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THE BEHAVIOR OF MOLASSES AS A MICROBIAL NUTRIENT IN THE ABSENCE OF MICROBES

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ABSTRACT

In this work the effect of molasses, as a bacterial nutrient, on the pH and surface tension of the aqueous phase, IFT, and phase behavior after one week contact time was studied at 60°C. The results have shown that the pH value, surface tension of molasses solution, and the IFT were decreased as the molasses concentration increased. These properties as well as the phase behavior are function of NaCl concentration, contact time, pressure and initial pH value of the molasses solutions.

INTRODUCTION

Microbial enhanced oil recovery (MEOR) process design requires the integrated efforts of biological, chemical, and petroleum disciplines in order to become a fully developed enhanced oil recovery technology. MEOR is a potentially attractive way to recover additional oil from a reservoir beyond conventional operations [1-3]. The process is inexpensive and has advanced from laboratory based studies [4-15] to field applications [16-20].

MEOR can occur through the in situ formation of normal metabolic products that result from the use of a nutrient by reservoir microorganisms or specially selected natural bacteria. In this case the MEOR fluid system consists of a nutrient or a nutrient and microbes. The nutrient is to feed the bacteria and is injected into the reservoir with and before bacteria by an interval of time which may reach one week [21]. Although it is assumed that fermentation of sugar such as sucrose in molasses by microorganisms causes the production of chemicals that can improve oil mobilization, the actual chemicals and the mechanisms involved in this process have not been fully identified.

The individual and combined effects of the separate components of the system on the pH, surface tension, interfacial tension (IFT) and phase behavior at ambient and reservoir conditions need more investigation.

In this study, in the absence of bacteria, the effect of molasses as a microbial nutrient on the pH, surface tension of the aqueous phase, and the phase behavior was studied. The effect of the following parameters on these properties was investigated: (i) molasses concentration, (ii) NaCl concentration, (iii) pressure, and (iv) initial value of the pH.

EXPERIMENTAL WORK

The laboratory study in this work was divided into two parts. The first part was to study the effect of the above mentioned parameters on the IFT between the molasses solutions and Ratawi crude oil, and the surface tension and the pH of the molasses solutions. The second part was to investigate the effect of molasses solutions on the phase behavior of Ratawi crude oil – molasses solutions at different salinity, pH's and pressures. The API degree of Ratawi crude oil is 28 and the viscosity varies with shear rate as shown in Fig.1.

It is worthwhile to mention here that the used fluids were analyzed for bacterial content before and after mixing and equilibration; it was found that there is no bacteria in the used solutions.

Through out this work. The fluid samples were analyzed in two different laboratories. Each sample of the oil, molasses solution, or fluid was plated on two plates of each of Blood agar (enriched media to support growth of most microorganisms), MacConkey's agar (selective and differential media to support growth of specifically gram-negative organisms) and Sabourond agar (selective media for yeast, and moulds). One of each agar and MacConkey's agar plates were incubated aerobically and the others were incubated anaerobically using anaerobic jar. Blood and MacConkey's agar plates were incubated at 37 °C and examined daily for 3 days. Sabourond agar plates were incubated at room temperature (25 °C) and examined daily for at least 7 days. This technique was followed in one of the laboratories. The other laboratory used the technique followed by M. Khairy et al [22].

The surface and the IFT were measured by using the ring method. The readings were displayed in dyne/cm. The sample vessel was cleaned before each measurement. Equal volumes of oil and molasses solutions were put in graduated cylinders. The oil and the molasses solutions were separated using a syringe after they had been shaken and left to equilibrate for predetermined time at the required temperature and pressure.

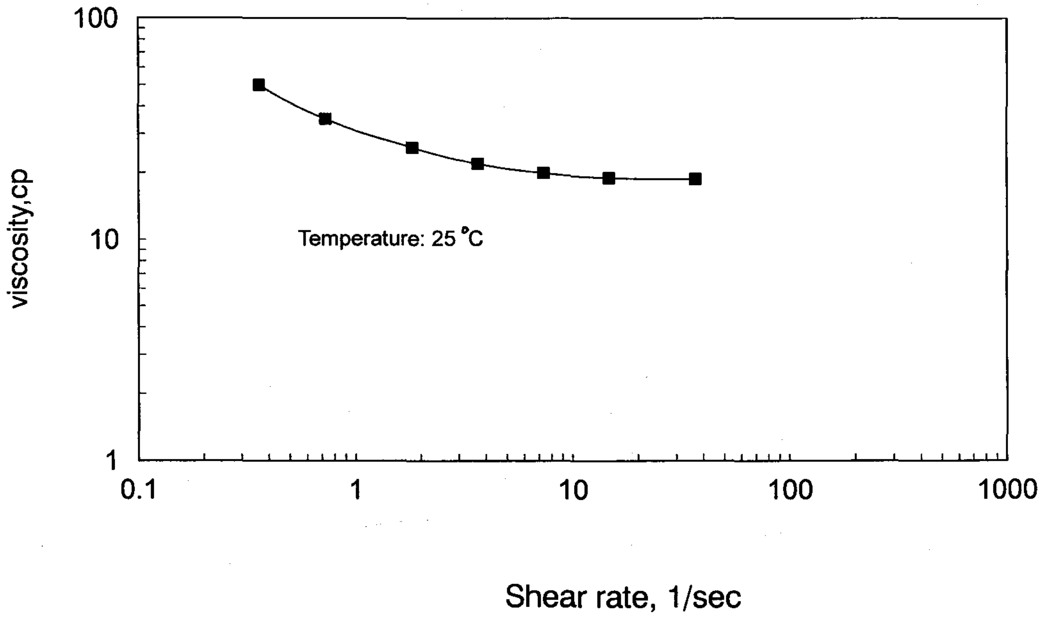

Fig. 1. Crude oil viscosity vs. shear rate.

RESULTS AND DISCUSSION

The effect of molasses solutions on the pH and surface tension of the aqueous phase, IFT, and phase behavior after one week contact time was studied at 60 °C. The effect of molasses and NaCl concentration, contact time, pressure, and initial value of the pH will be discussed.

Effect of Molasses Concentration and Salinity

Fig. 2 shows the effect of molasses and NaCl concentrations on the pH of the molasses solutions after one week contact time at 60°C and 1.0 atmosphere pressure. The figure indicates that the pH decreased as the molasses concentration increased, from zero to around 3% at any NaCl concentration.

After one week contact time, the NaCl concentration affects the pH of the molasses solutions. However, there is no clear trend to the effect of salinity. Normally, the NaCl does not affect the pH value, but this effect on the pH value may be attributed to the transportation of some acidic components from the crude oil to the molasses solutions.

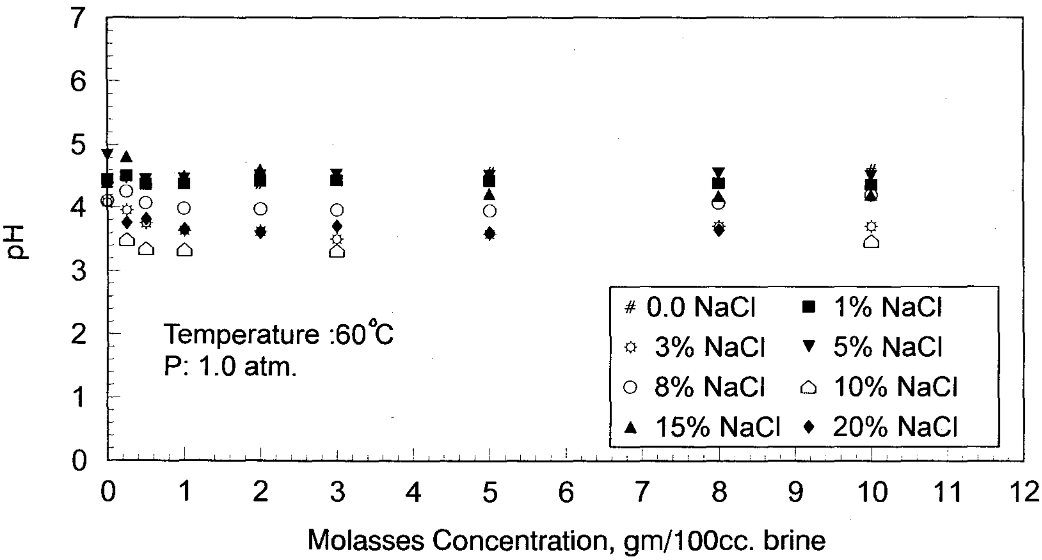

Fig. 2. Effect of molasses concentration on the pH of the molasses solution sat different salinity after one week contact time at 60°C

The surface tension of the molasses solution with different molasses concentration and salinity after one week contact time at 60 °C ,and 1.0 atmosphere pressure was plotted versus molasses concentration in Fig.3. The surface tension decreased as the molasses concentration increased. The effect of NaCl on the surface tension may be due to the change in the composition of molasses solution due to the solubility change of the acidic components from the crude oil as the salinity changes. This is clear from the behavior of the pH in Fig.2.

The IFT was plotted against molasses concentrations of different salinity at 60°C and 1.0 atmosphere pressure in Fig. 4. The figure illustrates that the IFT decreased as the molasses concentration increased at all NaCl concentrations studied, and there is no trend to the effect of NaCl on the IFT. At 5 and 8% NaCl there are bottoms and tops in the IFT as molasses concentration increased. However, the change in the IFT with salinity may be due to the change of both the ionic strength of the solutions and the composition of the oil and the molasses solution after the equilibration between them had established.

The variation in the aqueous phase volume fraction is shown in Fig.5 at 1 and 5% NaCl, where the volume of the oleic (oil + emulsion) increased at 1% NaCl concentration in the molasses concentration ranges from zero to 1.0%. The change in the composition of the aqueous phase was confirmed by the changes of the measured properties.

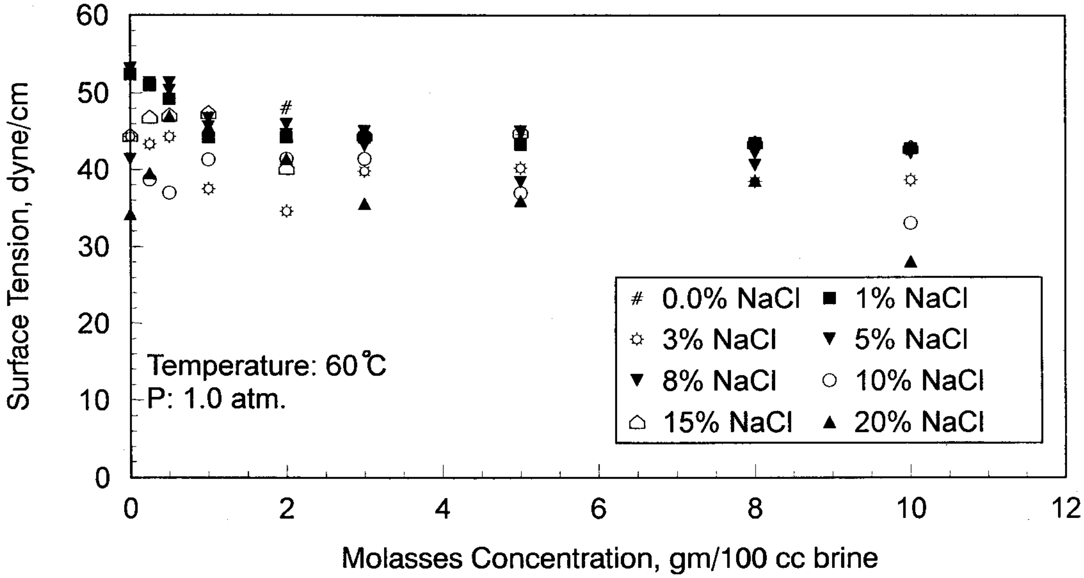

Fig. 3. Effect of molasses concentration on the surface tension of the molasses solutions of different salinity after one week contact time at 60°C

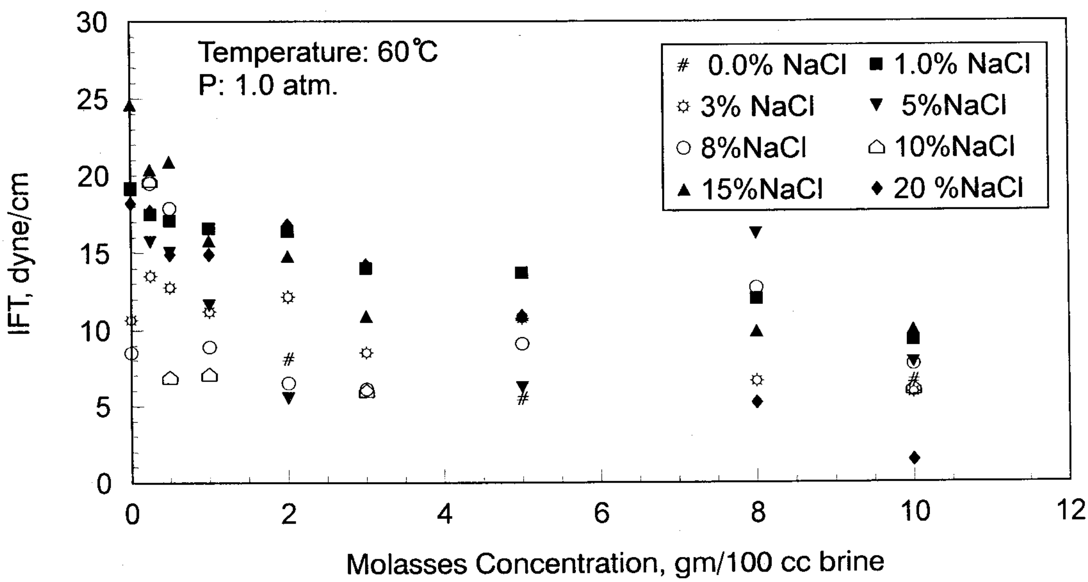

Fig. 4. Effect of molasses concentration on the IFT between ratawi oil and the molasses solutions of different salinity after one week contact time at 60°C

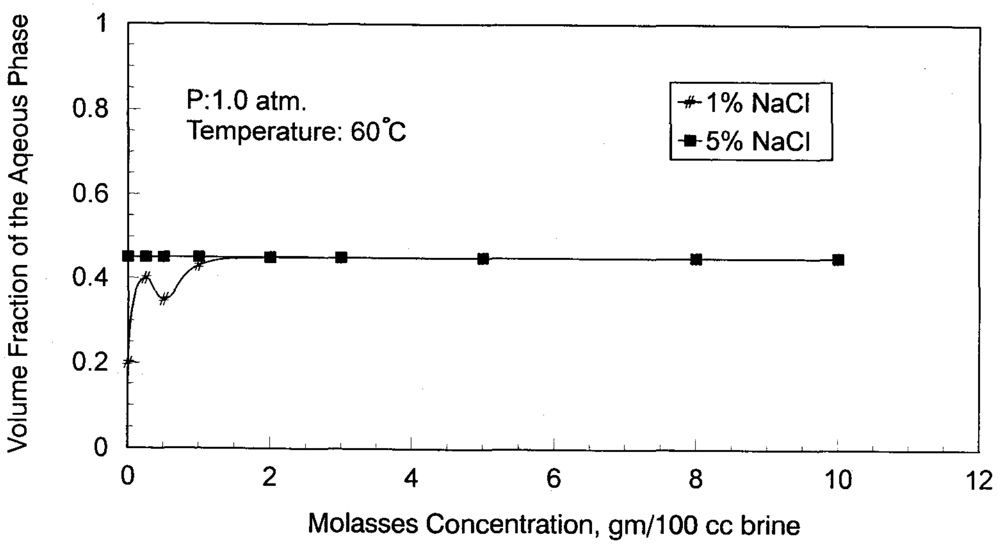

Fig. 5. Effect of NaCl concentration on the aqueous phase volume fraction at 60°C and 1 atmosphere pressure.

Effect of Contact Time

Figs. 6-11 show the effect of contact time on the pH and surface tension of molasses solutions, and IFT. Fig. 6 is a plot of the pH against molasses concentration at zero time and after one week contact time at 60°C, 10% NaCl and 1.0 atmosphere pressure. After one week contact time between molasses solutions and crude oil, the pH decreased compared to that at zero time .This reduction in the pH is attributed to the transportation of acidic components from the crude oil to the molasses solution during equilibrium establishment. Figs. 7 –9 are the same as Fig. 6, but at salinity 5, 8 and 15% NaCl. These figures show no effect on the pH except at zero molasses concentration. The figures 6,7,8 and 9 indicate that the reduction in the pH after one week contact time is function of both NaCl and molasses concentrations.

The surface tension was plotted versus molasses concentration, at zero time and after one week contact time at 60 °C, 10% NaCl and 1.0 atmosphere pressure, in Fig. 10. The decrease in the surface tension after one week contact time may be due to the change in the aqueous phase composition. This may be a result of the solubility of acidic components from the oil in the aqueous phase.

The reduction in the IFT after one week contact time compared to that at zero time, as shown in Fig. 11, is attributed to the reduction of the interfacial forces due to the change of the composition of the crude oil and molasses solution during equilibrium processes.

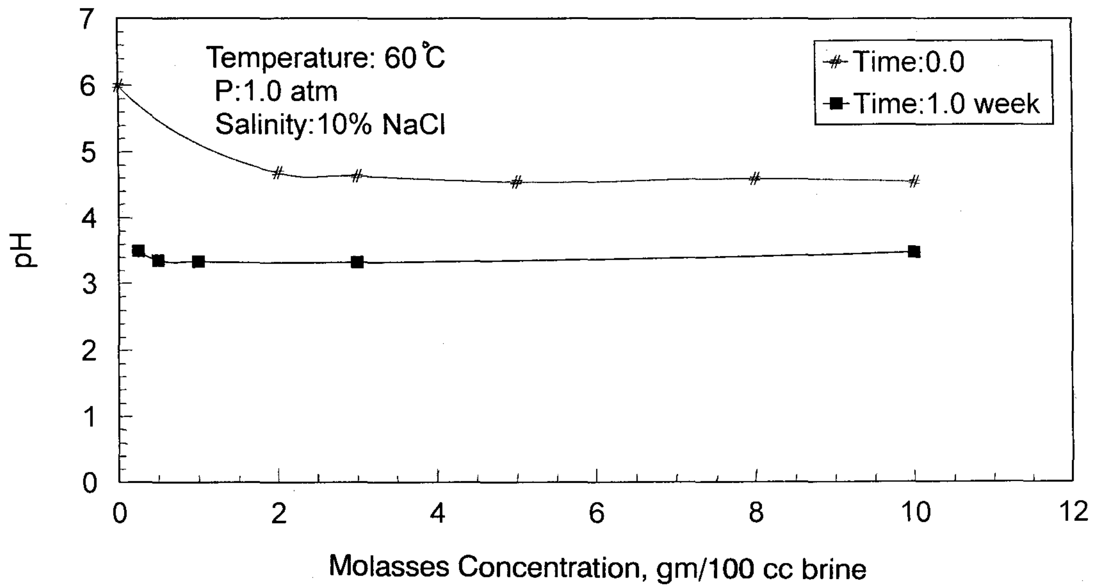

Fig. 6. Effect of contact time on the pH of 10% NaCl molasses solutions at 60°C

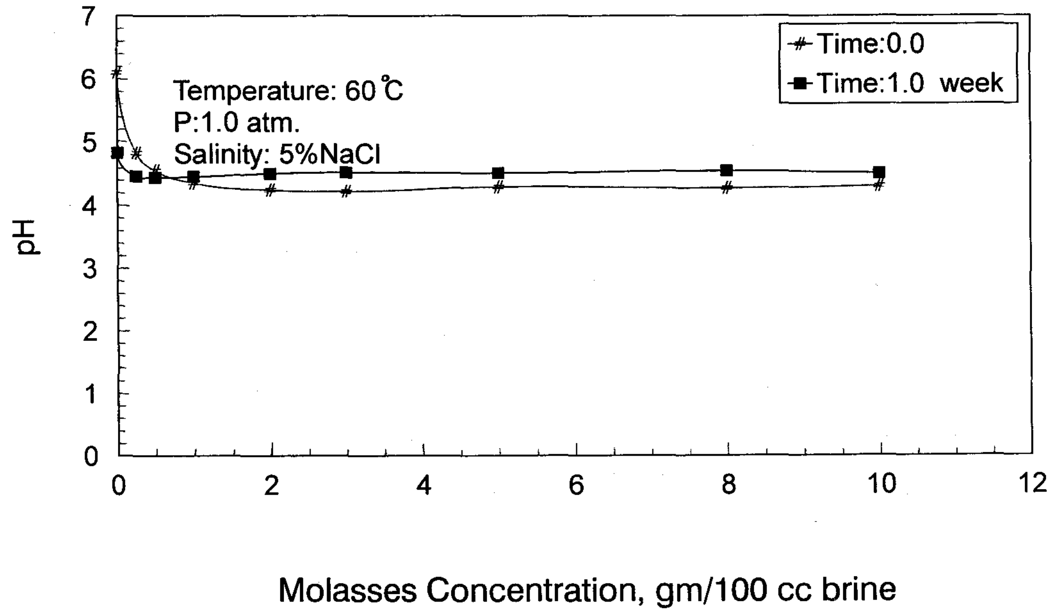

Fig. 7. Effect of contact time on the pH of 5% NaCl molasses solutions at 60°C

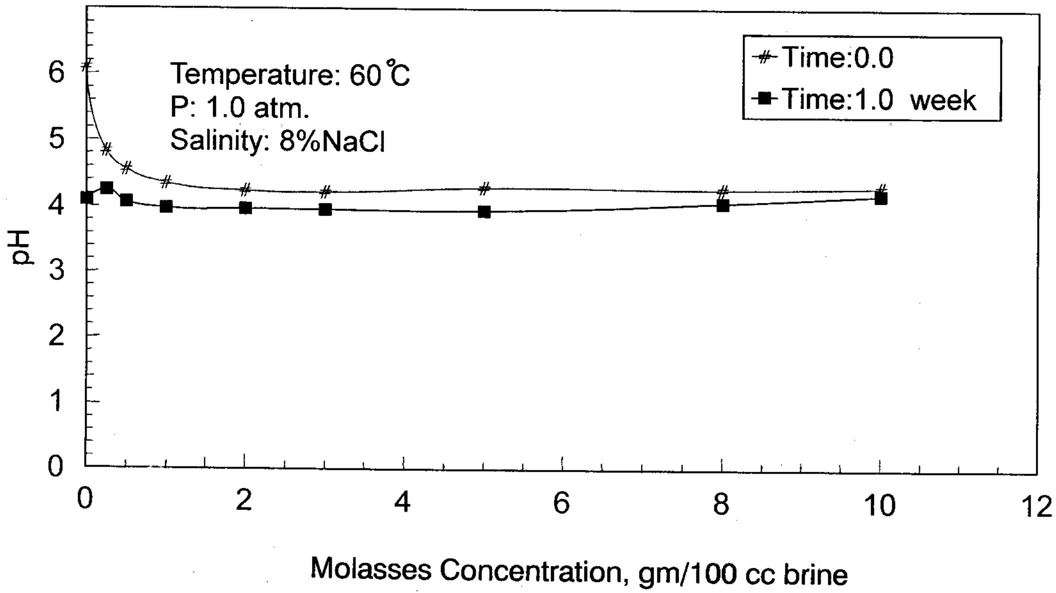

Fig. 8. Effect of contact time on the pH of 8% NaCl molasses solutions at 60°C

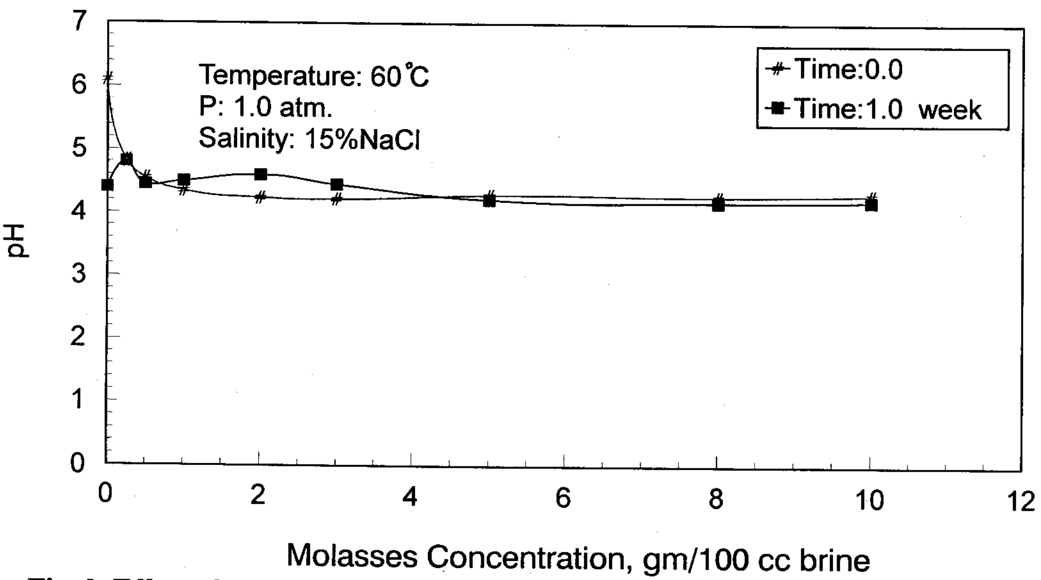

Fig. 9. Effect of contact time on the pH of 15% NaCl molasses solutions at 60°C

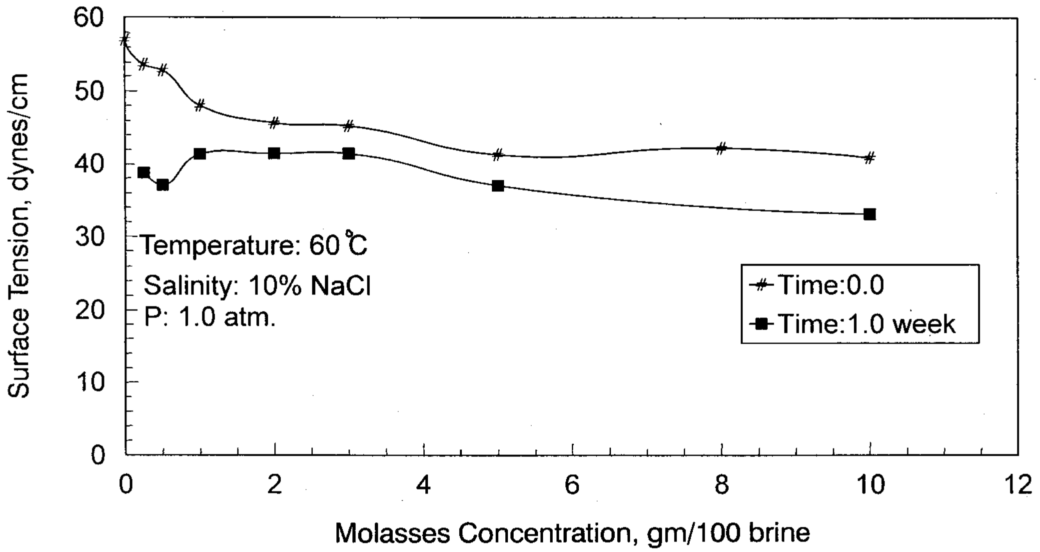

Fig. 10. Effect of contact time on the surface tension of 10% NaCl molasses solutions at 60°C

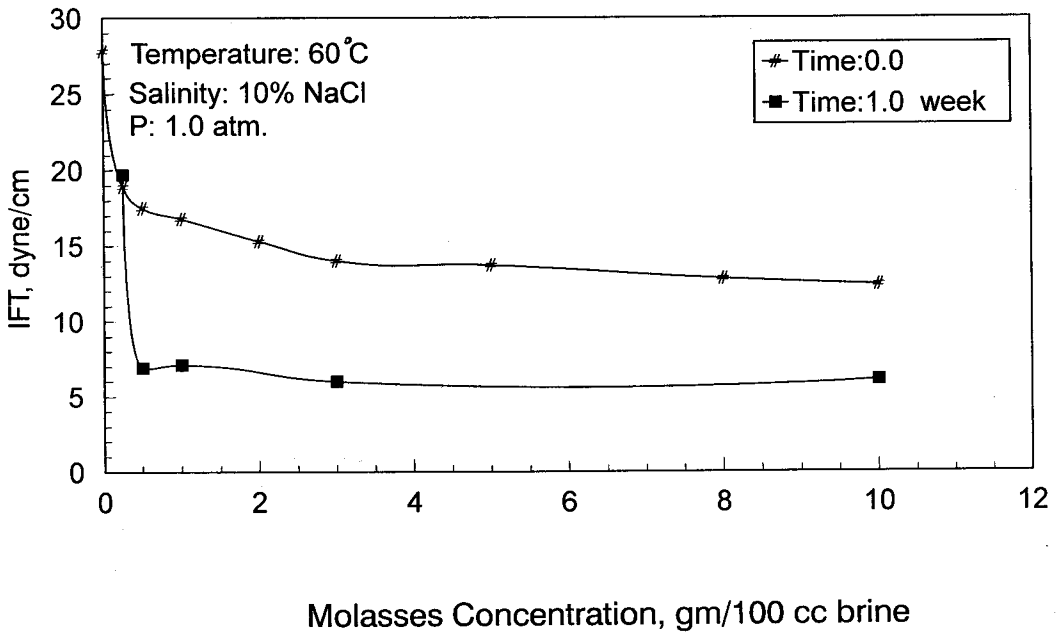

Fig. 11. Effect of contact time on the IFT between 10% NaCl molasses solutions and crude oil at 60°C

Effect of Pressure:

Figs. 12 and 13 illustrate the effect of pressure on the pH and surface tension of zero, 1.0 and 3% molasses solutions of 1.0% NaCl concentration at 60°C after one week contact time.

Fig. 12 shows that the pH increased as the pressure increased to 200 atmosphere. This means that, in this case, acidic components transported from the aqueous phase to the oleic phase. This is the opposite of that happened at 1.0 atmosphere as the contact time increased from zero to one week. This indicates that the partitioning of the system components is strong function of pressure.

Fig. 13 is a plot of the surface tension of zero, 1.0 and 3% molasses concentration solutions versus pressure at 60°C and 1.0% NaCl concentration. The surface tension increased as the pressure increased to 200 atmosphere. This is due to the change in the aqueous phase composition, which is approved, by the change in the color of the aqueous phase to dark.

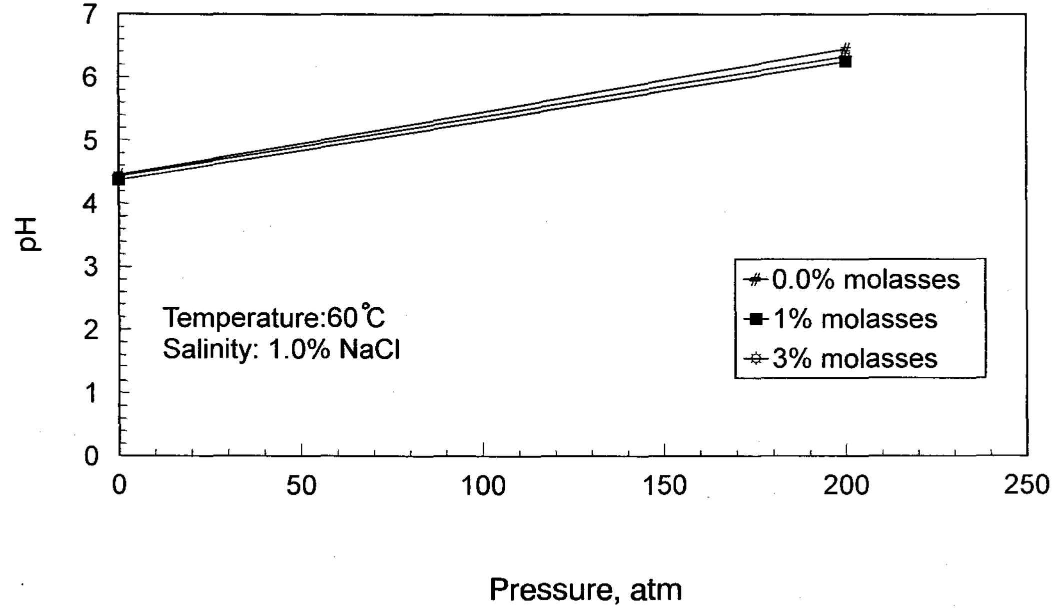

Fig. 12. Effect of pore pressure on the pH of the molasses solutions of 1% NaCl concentration after one week contact time with crude oil at 60°C

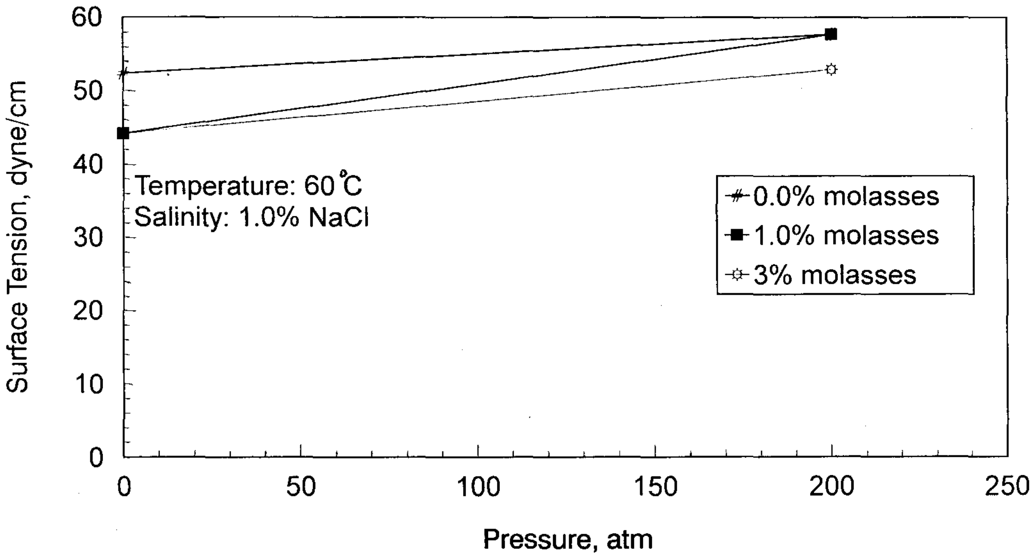

Fig. 13. Effect of pore pressure on the surface tension of molasses solutions of 1% NaCl concentration after one week contact time with crude oil at 60^0C

The volume change as a function of pressure were plotted in Fig.14. The figure indicates that there is a reduction in the aqueous phase volume. This reduction is almost constant in the presence of molasses. However, the aqueous phase volume is largely affected by the pressure in the absence of molasses.

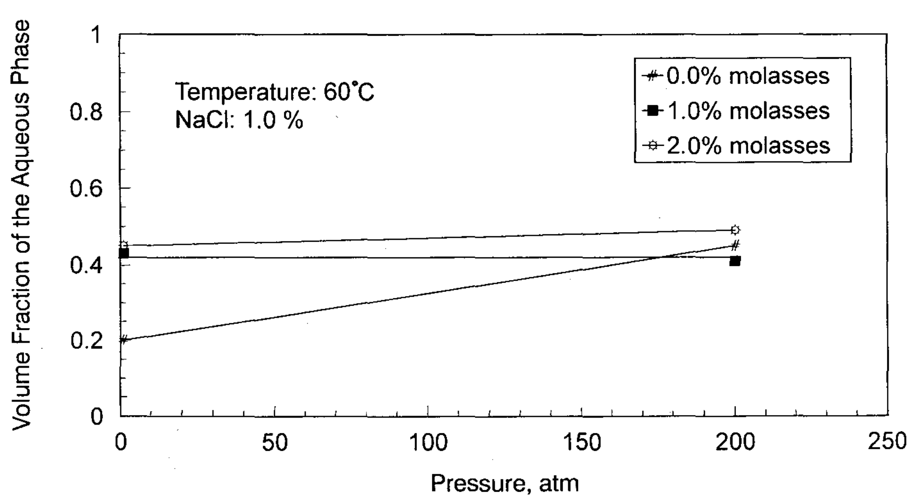

Fig. 14. Effect of pressure on the aqueous phase volume fraction of 1% NaCl molasses solutions at 60^0C

The IFT between the crude oil and molasses solutions of zero, 1.0 and 3.0% molasses concentration is plotted against the pressure at 60°C and 1.0% NaCl concentration in Fig. 15. The increase in the IFT with pressure is attributed to the change in the composition of the crude oil, molasses solution, and interfacial layer during the equilibration processes due to the partitioning of the system component in the aqueous phase, oleic phase, and at the interfaces.

Effect of the Initial pH Value

Figs. 16-18 show the effect of the initial pH of the molasses solutions on the final pH, surface tension of the molasses solution, and the IFT after one week contact time. Fig. 16 shows that as the initial pH increased, the final pH increased also. However, the difference between the initial and final pH increased with increasing the initial pH. This means that the amount of acidic components transported from the oil to the aqueous phase increased as the initial pH increased.

Figs. 17 and 18 show that there are changes in the composition of both the aqueous phase, the crude oil, and interfacial film due to the change in initial pH of the molasses solutions.

Fig. 19 indicates that the size of the formed emulsion increased as the initial pH of the molasses solutions increased from 7 to 9.2.

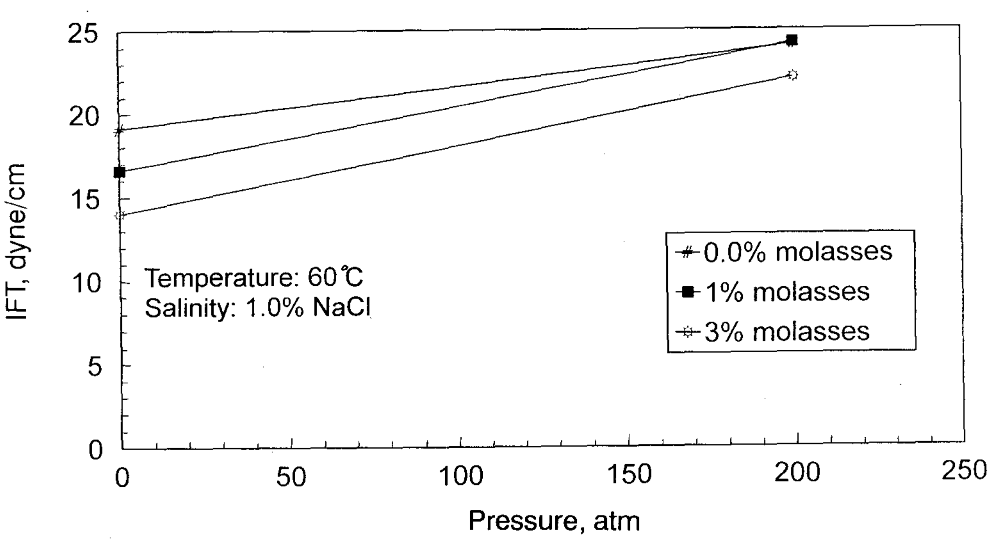

Fig. 15. Effect of pore pressure on the IFT between crude oil and molasses solutions of 1% NaCl concentration after one week contact time at 60°C

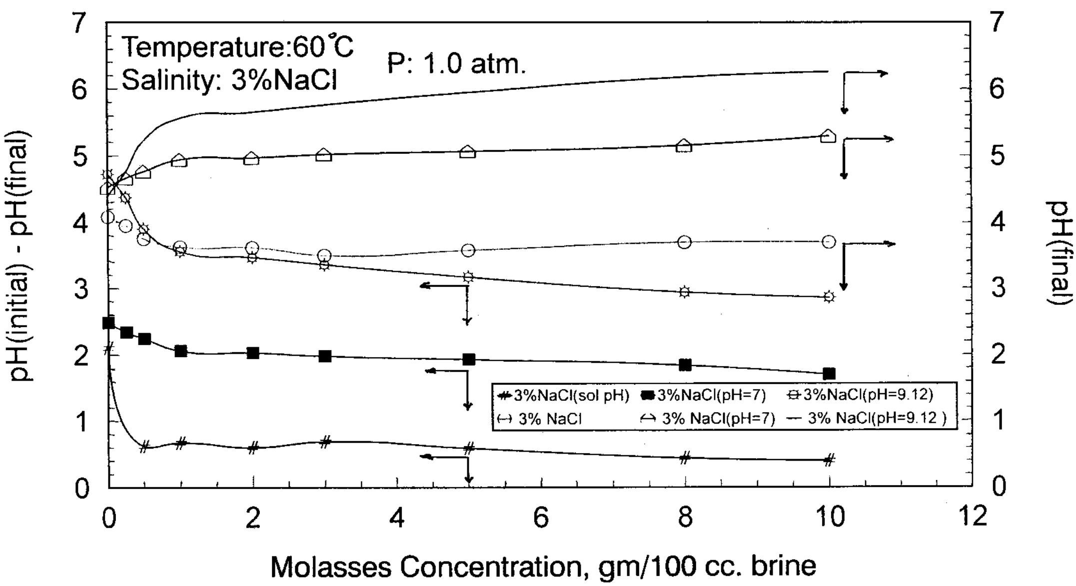

Fig. 16. Effect of the initial pH value of 3% NaCl molasses solutions on the pH after one week contact time at 1.0 atm. and 60°C

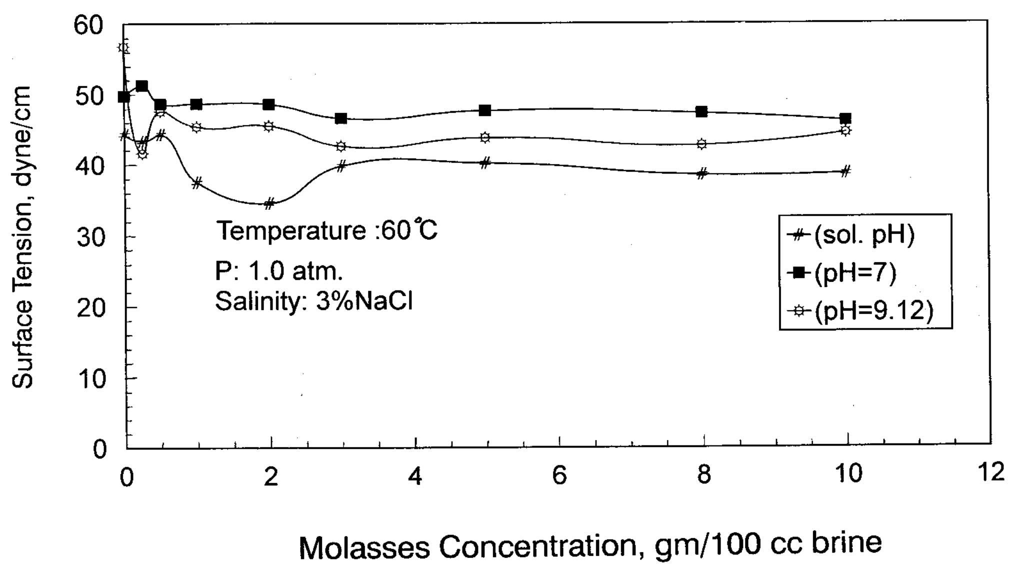

Fig. 17. Effect of the initial pH value of 3% NaCl molasses solutions on the surface tension of the molasses solutions after on e week contact time at 1.0 atmosphere and 60°C

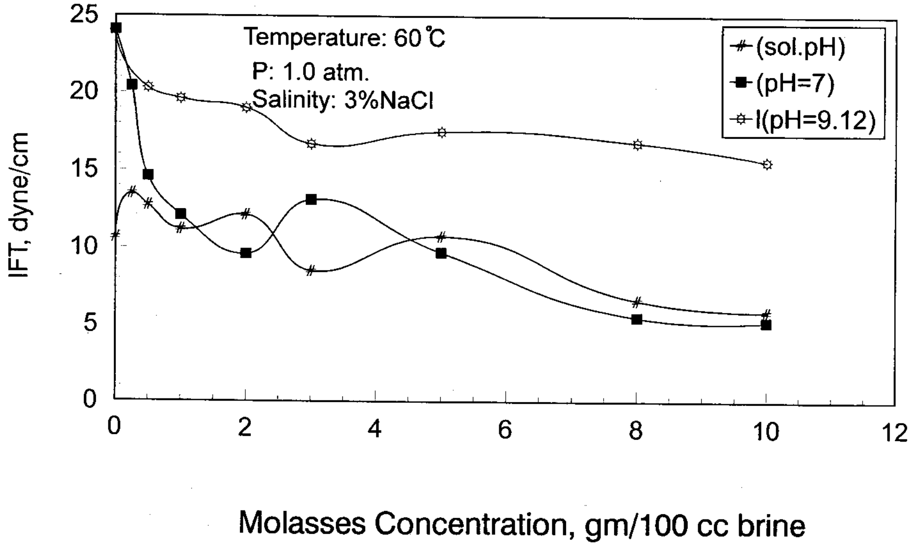

Fig. 18. Effect of the initial pH value of 3% NaCl molasses solutions on the IFT after one week contact time at 1.0 atmosphere and 60^{0}C

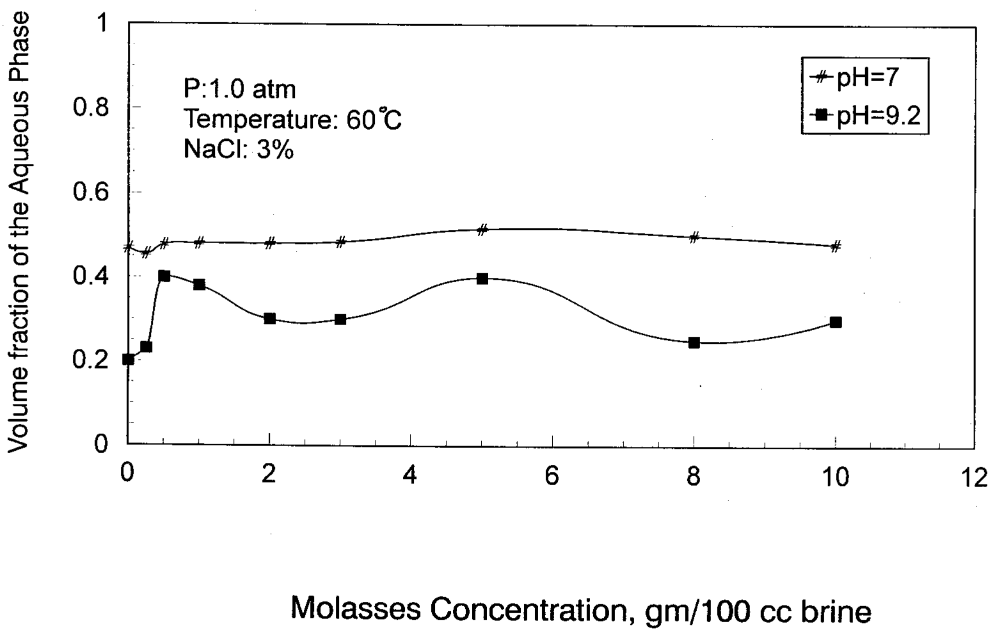

Fig. 19. Effect of the intial pH value on the aqueous phase volume fraction at 60^{0}C and 1.0 atmosphere.

CONCLUSIONS

Based on the experimental results, the following conclusions were arrived at:

The pH, surface tension of the molasses solutions and IFT decreased as the molasses concentration increased .

At one atmosphere and 10% NaCl, the pH and surface tension of the molasses solution and IFT decreased as the contact time increased from zero to one week at all molasses concentrations; at salinity 5, 8 and 15% NaCl, there was no effect on the pH except in the molasses concentration range from zero to .5%.

The pH, surface tension and IFT increased as the pressure increased from 1.0 to 200 atmosphere.

As the initial pH of the molasses solution increased, the difference between the initial and the final pH of the molasses solution increased. This means that the amount of acidic components transferred to the aqueous phase increased

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