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Deteriorated Citrus Limetta for the Application of Enhanced Oil Recovery

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Abstract: ***Citrus fruits are rich in citric acid content as well as highly medicinal valued fruits. Citrus fruits have the highest possibility of deterioration through microorganisms due to the presence of sugars, polysaccharides, organic acids and nitrogenous components. The chemical constituents in the Citrus fruits will serves as the food for the growth of microbes. In this research article, the competence of deteriorated Citrus limetta was examined through Oil Displacement Area (ODA) test, Emulsification Index (E_{24}) and sand pack column operation. The deteriorated Citrus limetta peels and pulp were individually investigated. The results of Oil Displacement Area test and Emulsification Index indicated that the deteriorated pulp of Citrus limetta has good compatibility with crude oil than the peels of Citrus limetta. The percentage of oil displacement achieved by the pulp of Citrus limetta was 44.89 % and emulsification index was found to be 80 %. The efficacy of deteriorated Citrus limetta pulp was confirmed in the sand pack column with the oil recovery percentage of 32.05 %.***

Keywords: Citrus limetta; Deteriorated, Microorganisms, Oil Recovery

I. INTRODUCTION

Most of the *Citrus* fruits are available nearly in all season and fruit shop in our country. There are varieties of *Citrus* fruits namely *Citrus natsudaidai, Citrus medica, Citrus bergamia, Citrus sinensis, Citrus medica var. sarcodactylis, Citrus limetta, Citrus tangerine, Citrus aurantiifolia, Citrus clementine, Citrus reticulata* and *Citrus paradisi.* The fruits get deteriorated in many possible situations such as the fruits are stored in large quantities to increase the demand, during transportation, dumping of many fruits in an improper container, damage of fruits in the time of harvest and fruits illnesses [2].

The *Citrus* fruits have many medicinal values and acts as remedies for many diseases such as kidney stone, common cold ad delay the sign of aging. The waste pulp and peels can be used as a molasses, essential oils, feed yeast, citric acid and manure however the outcomes may take either a long time or many process steps for the waste management. The *Citrus* fruit of microbial contaminated or illness or diseased fruit cannot be used for feedstock or manure due to the harm of microbes in animals or plants [3, 4].

Enhanced oil recovery is termed as tertiary recovery which recoveries the residual crude oil. Enhanced oil recovery comes into play when the primary and secondary recovery becomes incompetent in the crude oil reservoir. Primary recovery of crude oil was carried out by utilizing natural forces and secondary recovery was accomplished by water flooding mechanism. Enhanced oil recovery uses various methods depending upon the reservoir characteristics. The various enhanced oil recovery methods are chemical flooding, thermal flooding and gases flooding [4].

In the research article, *Citrus limetta* deteriorated by microorganisms which cannot be used for purpose of manure or animal feedstock was examined. The peel and pulp of the microbes contaminated *Citrus limetta* was extracted and subjected for the oil displacement and emulsion test. The efficiency of test samples obtained from decayed *Citrus* fruit was tested in the sand pack column for the oil recovery.

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II. MATERIALS AND METHODS

A. Materials Required

The deteriorated *Citrus limetta* were collected from the fruit shop. The crude oil was collected from the Indian oilfields. The properties of crude oil were listed in the table 1.

Petri-plate and glass bottle were required for the study of oil displacement test and emulsion test. Glass column and sieved sand particle of specific size were necessary for the experimental study.

Table 1 Specification of crude oil

Properties of crude oil	Observation
Color	Dark Brown
˚API	36.35˚
Specific gravity	0.843
Kinematic viscosity (stokes) at 50 ˚C	0.6823
Kinematic viscosity (stokes) at 75 ˚C	0.2149
Kinematic viscosity (stokes) at 100 ˚C	0.1149
Dynamic viscosity (cP) at 50 ˚C	58.004
Dynamic viscosity (cP) at 75 ˚C	17.837
Dynamic viscosity (cP) at 100 ˚C	9.537

B. Methodology

Five samples of same size deteriorated *Citrus limetta* were selected. The samples such as 1, 2 and 5 were extremely decayed whereas samples 3 and 4 were moderately decayed. Now, the experiment was conducted by using the deteriorated peels of samples from 1 to 4 fruits while the 5th sample analysis was made with the decayed pulp from *Citrus limetta*.

The samples from 1 to 4 deteriorated peels were immersed in the 100 ml water and boiled in the heating mantle at 80 ˚C for the extraction of chemicals compounds from *Citrus limetta*.

The microorganism decayed pulp of 5th sample was squeezed as the test sample. Now, the sample 1 and 3 will be the extracted substance from *Citrus limetta* for the time period of 1 hour. Then, the sample 2 and 4 will be the extracted substance from the decayed peels in the time duration of 2 hours. The 5th sample will simple be the deteriorated pulp of *Citrus limetta*.

Oil Displacement Area (ODA) Test

20 ml of distilled water was taken in the Petri-plate and 2 ml of crude oil was added to center of the plate. 0.2 ml of test sample was gently placed on the center of oil layer. The displaced diameter is measured after 30 seconds [1].

Emulsification Index (E24)

The E_{24} of culture supernatant was determined by adding 2 ml of crude oil and 2 ml of the test sample in test tube, vortexing at high speed for 2 minutes and allowed to stand for 24 hours. Measure the height of emulsion layer, after 24 hours [1, 4]. E_{24} was calculated using the following formula:

E_{24} = (ht. of emulsion layer / ht. of total solution) ×100

Sand Pack Column Operation

A sand pack column was designed to determine the efficiency of test sample in enhanced oil recovery process. A glass column was made with 12 cm in length and 3.5 cm in diameter. The column was packed with sand particle of 20 mm size and to achieve uniform packing, the sand was poured gently in the column as shown in the figure 1 [5, 6].

The column was flooded with brine (3% Nacl) and ensures that the column was 100% saturated. Then, the column was saturated with crude oil in the same way as brine, until residual brine saturation was reached. Initial oil saturation (S_{oi}) was calculated by measuring the volume of brine displaced by oil saturation, also called original oil in place (OOIP). Initial oil recovery was done by water flooding with brine, so the sand pack column was again flooded with 10-11 Pore volume of brine until there was no more oil found in the effluent, that is the residual oil saturation (S_{or}) was reached [4, 5].

0.5 Pore volume of test sample was passed through the column similar to brine and oil and incubated for 24 hours, then the column was again flooded with brine. Discharges from the column were collected to measure the amount of oil recovered using test sample [6, 7]. The percentage of oil recovered was calculated as follows,

Figure 1 Experimental setup of sand pack column

Initial Water Saturation, S_{wi} (%) = ((PV – OOIP)/PV) ×100

Initial Oil Saturation, S_{oi} (%) = (OOIP/PV) ×100

Residual Oil Saturation, S_{or} (%) = ((OOIP – S_{orwf})/OOIP) ×100

Additional Oil Recovery,

AOR (%) = (Oil recovered using test sample / Oil in column after water flooding) ×100

AOR (%) = (S_{ortsf} / (OOIP – S_{orwf})) ×100

Where,

Pore Volume (PV) (ml) = Volume of brine required to saturate the column

Original Oil in Place (OOIP) (ml) = Volume of brine displaced by oil saturation

S_{orwf} (ml) = Oil recovered after water flooding

S_{ortsf} (ml) = Oil collected over residual oil saturation after test sample flooding

III. RESULTS AND DISCUSSION

Oil Displacement Area (ODA) test

The test samples were subjected to oil displacement area test and the oil clear zone was measured. The percentage of oil displacement was calculated by dividing the diameter of clear zone to the diameter of the oil zone and multiplied by 100. Figure 2 shows the ability of the test sample to displace the crude oil.

Table 2 shows the percentage of oil displacement corresponding to the test samples. The 5th sample showed better oil displacement than the other test samples. The sample 2 and 4 showed more displacement area than sample 1 and 3 due to the difference in time duration during the extraction process.

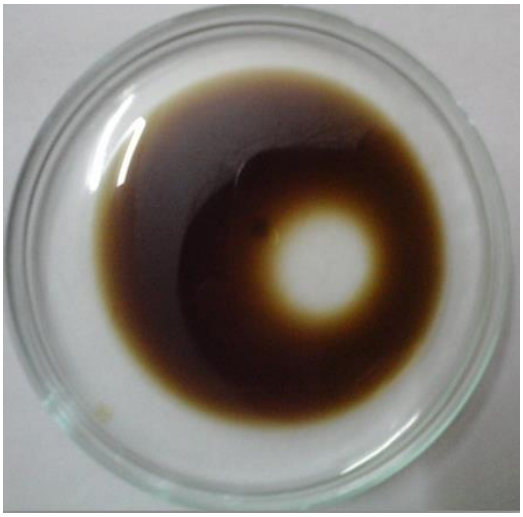

Figure 2 Oil displacement of a test sample in the crude oil

Table 2 Oil displacement area test

Test samples	Diameter of Clear zone (cm)	Diameter of Total zone (cm)	Percentage of oil displacement zone (%)
1	0.4	5.1	7.84
2	1.2	5.3	22.64
3	0.5	4.8	10.42
4	1.7	5.2	32.69
5	2.2	4.9	44.89

Emulsification Index (E24)

Equal volume of crude oil and test sample were mixed and the emulsifying ability of the test samples was noted through height measurement. Figure 3 shows the emulsion test of all the five test samples with crude oil. Table 3 shows the test samples emulsion stability after 24 hour time period. Sample 5 indicated good emulsification stability with the crude oil than the other samples. The results of oil displacement test and emulsification index were found to be approximately similar. Figure 4 shows the graph of oil displacement test and emulsification index with respect to the test samples.

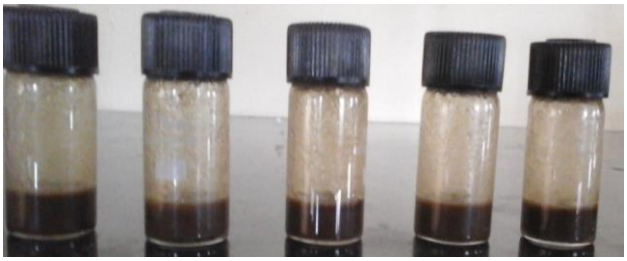

Figure 3 Emulsion tests of test samples and crude oil

Table 3 Emulsification Index analysis of test samples

Test samples	Total height (cm)	Emulsion height (cm)	Emulsification Index (E_{24})
1	1.2	0.4	33.33
2	1.1	0.6	54.54
3	1.1	0.5	45.45
4	1.1	0.7	63.64
5	1	0.8	80

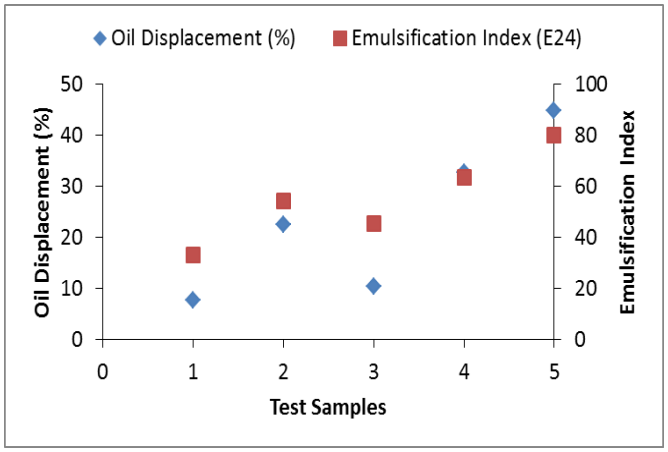

Figure 4 Analysis of test samples through oil displacement test and emulsification index

Sand Pack Column Analysis

The sand pack column operation was performed with the test samples for enhanced oil recovery. Pore volume of the column was in the range of 17.3 to 18.9 ml besides OOIP from 13.7 to 15.5 ml. The residual oil saturation was achieved in the sand pack column between 51.82 to 65.1 %. The test sample 5 shows an additional oil recovery of 32.05 % among the other test samples. The sample 2 and 4 shows a slightly more oil recovery than sample 1 and 3 due to the better extraction of deteriorated *Citrus limetta*.

Table 4 Enhanced oil recovery of test samples in the sand pack column

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
PV (ml)	17.3	18.1	18.9	17.9	18.4
OOIP (ml)	14.9	13.7	14.4	15.5	14.3
S_{orwf} (ml)	5.2	6.6	5.9	6.1	6.5
S_{ortsf} (ml)	0.5	1.2	0.8	1.8	2.5
S_{oi} (%)	86.13	75.69	76.19	86.59	77.72
S_{wi} (%)	13.87	24.31	23.81	13.41	22.28
S_{or} (%)	65.1	51.82	59.03	60.64	54.54
AOR (%)	5.15	16.90	9.41	19.15	32.05

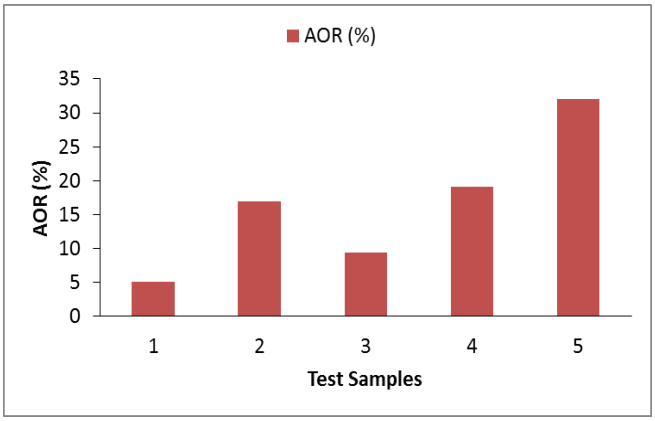

Figure 5 Percentage of AOR by test sample in sand pack column

IV. CONCLUSION

Citrus limetta is the most commonly available fruit in the southern India. The microbial contaminated *Citrus limetta* will not be useful for the purpose of feedstock or manure. The effectiveness of deteriorated *Citrus limetta* in the recovery of crude oil was examined through ODA, E_{24} and sand pack column operation.

The oil displacement test helps in analyzing the ability of deteriorated *Citrus limetta* to remove the crude oil from the water surface. The results of ODA and E_{24} showed that the deteriorated *Citrus limetta* pulp was better than the peels test samples. The 2 hours heated peels of deteriorated *Citrus limetta* showed improved results in the entire assessment than 1 hour heated peels.

The sand pack column showed that the deteriorated *Citrus limetta* pulp has a good oil recovery efficiency of 32.05 %. The investigation on deteriorated *Citrus limetta* observed to supportive in the enhanced oil recovery.

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