubilization is also important. For the oil extraction process in this study, the solubilization is even more important than detergency process since efficiency of oil extraction is measured from only free oil phase, not from detached oil from solid surface as did in detergency measurement. This is why the system needed for oil extraction should provide reasonably low IFT and also low solubilization. As a consequent, for the next experiment for the contact time all salinity concentrations for both systems were conducted.

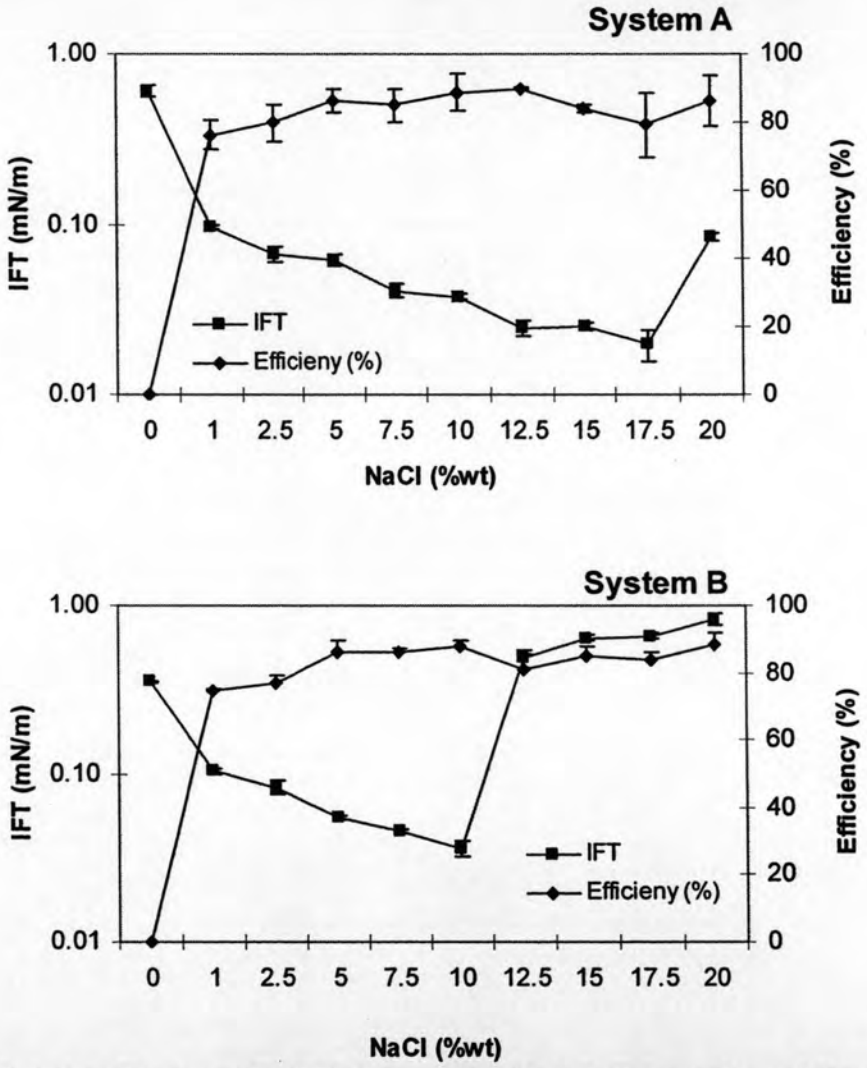


Figure 4.5 Relationship between IFT value and efficiency extraction of the aqueous surfactant system A (3% Comperlan KD and 0.1% Alfoterra145-5PO) and system B (3% Comperlan KD and 30.1% Alfoterra5-8PO) with palm kernel oil at various salinities.

4.2.2 Palm kernel oil extraction efficiency at various contact times

Another important parameter which influences the extraction efficiency is the contact time between surfactant solution and ground seeds since it allow the surfactant solution to coalesce palm kernel seeds and reduce IFT and hence detached oil from solid phase into the surfactant solution. In this experimental part, ground seed at the medium size (35- 65 mesh) was used. Figures 4.6 and 4.7 are the plots to illustrate the efficiency of oil extraction for the system A and system B at different salinities added to the systems.

From Figures 4.6 and 4.7 the graphs show the similar trend for both systems that the contract time up to 30 minutes indicate the maximum efficiency, then extraction efficiency after 30 minutes tend to be plateau or slightly decreased. As a consequence, for these two systems, the contact time at 30 minutes can be considered as the optimum time for extraction. From these results, 30 minutes is enough time for reducing IFT of oil and solid surface and thus enable the oil to detach to the aqueous surfactant solution. On the other hand, if the contact time increase further, detached free oil has more possibility to solubilize into micelle in surfactant solution, thus at only a certain period of time can express optimum efficiency of extraction.

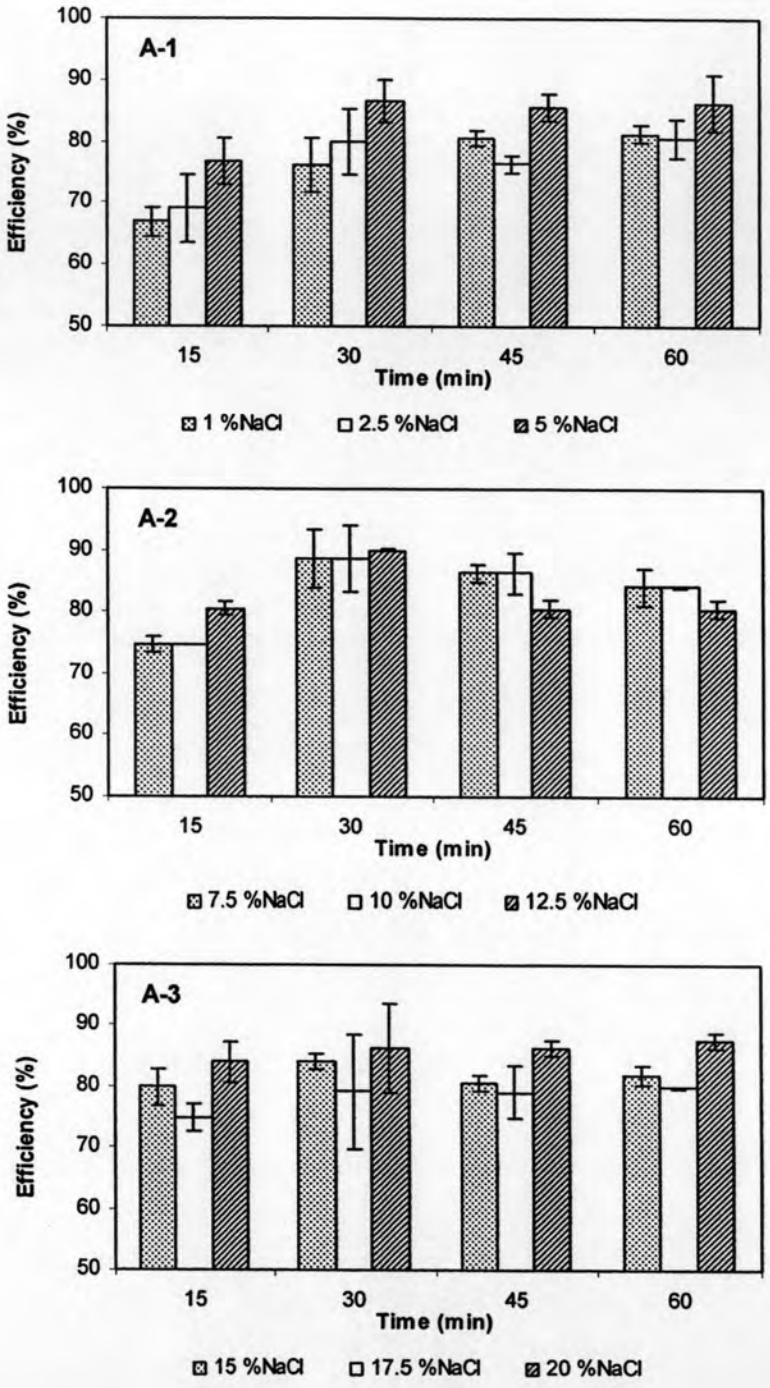


Figure 4.6 Palm kernel oil extraction efficiency (%) at different contact time by using mixed 0.1% Alfoterra145-5PO and 3% Comperlan KD (System A); A-1 for the system at low salinity range, A-2. for the system at medium salinity range, A-3 for the system at high salinity range.

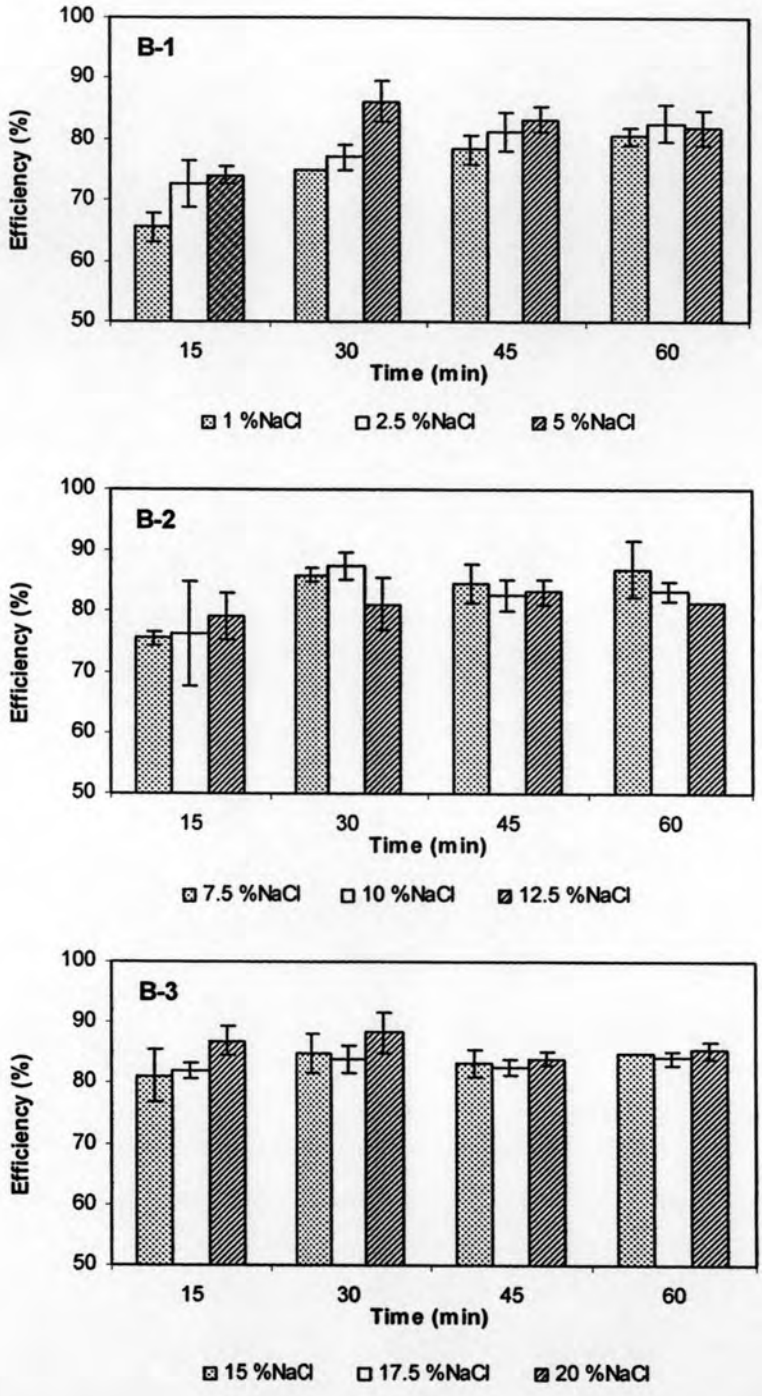


Figure 4.7 Palm kernel oil extraction efficiency (%) at different contact time by using mixed 0.1% Alfoterra5-8PO and 3% Comperlan KD (System B; B1 for the system at low salinity range, B2. for the system at medium salinity range, B3 for the system at high salinity range.

4.2.3 Palm kernel oil extraction efficiency at various palm kernel load

From the experiment on contact time, there are three salinities for each mixed surfactant solution system was selected for future study. For the system A (the mixed surfactant 0.1% Alfoterra145-5PO and 3% Comperlan KD), salinities selected for the seeds load study was at 10, 12.5 and 20% NaCl and for the system B (the mixed surfactant 0.1% Alfoterra5-8PO and 3% Comperlan KD), salinities selected for the study was at 7.5, 10 and 20% NaCl. In this experiment, the kernel load varied from 0.5, 1, 1.5 and 2.0 g with 10 ml of mixed surfactant solution. The conditions for extraction were 30 second mixing with vortex, 30 minutes contact time and 15 minutes centrifuge. The purpose of this experiment was to find the optimum of palm kernel loading in 10 ml of surfactant solution which yield the high extraction efficiency. Figure 4.8 shows the relationship between extraction efficiency with various palm kernel loading at selected salinity for each mixed surfactant system.

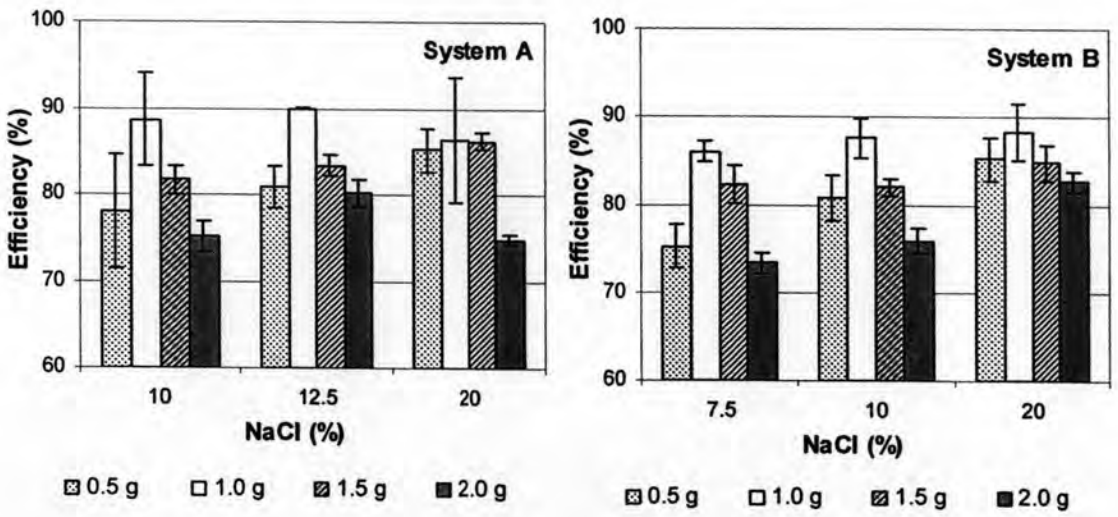


Figure 4.8 Palm kernel oil extraction efficiency (%) using aqueous surfactant systems; and 3%ComperlanKD and Alfoterra145-5PO (System A) and 3%ComperlanKD and Alfoterra5-8PO (System B) at different load of oil seeds.

From Figure 4.8, both systems A and B show the same trend that the optimum condition of extraction at almost concentrations of salt appears at 1 gm oil seeds loading. When increased the palm kernel load into the system, the extraction efficiency tend to decrease because a higher mass of palm kernel load leads to less penetration of surfactant monomers into the kernel and less coalesce between surfactant monomers and oil. Thus, it is quite obvious that the optimum palm kernel load is at 1g for 10 ml of mixed surfactant solution or 1:10 solid to liquid ratio. Although at solid to liquid ratio 0.5:10, the surfactant solution or liquid could penetrate more into the solid seed phase.

Conclusively, the optimum salinity for both systems of mixed 0.1% Alfoterra145-5PO and 3% Comperlan KD and of mixed 0.1% Alfoterra5-8PO and 3% Comperlan KD is 10% NaCl due to the high extraction efficiency. These two systems will be evaluated for further study on extracted oil quality.

4.2.4 Palm kernel oil extraction by using hexane

Palm kernel oil extraction by hexane was also carried out using same ground seed and same load of seeds to compare the efficiency to our optimum systems; grain size 35-65 mesh, 30 minutes of contact time and 1 g of palm kernel loading. The extraction experiment was done by using reflux soxlet method. After the extraction, hexane was evaporated out. Figure 4.9 compares the extraction efficiency of palm kernel oil by using hexane and our surfactant system A. The results show that the efficiency of oil extraction from both the surfactant aqueous-based of system A and of system B was insignificantly different but was slightly lower than hexane extraction. However, if we consider the maximum yield from our replication (see the plus error bar), it can be assumed that system A is almost as good as the extraction by hexane. Nonetheless, in order to induce the surfactant aqueous-based extraction to replace hexane extraction, besides the extraction yield, the extracted oil quality is needed to be proved that it is as good as or even better than the one obtained from hexane extraction. In the next part will be described the result of the extracted oil from both methods.

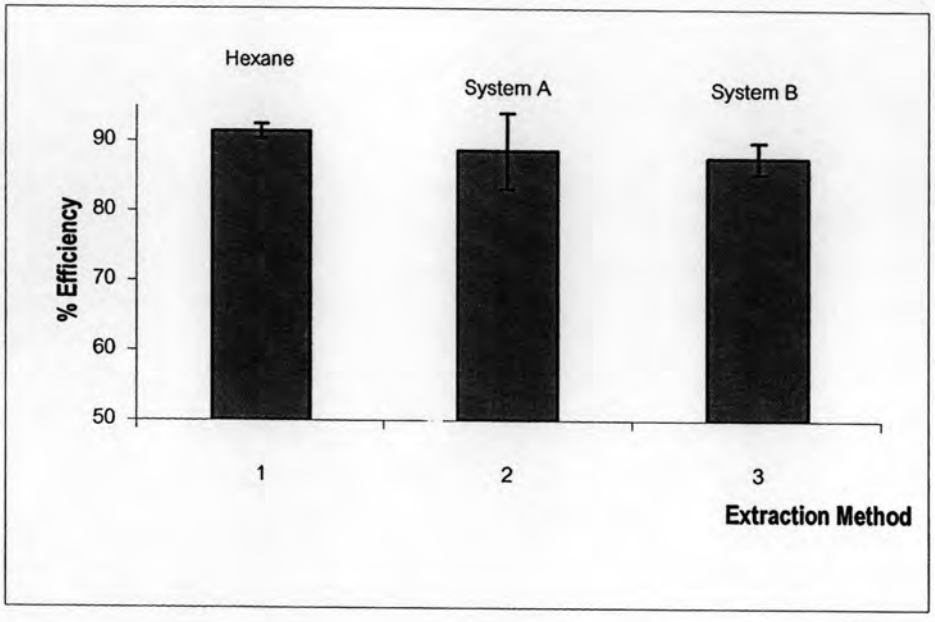


Figure 4.9 Comparison of the extraction efficiency for palm kernel oil using conventional extraction method and surfactant aqueous-based method; System A is the system of mixed 0.1% Alfoterra145-5PO and 3% Comperlan KD at 10% NaCl and System B is the system of mixed 0.1% Alfoterra5-8PO and 3% Comperlan KD at 10% NaCl .

4.3 Oil quality

Due to different characteristics of different vegetable oil, the parameters selected for the quality of the two extracted oil in this study are different. The parameter selected for PKO quality are water content, surfactant penetration, and fatty acid compositions in the free oil phase or extracted oil. The same parameters were also determined for the PKO obtained from hexane extraction for the comparison. The parameters and methods for determination of extracted palm kernel oil are as described in Chapter III.

For the soybean oil obtained by using the system selected from previous study (3% Comperlan KD and 0.1% Alfoterra145-5PO), since the amount of extracted oil is relatively low efficiency and the emulsion tended to be generated, the oil quality parameters was not determined directly from the extracted oil but parameters selected in

this study were analyzed from the aqueous surfactant solution and indirectly referred to the quality of the extraction method. The parameters included surfactant remaining and the amount of protein in the aqueous surfactant solution after extraction process. The first parameter is expected to refer to amount of surfactant penetration to extracted oil phase while the latter one indicates protein loss from residue seed meal. This is important since in the real practice, soybean meal is the major source of protein and can be used for feedstock.

From Table 4.2, the results show that at around 30% up to 50% of the initial concentration of Comperlan KD (3% wt) loss from the surfactant aqueous solution after extraction. While the Alfoterra145-5PO loss from the surfactant aqueous solution in the similar proportion as Comperlan KD. This means that both surfactants partitioned into the oil phase. It may be the reason that why emulsion tend to occur in the free oil phase. This result may not be preferable due to the loss of surfactant and may affect to oil quality. Thus, the surfactant aqueous system is needed to be improved. However, the concentration of protein found in water phase is only in part per million (ppm) level as compared to the amount of protein which can dissolve in water 3.37 g/L, the result can be considered that the protein loss from seed meal is insignificant. Thus for soybean extraction by the surfactant aqueous-based the study further may be needed to improve the system to be less solubilization. However, this approach still has a good point on the less protein loss and residue meal is still high value for feedstock production.

Table 4.2 The parameters indicate soybean oil quality by using surfactant aqueous-based method. (0.1% Alfoterra145-5PO and 3% Comperlan KD at various NaCl concentration that extraction efficiency above 70%)

Parameters	NaCl in the surfactant system (% wt)			
	5.0	7.5	10.0	12.5
Surfactant remaining in water phase For Comperlan KD(%)	1.846±0.169	2.063±0.163	1.443±0.111	1.419±0.054
Surfactant remaining in water phase For alfoterra145-5PO(%)	0.085±0.002	0.067±0.002	0.061±0.001	0.062±0.001
Protein remaining in water phase (mg/L or ppm)	64.17±2.887	60.00±5.000	56.66±5.204	25.83±10.410

Table 4.3 illustrates the palm kernel oil quality from surfactant aqueous-based extraction and from hexane extraction. For general appearance like color and clearness from visual observation, they can consider insignificantly different. However for the water content, it is found that the extracted PKO from both extraction the surfactant aqueous-based and hexane extraction meet the standard that should not exceed 0.5%wt (Gunstone, 2002) but the oil from the surfactant aqueous-based show the better quality from the less water content. Similar to soybean oil, the amount of surfactants Comperlan KD and Alfoterra remaining in water phase were analyzed to indirectly indicate oil quality. The results as shown in Table 4.3 show that almost 2.5%wt reduce from the initial concentration (3%wt) for Comperlan KD which is around 80% of the initial Comperlan KD loss to oil phase. This is quite understandable since Comperlan KD is a surfactant produced from coconut oil which contains similar composition of fatty acid as found in PKO. These would result to partition of Comperlan KD to the extracted oil phase. However, for extended ionic surfactant concentration both Alfoterra145-5PO and 5-8PO were found almost the same concentration as initial concentration in water phase. This means that ratio of surfactant in surfactant aqueous solution has been changed. To confirm the result, the experiment on re-use surfactant solution for extraction the new palm kernel seeds were carried out. The result will be expressed in next topic.

Table 4.3 Comparison of the parameters indicate extracted palm kernel oil quality by hexane extraction and surfactant aqueous- based methods.

Parameters	Commercial Standard*1	Extraction Methods		
		Hexane	Surfactant aqueous –based system	
			System A*2	System B*3
Color	Clear yellow	Clear yellow	Clear yellow	Clear yellow
Water in oil (%wt)	<0.5	0.385	0.191	0.223
Surfactant remaining in water phase (%wt)				
• Comperlan KD	-	-	0.602 ± 0.041	0.536 ± 0.030
• AF 145-5PO	-	-	0.099 ± 0.364	-
• AF 5-8PO	-	-	-	0.090±0.003
Fatty acid (%wt)				
• C12	45-55	49.41	49.52	49.64
• C14	14-18	17.56	17.44	17.47
• C16	6.5-10	9.24	9.17	9.15
• C18:0	1.0-3.0	2.73	2.74	2.74
• C18:1	12.0-19.0	18.18	18.21	18.05
• C18:2	1.0-3.5	2.88	2.92	2.90
• C18:3	ND	ND	ND	ND

Note

*1Codex, 2001.

*2The system of mixed 0.1% Alfoterra145-5PO and 3% Comperlan KD at 10% NaCl

*3 The system of mixed 0.1% Alfoterra5-8PO and 3% Comperlan KD at 10% NaCl

4.4 Re-use of aqueous surfactant solution for new ground seed extraction

This experiment was set up in order to find the extraction efficiency of palm kernel oil by re-use the surfactant solution or carried out the extraction for the second batch of new ground seed as mentioned earlier. Figure 4.9 comparisons the efficiency between first extraction and in the second extraction by re-used surfactant solution with the new palm kernel seed in the same condition; grain size 35-65 mesh, contact time 30 minutes and 1 g of palm kernel load in 10 ml of re-use surfactant solution. Both of surfactant system A (0.1% Alfoterra145-5 PO and 3% Comperlan KD) and system B (0.1% Alfoterra5-8PO and 3% Comperlan KD) at 10% NaCl concentration for both systems were carried out in this part. In addition the amount of Comperlan KD partitioning into oil phase from the second batch of extraction was also studied in order to confirm that this non-ionic surfactant move in to oil phase or not.

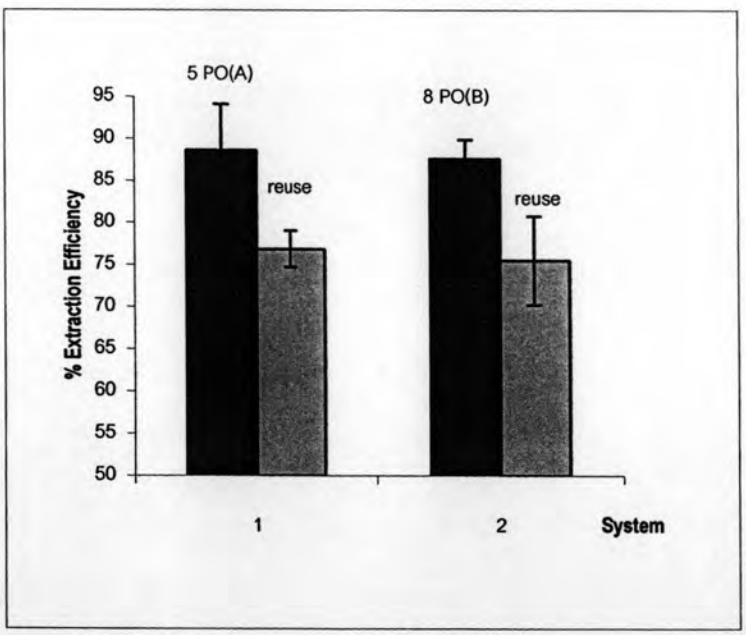


Figure 4.10 Comparison of the extraction efficiency between first batch extraction by the systems with 2 surfactant systems A and system B at 10% NaCl and the re-use surfactant solution for the second batch

Figure 4.10 shows that the efficiency of extraction by re-use surfactant still looks promising up to 77% for both surfactant systems, however, they were still lower than the extraction by the fresh surfactant system. In addition, the amount of Comperlan KD remaining in water phase after the second extraction was found 0.083 $\pm$ 0.039%. This result confirms that Comperlan KD from surfactant aqueous solution partition into in the free oil phase. However, since this surfactant is considered as edible surfactant, this will not affect the quality of extracted oil, only the loss of the surfactant may cost the extraction process. In addition, the toxicology data of Comperlan KD revealed that no evidence data of carcinogenic activity for male rat in vitro. (http://ntp-server.niehs.nih.gov/index.cfm?objectid=070AB52E-BD83-93EB-0E12218BE5A17FDC). Furthermore, information reveals that the non-ionic surfactant Comperlan KD that used in this research produced by Congins Company which claimed that this product is obtained an eco- label as "Good environmental choices" by the Swedish Society for Natural Conservation. Therefore, although this surfactant exists in oil phase, it can be considered still "safe for health", especially, as compared to hexane.