CHAPTER IV
RESULTS AND DISCUSSION

In this study, the process performances of the studied SBR system treating the biodiesel wastewater were assessed by using the following process parameters: chemical oxygen demand (COD), biochemical oxygen demand (BOD), total organic carbons (TOC), mixed liquor suspended solids (MLSS), and effluent suspended solids (Effluent SS). All experimental data are summarized in appendix of this thesis book. Again, the feed COD was fixed at 600 mg/L by diluting the dilute biodiesel wastewater with distilled water.

4.1 Effect of Nutrient Supplementation

In this part, the COD loading rate was fixed at two values of 0.10 and 0.60 kg/m^{3}d in order to examine the effect of nutrient supplement on the treatment performance of the studied SBR system in treating the dilute biodiesel wastewater.

4.1.1 Effect of Nutrient Supplementation on COD Removal

Figure 4.1 and Figure 4.2 show the profiles of effluent COD and COD removal at a COD loading rate 0.10 kg/m^{3}d with and without nutrient supplement, respectively. For any given operational conditions, the studied SBR system reached steady state after about 12 days. For the COD loading rate of 0.10 kg/m^{3}d after steady state, the COD removal increased from 72% to 90% after the nutrient supplementation.

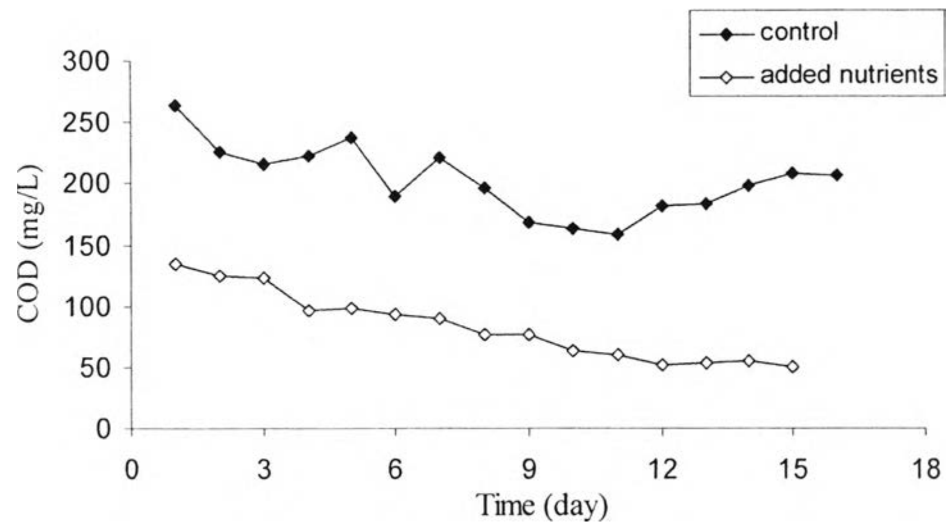

Figure 4.1 Profiles of effluent COD at a COD loading rate of 0.10 kg/m^{3}d with and without nutrient supplementation.

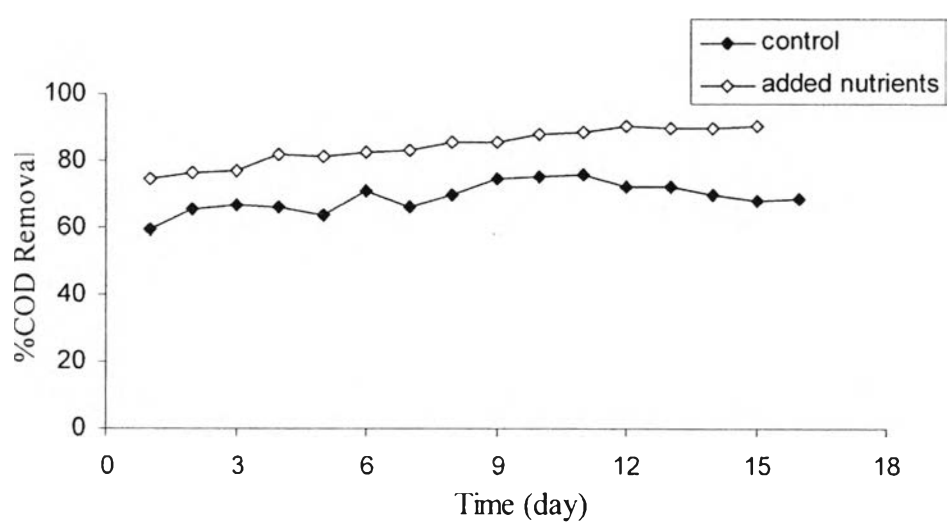

Figure 4.2 Profiles of COD removal at a COD loading rate of 0.10 kg/m^{3}d with and without nutrient supplementation.

Figure 4.3 and Figure 4.4 show the profiles of effluent COD and COD removal of the studied SBR operated at a COD loading rate of 0.60 kg/m^{3}d with and without nutrient supplementation, respectively. It can be seen that the addition of nutrient could enhance the treatment performance of the dilute biodiesel wastewater of the studied SBR system in terms of COD. Moreover, with nutrient supplementation, the studied SBR unit trended to have a better process stability in terms of less fluctuation of both profiles of effluent COD and COD removal. At the COD loading rate of 0.60 kg/m^{3}d, the nutrient supplementation could increase the COD removal from 48.5% to 68.1%. In a comparison between these two COD loading rates, an increase in COD loading rate decreased the COD removal efficiency.

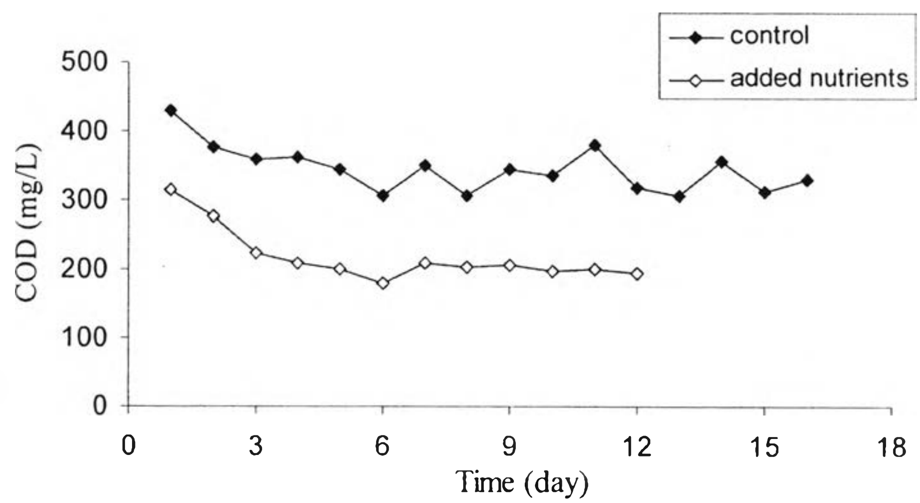

Figure 4.3 Profiles of effluent COD at a COD loading rate of 0.60 kg/m^{3}d with and without nutrient supplementation.

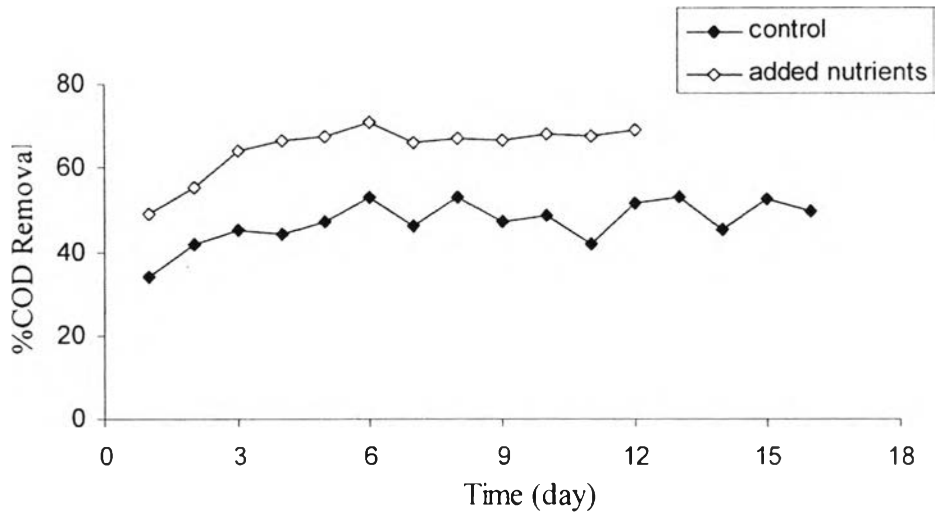

Figure 4.4 Profiles of COD removal at a COD loading rate of 0.60 kg/m^{3}d with and without nutrient supplementation.

4.1.2 Effect of Nutrient Supplementation on TOC Removal

Total organic carbon (TOC) is a parameter to determine the total amount of carbon bound in organic compounds present in the wastewater. Figure 4.5 shows the profiles of effluent TOC at a COD loading rate 0.10 kg/m^{3}d with and without nutrient supplementation. The effluent TOC was found to decrease from 139 mg/L to 88.30 mg/L when the studied SBR system was operated under nutrient supplementation. Figure 4.6 shows a significant improvement in terms of TOC removal with nutrient supplementation.

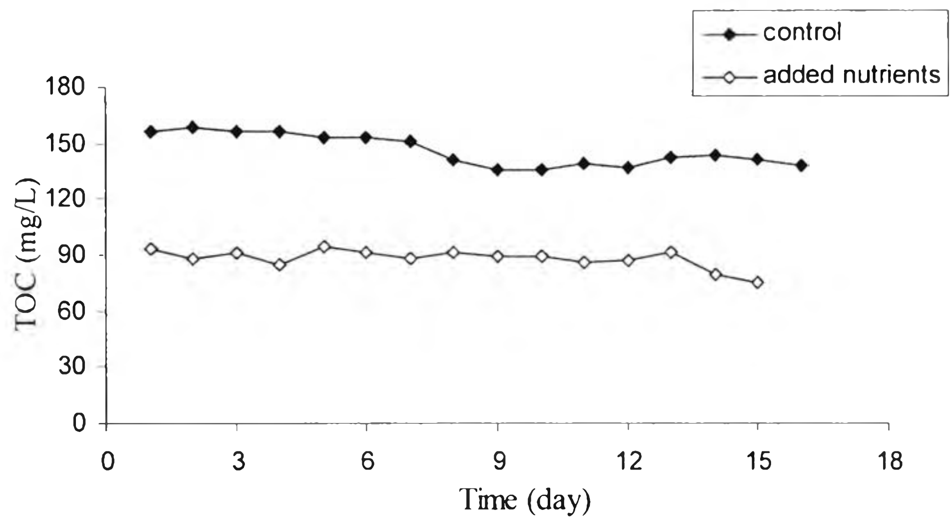

Figure 4.5 Profiles of effluent TOC at a COD loading rate of 0.10 kg/m^{3}d with and without nutrient supplementation.

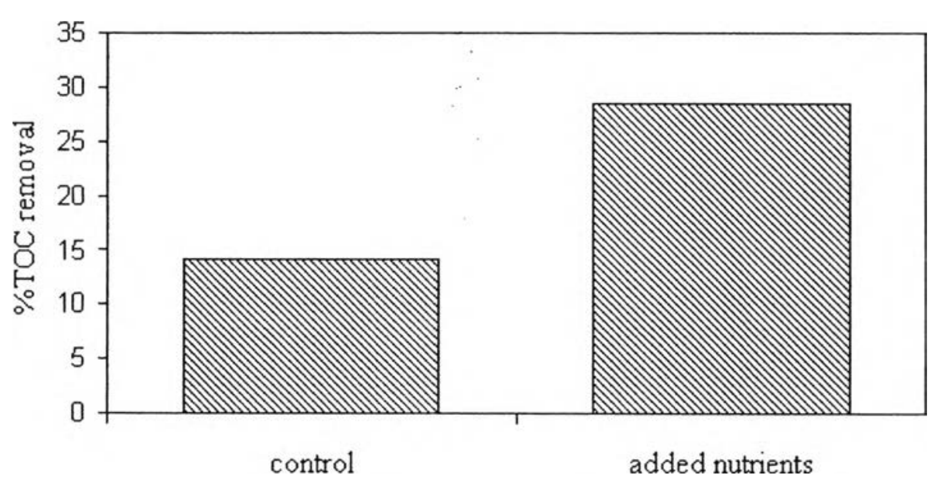

Figure 4.6 TOC removal at a COD loading rate of 0.10 kg/m^{3}d with and without nutrient supplementation.

Figure 4.7 the profiles of effluent TOC at a COD loading rate of 0.60 kg/m^{3}d with and without nutrient supplementation while Figure 4.8 shows the TOC removal at a COD loading rate of 0.60 kg/m^{3}d with and without nutrient supplementation. Again, the addition of nutrients showed the enhancement of TOC reduction but the effect at this high COD loading rate of 0.60 kg/m^{3}d was much lower than that at the lower COD loading rate of 0.10 kg/m^{3}d.

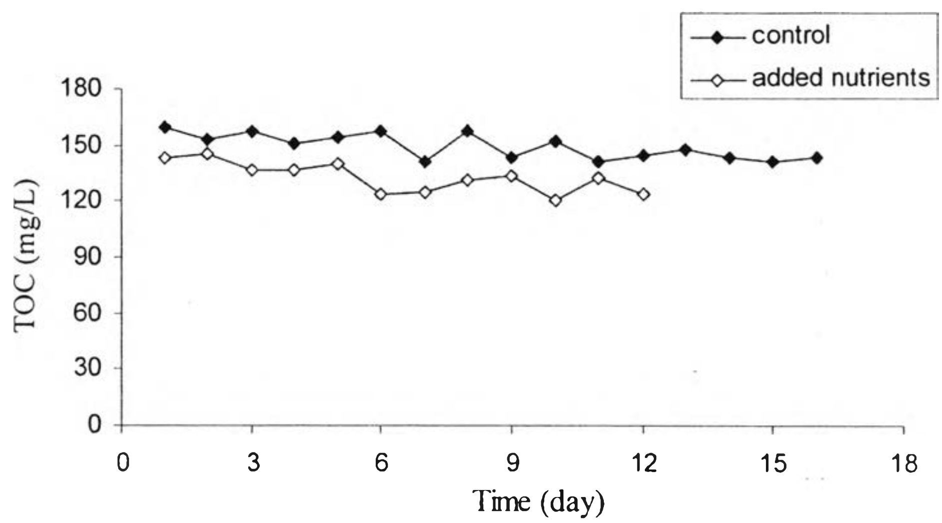

Figure 4.7 Profiles of effluent TOC at a COD loading rate of 0.60 kg/m^{3}d with and without nutrient supplementation.

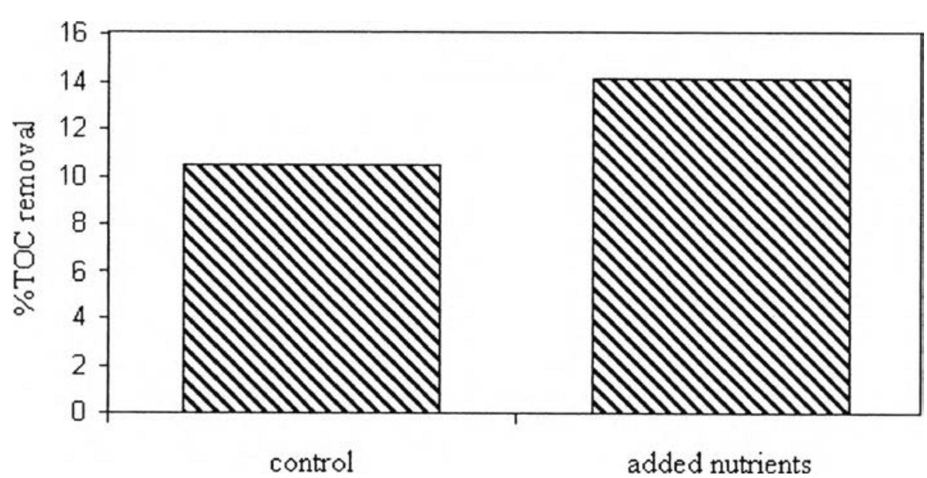

Figure 4.8 TOC removal at a COD loading rate of 0.60 kg/m^{3}d with and without nutrient supplementation.

4.1.3 Effect of Nutrient Supplementation on BOD Removal

Table 4.1 shows the effect of nutrient supplementation on the treatment performance in terms of effluent BOD of the studied SBR system operated at two COD loading rates. The BOD effluent decreases with decreasing COD loading rate. The addition of nutrients also showed significant improvement of the treatment performance efficiency. Regarding to the effluent standards, the dilute biodiesel wastewater should be treated at a COD loading rate 0.10 kg/m^{3}d with nutrient supplement.

Table 4.1 Effluent BOD of the studied SBR system operated at two different COD loading rates with and without nutrient supplementation

COD loading rate (kg/m^{3}d)	Effluent BOD (mg/L)	
	Without nutrient supplement (Control)	With nutrient supplement
0.10	30	13
0.60	54	36

4.1.4 Effect of Nutrient Supplementation on Microbial Concentration

Mixed Liquor Suspended Solids (MLSS) is a parameter used to represent the microbial concentration in the SBR system. Figure 4.9 shows the profiles of the microbial concentration in the SBR reactor operated at a COD loading rate of 0.10 kg/m^{3}d with and without nutrient supplementation. It was clearly seen that the microbial concentration in the SBR reactor increases significant when the nutrients were added. This is because the microbial growth requires the sufficient amounts of nutrients. Figure 4.10 shows the profiles of microbial concentration in the SBR reactor operated at a COD loading rate of 0.60 kg/m^{3}d with and without nutrient supplementation. At this higher COD loading rate of 0.60 kg/m^{3}d, the studied SBR system showed the similar results as that the lower COD loading rate of 0.10 kg/m^{3}d. In a comparison between these two COD loading rate with and without nutrient supplementation, the microbial concentration in the SBR reactor increased with increasing COD loading rate. This is because the system has a higher substrate available for the microbial growth with increase COD loading rate.

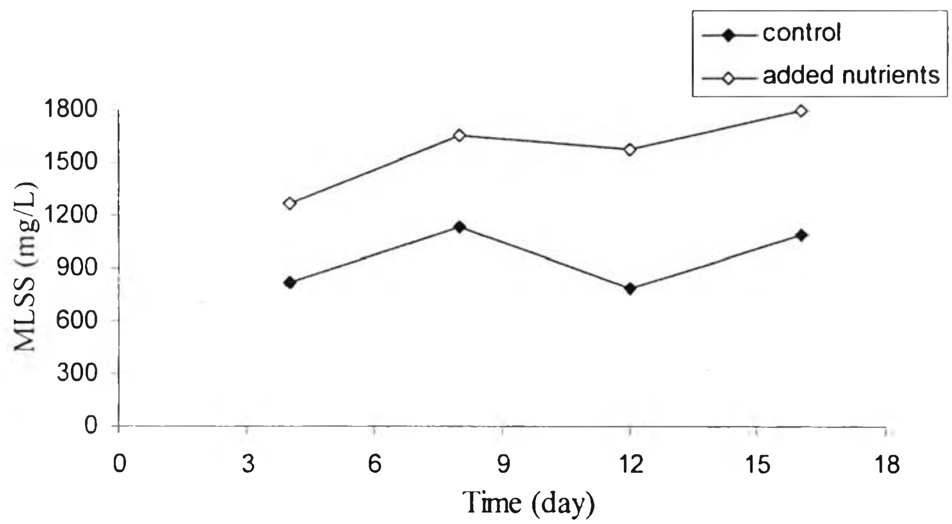

Figure 4.9 Profiles of microbial concentration in the SBR operated at a COD loading rate of 0.10 kg/m^3d with and without nutrient supplementation.

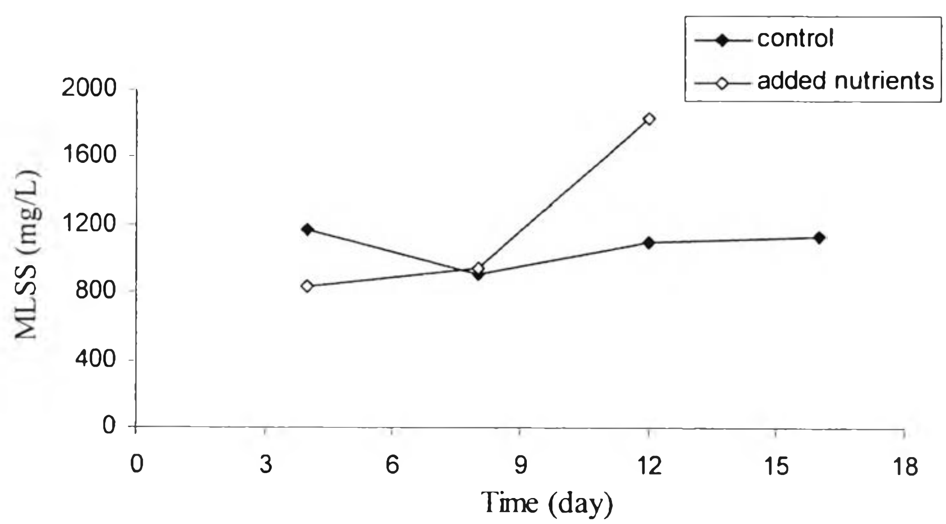

Figure 4.10 Profiles of microbial concentration in the SBR operated at a COD loading rate of 0.60 kg/m^3d with and without nutrient supplementation.

4.1.5 Effect of Nutrient Supplementation on Microbial Wash-out

Effluent Suspended Solids (Effluent SS) is a parameter used to indicate the amount of microbial wash-out from a biological treatment system. Figure 4.11 and Figure 4.12 show the profiles of effluent SS of the studied SBR system operated at two COD loading rate of 0.10 and 0.60 kg/m^{3}d, respectively with and without nutrient supplementation. The results reveal that the nutrient supplementation can reduce the microbial wash-out and an increase in COD loading rate can increase the microbial concentration in the SBR reactor under the studied conditions. Hence, the dilute biodiesel wastewater was supplemented to obtain a constant ratio of COD:N:P of 100:2.5:0.5 for further investigation.

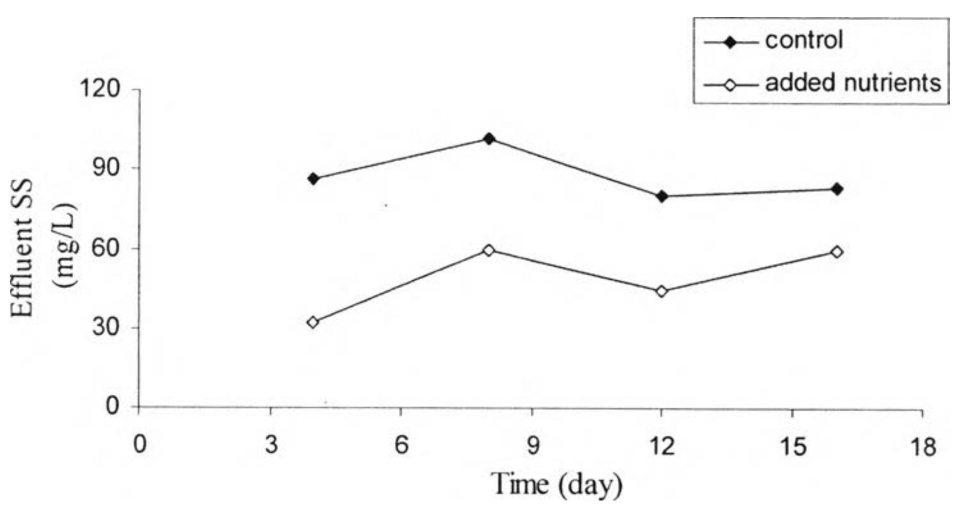

Figure 4.11 Profiles of effluent SS of the SBR operated at a COD loading rate of 0.10 kg/m^{3}d with and without nutrient supplementation.

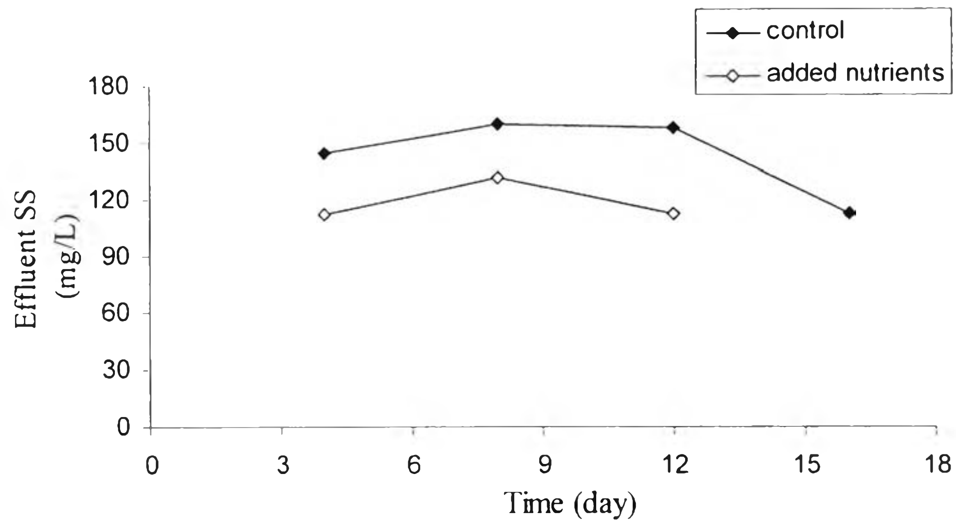

Figure 4.12 Profiles of effluent SS of the SBR operated at a COD loading rate of 0.60 kg/m^3d with and without nutrient supplementation.

4.2 Effect of COD Loading Rate

In this part of the study, the effect of COD loading rate was examined by varying the COD loading rates of 0.05, 0.075, 0.10, 0.20, 0.40, and 0.60 kg/m^3d at 4 cycles per day. The results were quantified by the methods mentioned before.

4.2.1 Effect of COD Loading Rate on COD Removal

Figure 4.13 shows the profiles of COD effluent of the studied SBR operated at different COD loading rates and Figure 4.14 shows the profiles of COD removal of the studied SBR operated at various COD loading rates. Figure 4.15 shows the effect of COD loading rate on the COD removal efficiency. The COD removal increased with increasing COD loading rate. It can be seen that the lowest COD loading rate 0.05 kg/m^3d gave the highest COD removal.

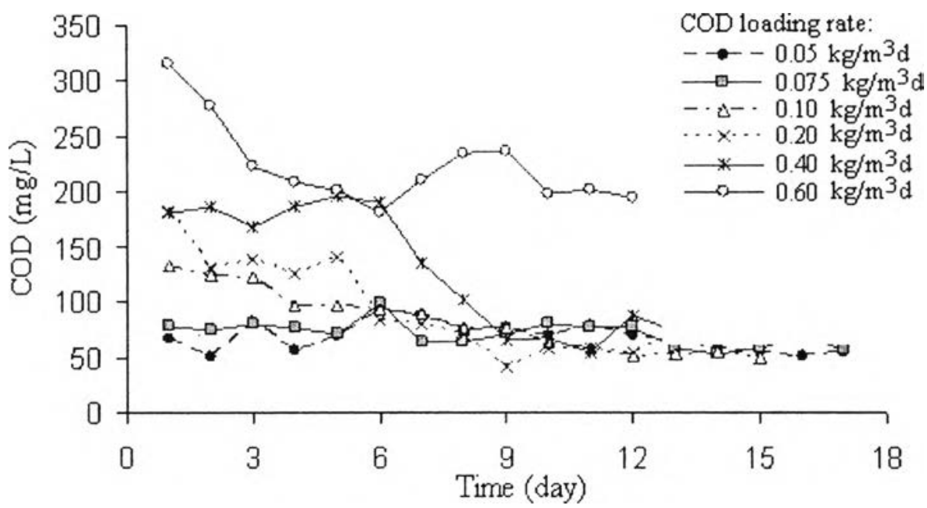

Figure 4.13 Profiles of effluent COD at different COD loading rates with nutrient supplementation.

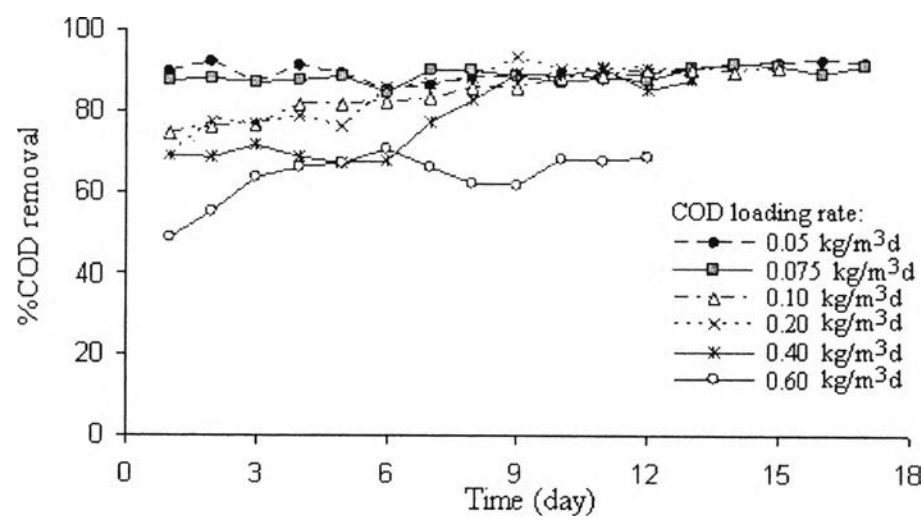

Figure 4.14 COD removal at different COD loading rates with nutrient supplementation.

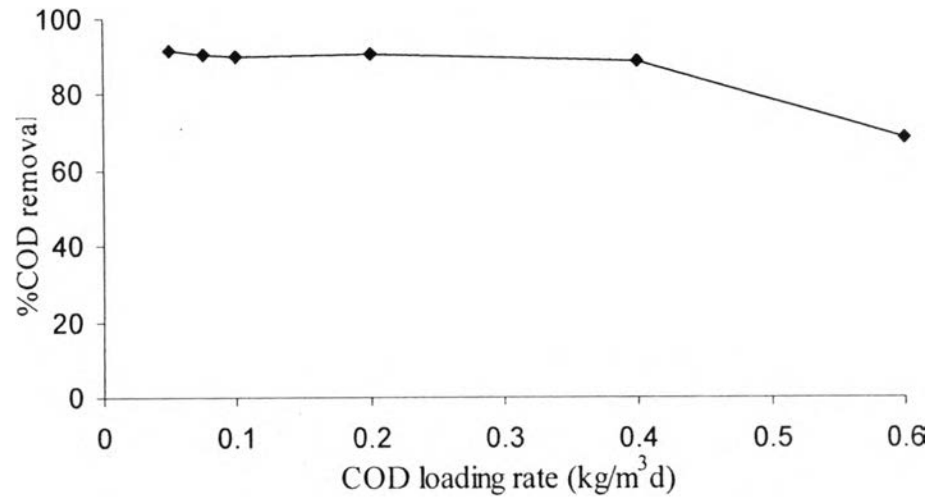

Figure 4.15 Effect of COD loading rate on TOC removal efficiency of the studied SBR with nutrient supplementation.

4.2.2 Effect of COD Loading Rate on TOC Removal

Figure 4.16 and Figure 4.17 show the profiles of effluent TOC and TOC removal of the studied SBR operated at different COD loading rates. As increasing COD loading rate, for any given operational time, the effluent TOC and TOC removal on TOC removal tended to increase. As shown in Figure 4.18, the TOC removal decreases with increasing COD loading rate. The results were quite similar to the COD removal that at a lowest COD loading rate of 0.05 kg/m^3d provided the highest TOC removal of 35.7%.

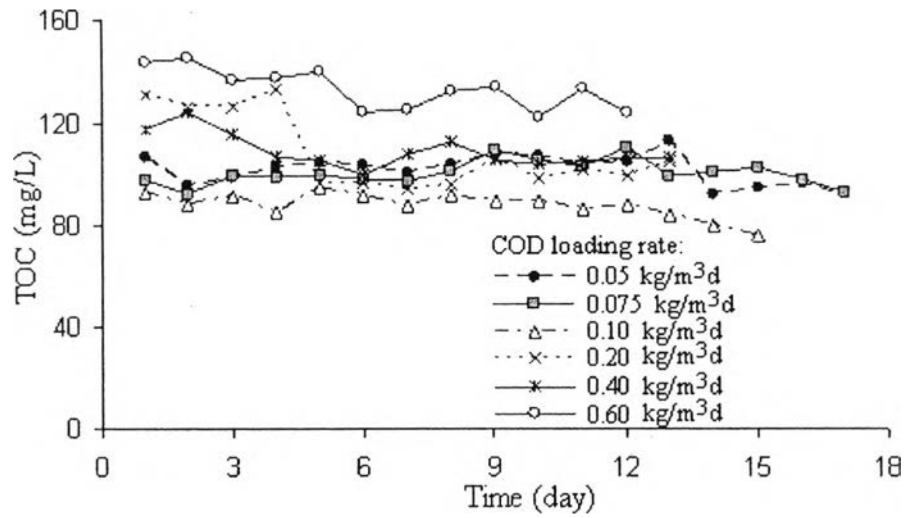

Figure 4.16 Effluent TOC at different COD loading rates with nutrient supplementation.

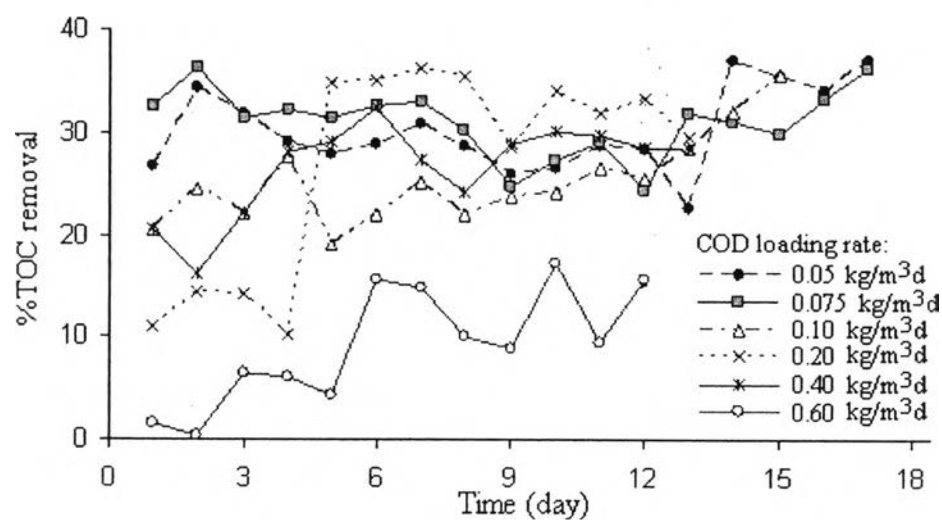

Figure 4.17 TOC removal at different COD loading rates with nutrient supplementation.

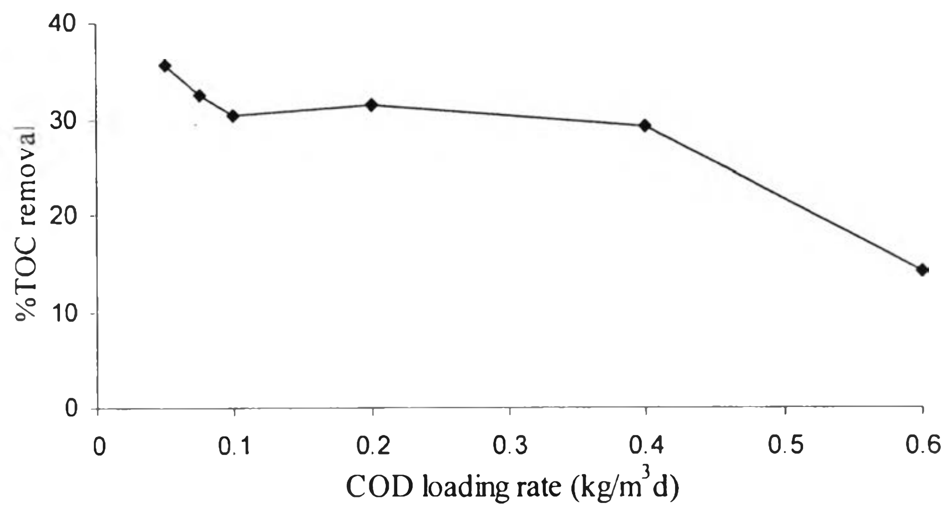

Figure 4.18 Effect of COD loading rate on TOC removal efficiency of the SBR system with nutrient supplementation.

4.2.3 Effect of COD Loading Rate on BOD Removal

Figure 4.19 and Figure 4.20 show the effluent BOD and BOD removal as a function of COD loading rate. At a least COD loading rate of 0.05 kg/m^3d provided the lowest BOD value to as low as 11 mg/L and the highest BOD removal to as high as 96.1%. Again, the results were quite similar to the COD and TOC results that at a lowest COD loading rate of 0.05 kg/m^3d provided the lowest BOD values and the highest BOD removal. It can be seen that the effluent BOD increased with increasing the COD loading rate.

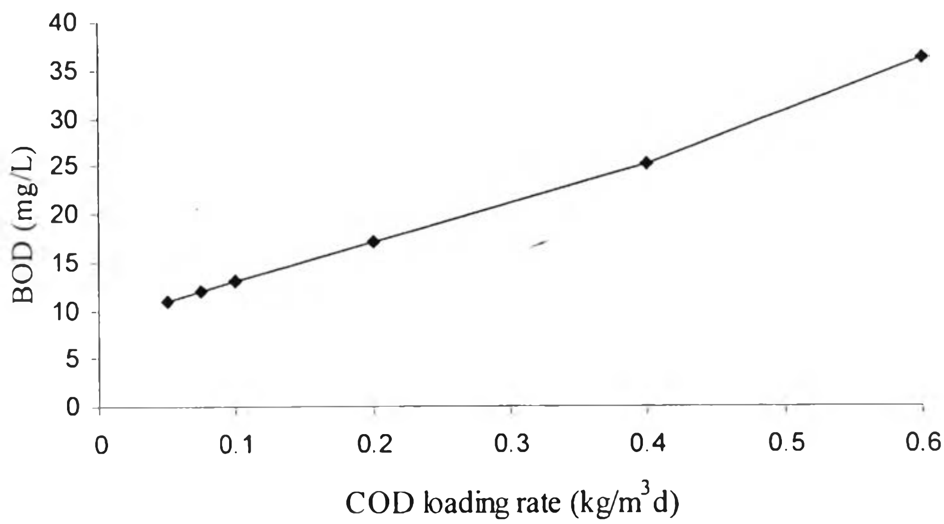

Figure 4.19 Effect of COD loading rate on effluent BOD of the SBR system with nutrient supplementation.

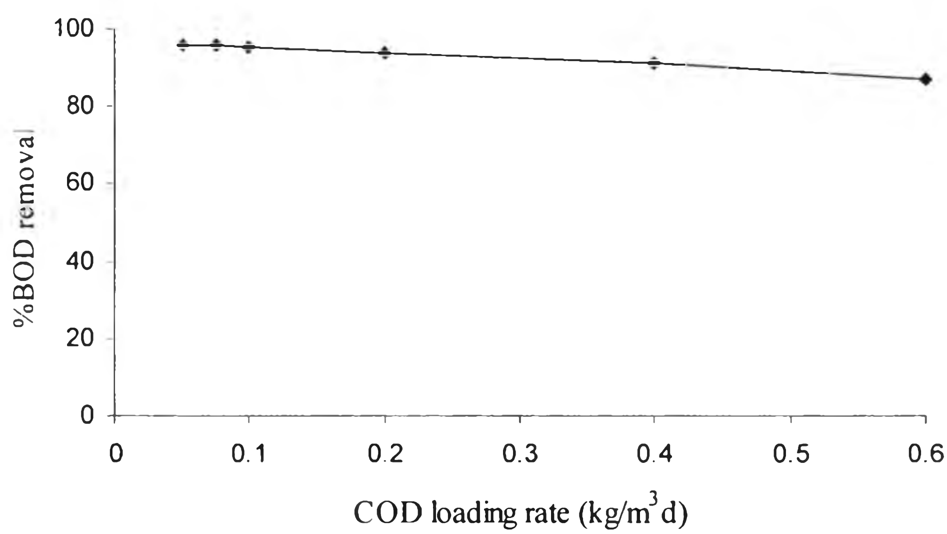

Figure 4.20 Effect of COD loading rate on BOD removal efficiency of the SBR system with nutrient supplementation.

4.2.4 Effect of COD Loading Rate on Microbial Concentration

Figure 4.21 shows the average growth of microorganisms in the reactor at different COD loading rates. It can be seen that the MLSS increased with decreasing the COD loading rate. At a lowest COD loading rate of 0.05 kg/m^{3}d, the system had the highest MLSS value to as high as 1,870 mg/L. It is very interesting to point out that the removal effluent of the studied SBR system directly corresponded to the MLSS in the bioreactor.

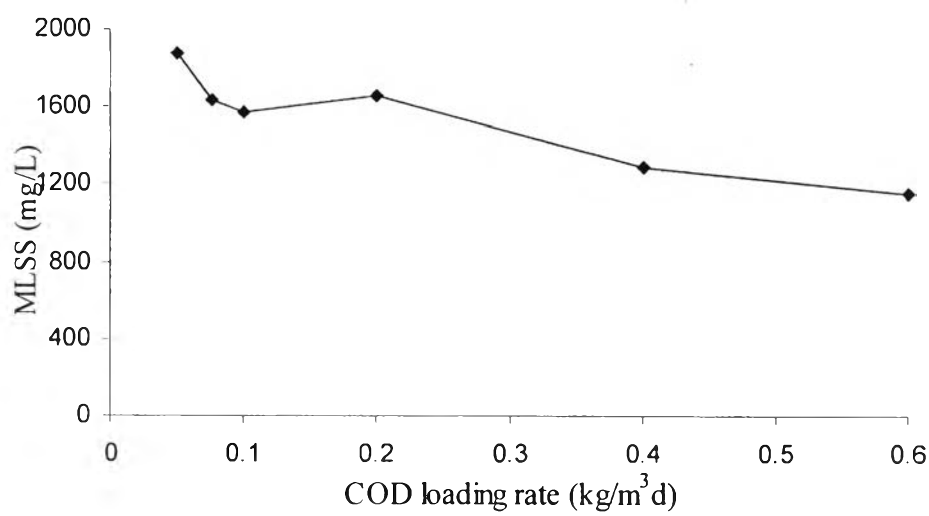

Figure 4.21 Effect of COD loading rate on microbial concentration in the SBR system with nutrient supplementation.

4.2.5 Effect of COD Loading Rate on Microbial Wash-out

As mentioned before, the effluent SS can be used to indicate the microbial wash-out from a system. Figure 4.22 shows the effluent SS as a function of COD loading rate. The effluent SS increased with increasing COD loading rate especially from 0.4 to 0.6 kg/m^{3}d. The higher the effluent SS (the microbial wash-out), the lower the microbial concentration in the system.

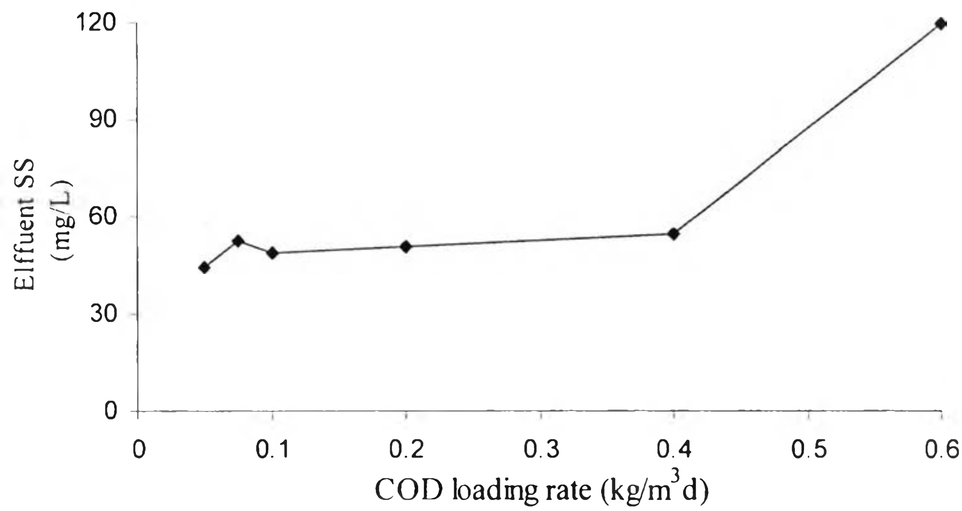

Figure 4.22 Effect of COD loading rate on effluent SS of the studied SBR with nutrient supplementation.

4.3 GC results

In this part of the study, the organic compounds in the dilute biodiesel wastewater before and after the aerobic treatment were qualified by using gas chromatography (GC). Figure 4.23 and Figure 4.24 show the ethanol was completely degraded biologically but the glycerol still remained after the treatment.

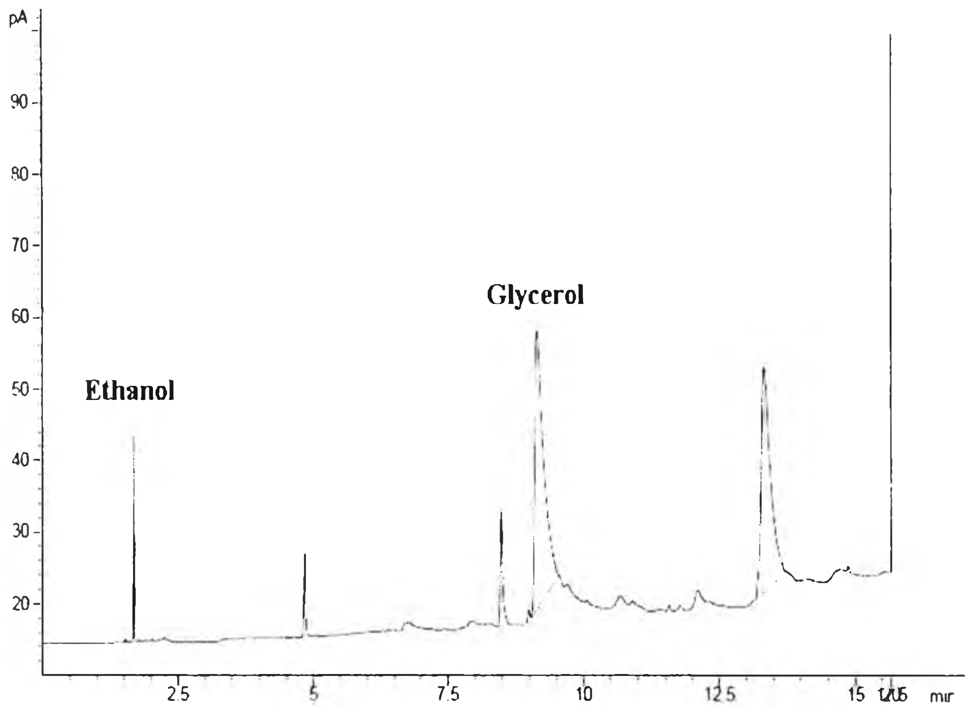

Figure 4.23 The organic compounds in the dilute biodiesel wastewater before aerobic treatment.

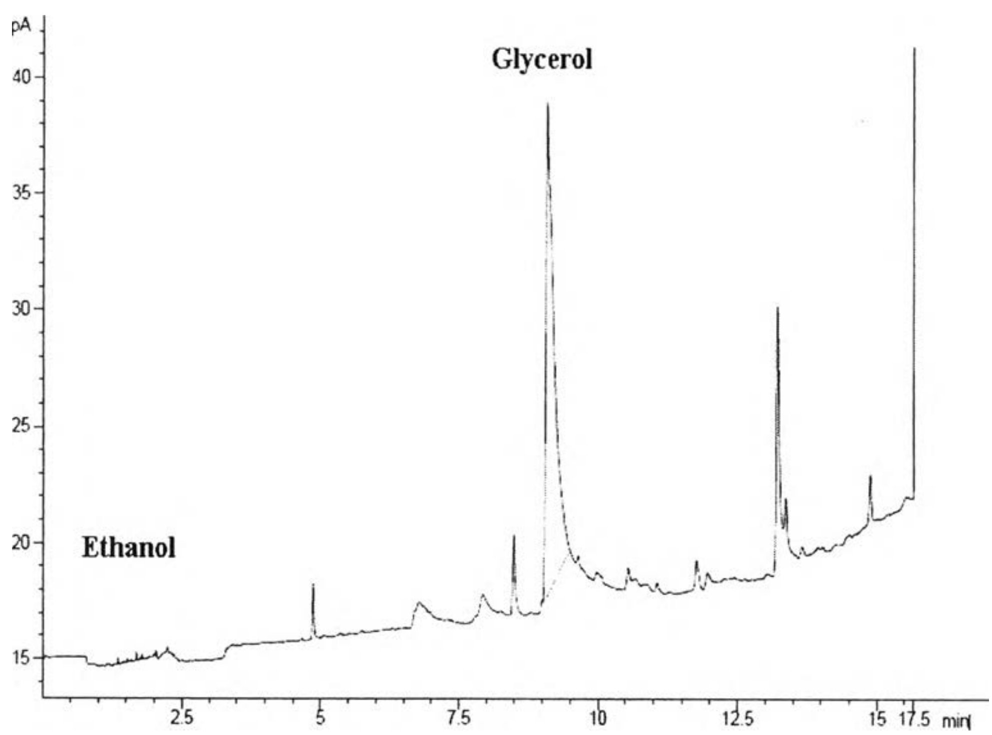

Figure 4.24 The organic compounds in the dilute biodiesel wastewater after aerobic treatment.