



CHAPTER IV RESULTS AND DISCUSSION

4.1 Feed Biodiesel Analysis

In order to determine FAME composition of the feed biodiesel, a gas chromatograph (GC) equipped with a flame ionization detector (FID) was used. The FAMES composition of feed biodiesel is shown in Table 4.1.

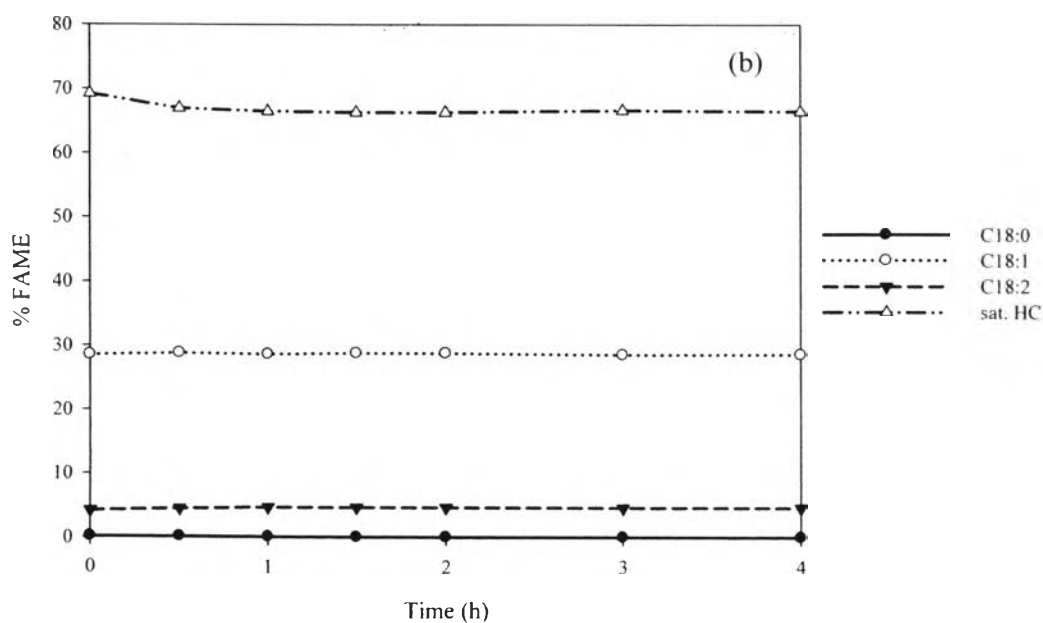
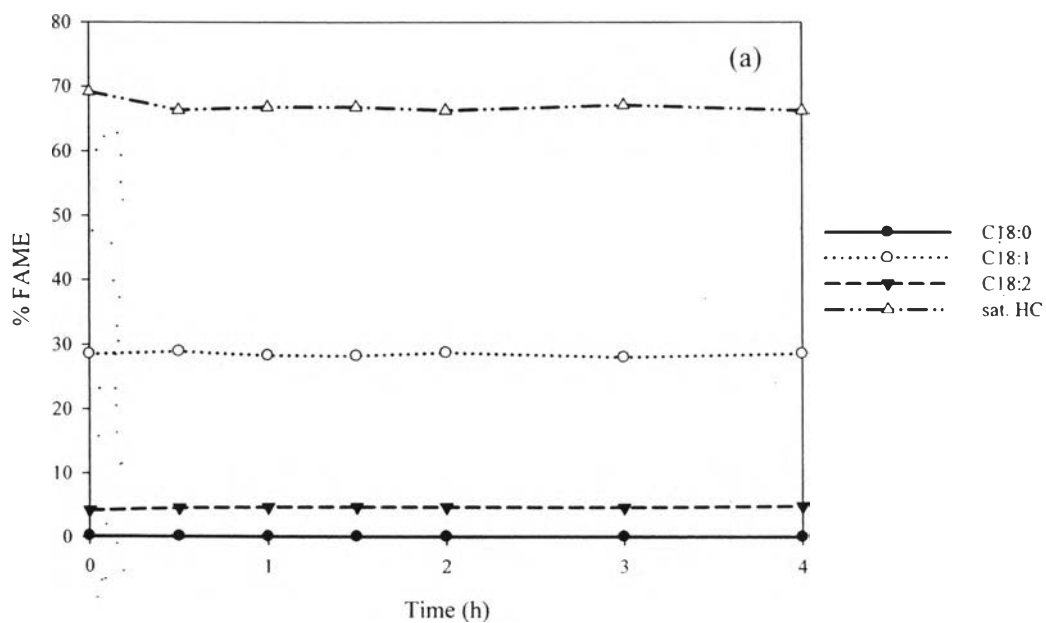
Table 4.1 FAME composition of feed biodiesel

FAME	Structure	%
methyl laurate	C12:0	0.37
methyl myristate	C14:0	1.63
methyl palmitate	C16:0	66.93
methyl stearate	C18:0	0.14
methyl oleate	C18:1	26.50
methyl linoleate	C18:2	4.18
methyl arachidate	C22:0	0.25

4.2 Effect of Types of Carbon Support

Firstly, the effect of carbon support without Pd loading was studied. Three types of support without Pd loading: carbon aerogel, activated carbon, and granule activated carbon were used as supports for the catalysts in the partial hydrogenation of biodiesel. The reaction was operated at a condition of 120°C, 4 bar, 50 ml/min of hydrogen flow rate, and 500 rpm of stirring rate. The percentages of C18:0, C18:1, C18:2, and other FAMES (C12:0, C14:0, C16:0, and C22:0) after partial hydrogenation reaction for three types of carbon support are shown in Figure 4.1. And from Figure 4.1(a),(b), and (c) show that the percentages of FAMES did not

change significantly with time on steam. Therefore, it can be concluded that carbon support without Pd loading has no significant effect on partial hydrogenation of polyunsaturated FAMES.



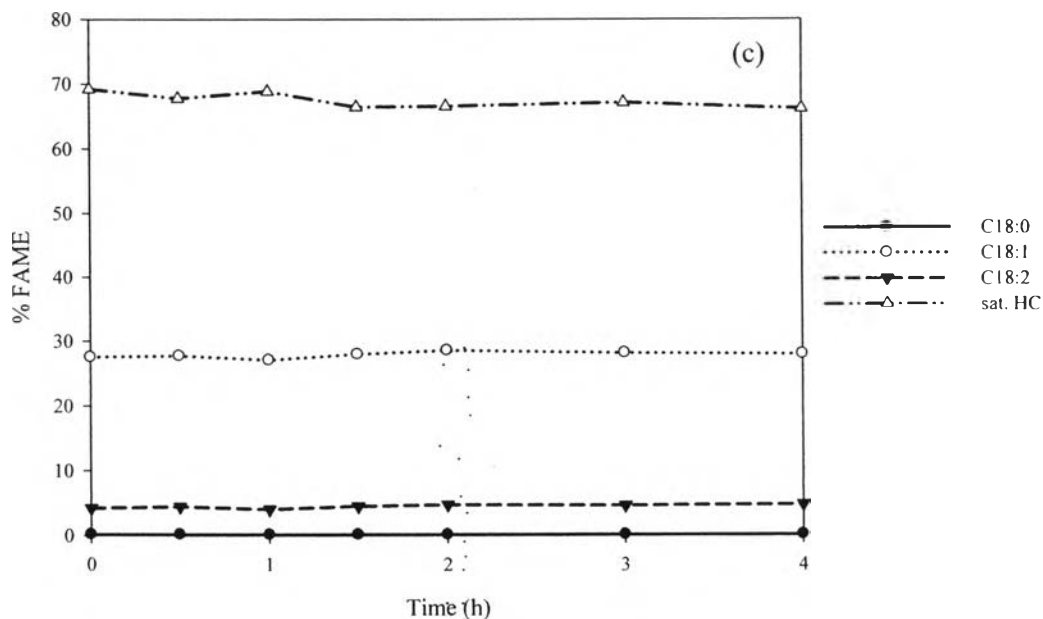


Figure 4.1 (cont) Effect of carbon support: (a) carbon aerogel, (b) activated carbon, and (c) granules activated carbon on FAME composition of biodiesel after partial hydrogenation reaction (Reaction conditions: 120°C, 4 bar, 50 ml/min of H₂ flow rate, and 500 rpm of stirring rate).

Then, the effect of type of carbon support was carried out over Pd/carbon aerogel, Pd/activated activated, and Pd/granule activated carbon in the partial hydrogenation of polyunsaturated FAMES. The catalytic activity of these catalysts was determined by examining FAME composition in the product stream.

Three types of carbon support: carbon aerogel, activated carbon, and granule activated carbon were used as supports for the catalysts in the partial hydrogenation of biodiesel. The reaction was operated at a condition of 120°C, 4 bar, 50 ml/min of hydrogen flow rate, 500 rpm of stirring rate, and 1.5 wt.% of catalyst compared to starting oil. The percentages of C18:0, C18:1, C18:2, and other FAMES (C12:0, C14:0, C16:0, and C22:0) after partial hydrogenation reaction for three types of carbon support are shown in Figure 4.2. From Figure 4.2(a), the Pd/carbon aerogel could rapidly reduce C18:2 and C18:1 from 4.18% to 0.04% and from 26.50% to 2.79%, respectively, after 1.0 h of reaction; while C18:0 sharply increased from

0.14% to 28.85% after 1.0 h, and continuously increased to almost 32.75% after 4 h of reaction. After 1.5 h of reaction, composition of C18:2 and C18:1 were completely hydrogenated whereas the composition of C18:2 and C18:1 in biodiesel product were almost 0%. From these results, it suggested that the Pd/carbon aerogel exhibited complete hydrogenation activities. And from Figure 4.2(b), the Pd/activated carbon also rapidly reduced C18:2 and C18:1 from 4.18% to 0% and from 26.50% to 3.68%, respectively, after 1.0 h of reaction; while C18:0 sharply increased from 0.14% to 27.77% after 1.0 h, and continuously increased to almost 32.08% after 4 h of reaction. From these results, it suggested that the Pd/activated carbon also exhibited complete hydrogenation activities similar to Pd/carbon aerogel. For the Pd/granule activated carbon, C18:2 decreased from 4.18% to 0.26% and C18:1 slowly decreased from 26.50% to 22.05%, whereas C18:0 increased from 0.14% to 8.60%, after 1.0 h of reaction as shown in Figure 4.2(b). And after 2.0 h of reaction C18:2 were completely hydrogenated. These results could suggest that Pd/granule activated carbon seem to meet the purpose in the partial hydrogenation. Nikolaou *et al.*, (2009) suggested that the higher amounts of saturated FAMES are less prone to oxidation, but the lower cold flow property. If we compare the relative rates of autoxidation of methyl linoleate (C18:2) is 41 and methyl oleate (C18:1) is 1, it means that we need to control C18:1 constant while decrease C18:2 content to improve oxidative stability while not affect to cold flow properties.

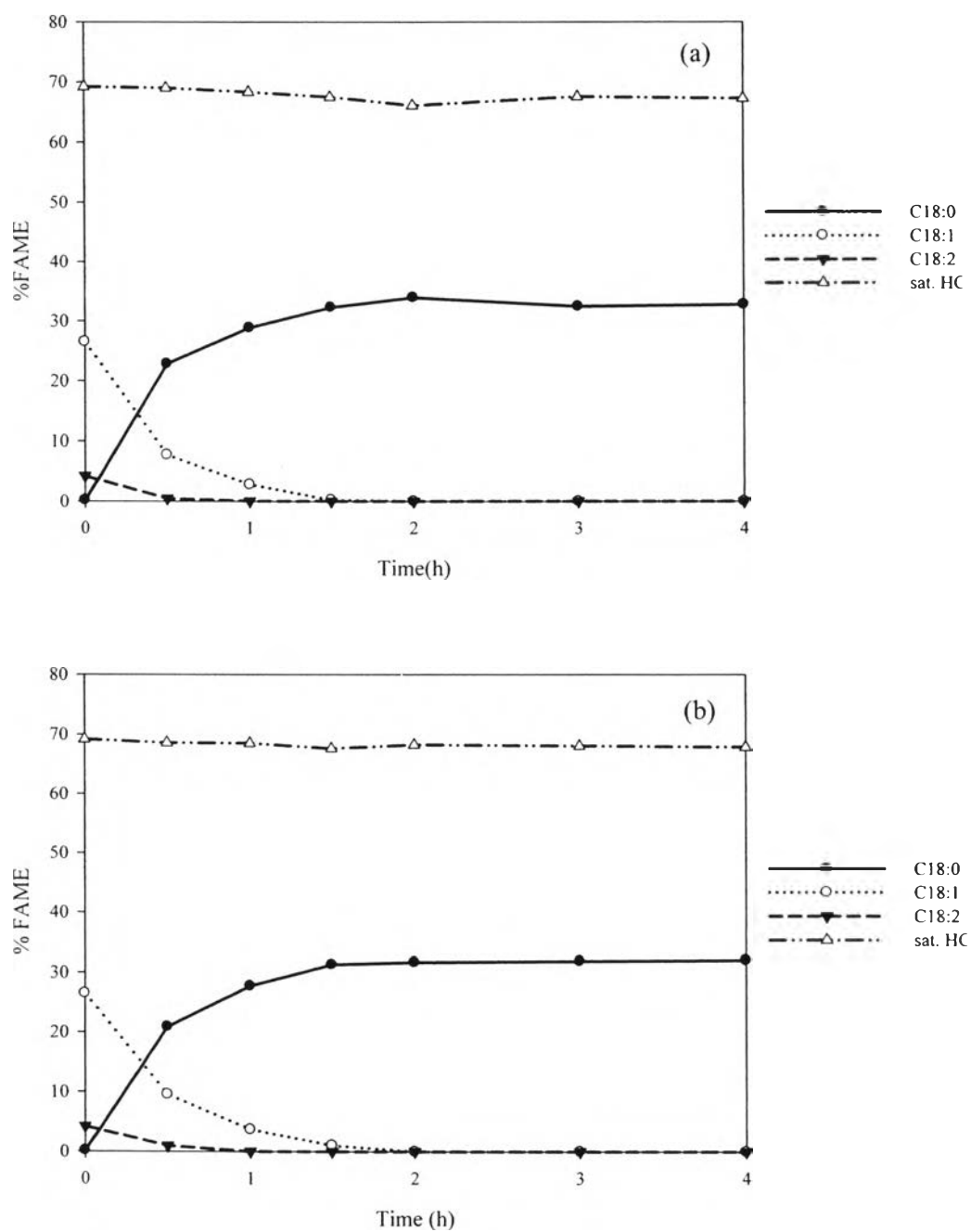


Figure 4.2 Effect of type of carbon support: (a) Pd/carbon aerogel, (b) Pd/activated carbon, and (c) Pd/granules activated carbon on FAME composition of biodiesel after partial hydrogenation reaction (Reaction conditions: 120°C, 4 bar, 50 ml/min of H₂ flow rate, 500 rpm of stirring rate, and 1.5 wt.% of catalyst compared with starting oil).

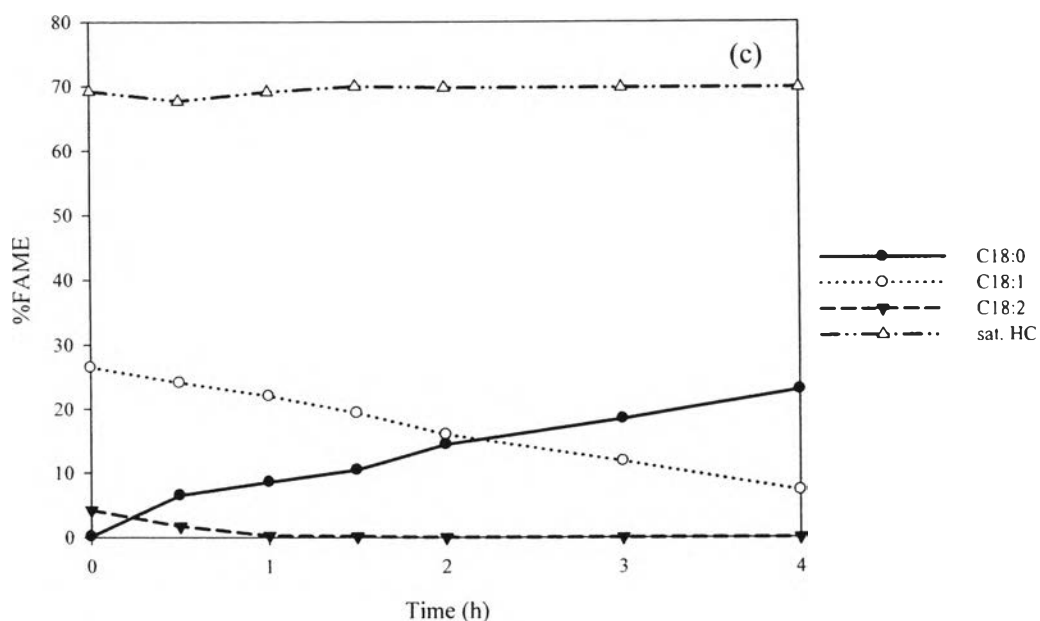


Figure 4.2 (cont.) Effect of type of carbon support: (a) Pd/carbon aerogel, (b) Pd/activated carbon, and (c) Pd/granules activated carbon on FAME composition of biodiesel after partial hydrogenation reaction (Reaction conditions: 120°C, 4 bar, 50 ml/min of H₂ flow rate, 500 rpm of stirring rate, and 1.5 wt.% of catalyst compared with starting oil).

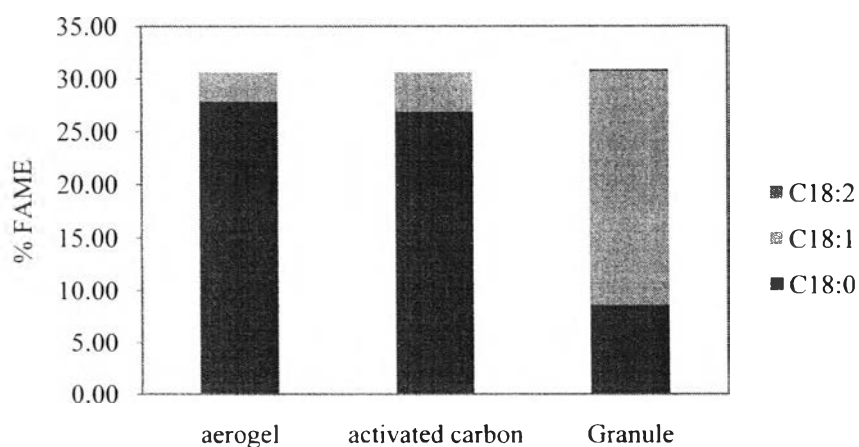


Figure 4.3 FAMES composition after 1 h of partial hydrogenation using three types of carbon support: carbon aerogel, activated carbon, and granule activated carbon.

According to these results, it can be concluded that the higher amounts of saturated FAMES are less prone to oxidation, but low cold flow property. Therefore, in this work we aim to decrease the C18:2 content, and keep C18:1 constant to improve oxidative stability while not affect to cold flow properties. From Figure 4.2, it can be concluded that the Pd/carbon aerogel and Pd/activated carbon showed the better catalytic activity in term of complete hydrogenation, whereas the Pd/granule activated carbon exhibited better property in term of partial hydrogenation. This suggests that biodiesel product after 1.0 h using Pd/granule activated carbon exhibited good biodiesel properties, especially oxidative stability and cold flow properties. Therefore, Pd/granule activated carbon catalyst was selected to be used for further studies.

Atomic absorption spectroscopy (AAS) was used to determine amount of Pd loading on carbon support which synthesized by impregnation (IWI) method using $\text{Pd}(\text{NO}_3)_2 \cdot 2\text{H}_2\text{O}$ precursor. In this work 2 wt.% Pd was loaded on carbon aerogel, granules activated carbon, and Activated carbon. The percentages of Pd loading on each types of carbon are shown in Table 4.2.

Table 4.2 The percentage of Pd loading on each types of carbon

Types of carbon	Pd loading (%wt)
Carbon aerogel	1.90
Granules activated carbon	1.87
Activated carbon	1.94

XRD patterns of fresh and spent 2wt.% Pd supported on carbon aerogel and granules activated carbon are shown in Figure 4.4. Both catalysts prepared by incipient wetness impregnation (IWI) using $\text{Pd}(\text{NO}_3)_2 \cdot 2\text{H}_2\text{O}$ precursor. The broad signal at about 25° , which is assigned to the amorphous carbon, was observed in all catalysts (Wu *et al.*, 2009). The main characteristic peak of crystalline Pd plane (111) at 2θ of 40.20° was observed for both Pd/carbon aerogel and Pd/granule activated carbon catalyst after calcination under N_2 at 500°C . The mean particle size of Pd

was calculated from the peak width at half height of the Pd (111) diffraction peak by applying Scherrer's equation (Harada *et al.*, 2007).

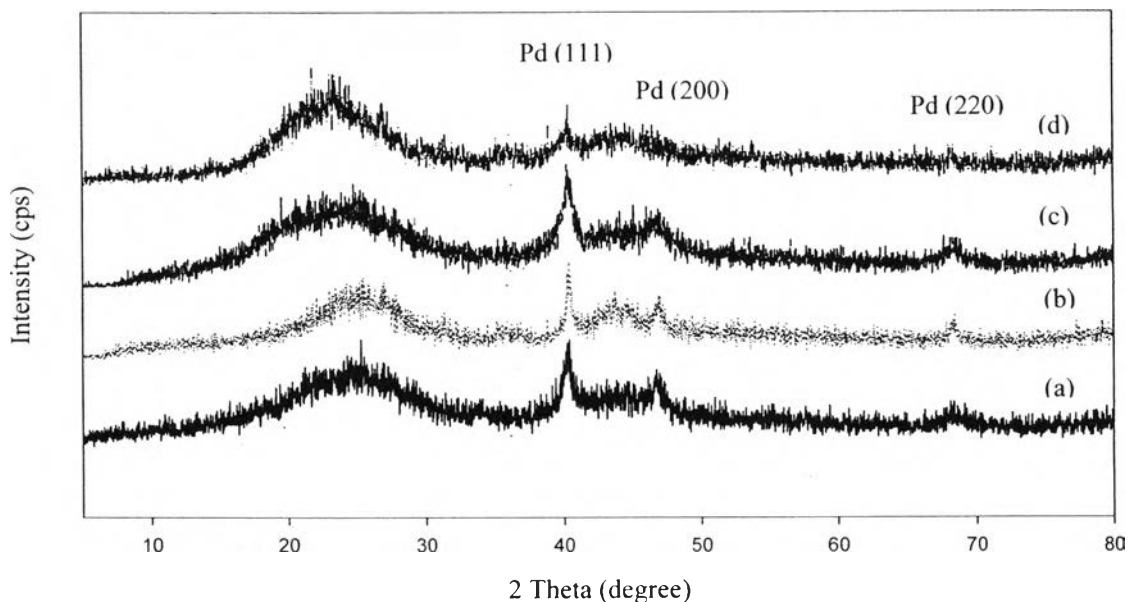


Figure 4.4 XRD patterns of (a) Pd/carbon aerogel, (b) Pd/granule activated carbon, (c) spent Pd/carbon aerogel, (d) spent Pd/granule activated.

The Pd particle sizes of Pd/carbon aerogel and granule activated carbon were calculated by applying Scherrer's equation. As shown in Table 4.3, Pd particle size of Pd/carbon aerogel was about 9.97 nm and particle size of Pd/granule activated carbon was about 18.5 nm. Moreover, surface area, total pore volume, and average pore diameter of carbon support and Pd/carbon support were analyzed by using Autosorb-1 MP surface area analyzer. As shown in Table 4.3, surface area of carbon aerogel was about 280.1 m²/g, with the total pore volume about 0.2142 ml/g, and average pore diameter of 3.059 nm, which can be indicated as mesoporous material (pore size: 2–50 nm). Whereas the surface area of granule activated carbon was 799.5 m²/g, with the total pore volume of 0.4583 ml/g, and average pore diameter of 2.293 nm, which can be also indicated as mesoporous material (pore size: 2–50 nm).

Table 4.3 Characteristics of carbon aerogel, granule activated carbon, Pd/carbon aerogel, and Pd/granule activated carbon support catalysts

Catalyst	Pd (111) particle size from XRD (nm)	Surface area (m ² /g)	Total pore volume (ml/g)	Average pore diameter (nm)
Carbon aerogel	-	280.1	0.2142	3.06
Granule activated carbon	-	799.5	0.4583	2.29
Pd/Carbon aerogel	9.97	-	-	-
Pd/granule activated carbon	18.5	875	0.496	2.68

The TPR profiles revealed the information about the variation of reduction temperature of Pd species with respect to type of activated carbon. The TPR diagrams of granule activated carbon, Pd/granule activated carbon are shown Figure 4.5(a) and (b), the peaks at 722°C and 701°C may be attributed to the carbon gasification (Chandra *et al.*, 2003). Moreover, the negative peaks at 105°C and 89°C generally attributed to the decomposition of β -hydride palladium phase (Ferrer *et al.*, 2005). And the TPR diagram obtained for Pd/carbon aerogel and spent Pd/carbon aerogel, as shown Figure 4.5(a) and (b), showed peaks of reduction temperature at 608°C, 636°C and 638°C which attributed to the carbon gasification.

The palladium dispersion was calculated using a CO:Pd ratio of 1:1 and assuming that all CO was adsorbed on the exposed Pd atoms (Luo *et al.*, 1998). CO adsorption on Pd was measured by a pulse chemisorptions method. As shown in Table 4.4, palladium dispersion of Pd/carbon aerogel was about 48.34% and Palladium dispersion of spent Pd/carbon aerogel was about 37.48%. Moreover, the palladium dispersion of Pd/granule activated carbon and spent Pd/granule activated carbon were about 15.81% and 15.36%, respectively. The higher Pd dispersion showed the higher active size and give higher activity.

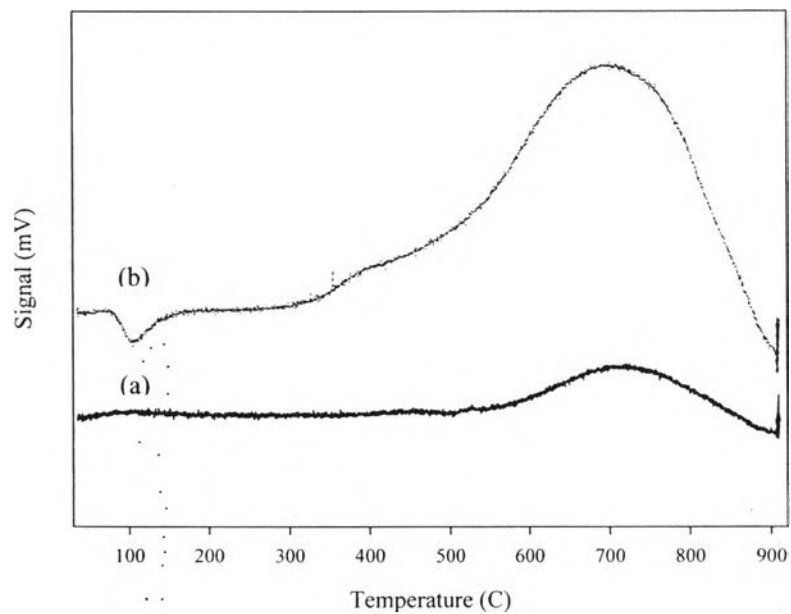


Figure 4.5 TPR patterns of (a) granule activated carbon and (b) Pd/ granule activated carbon.

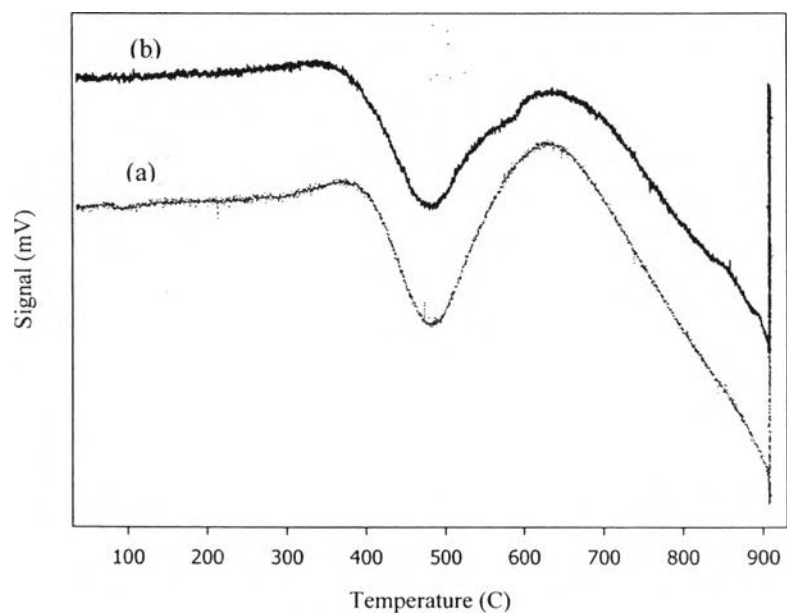
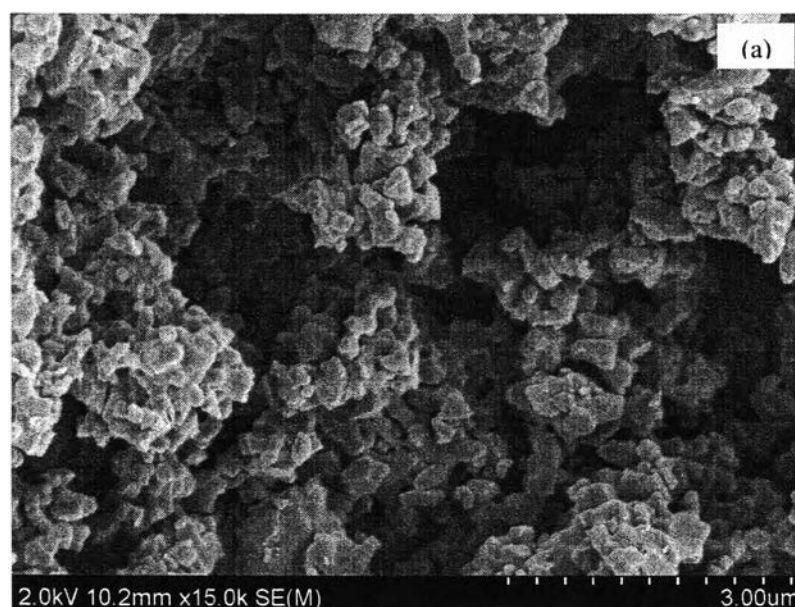


Figure 4.6 TPR patterns of (a) Pd/carbon aerogel, (b) Spent Pd/carbon aerogel.

Table 4.4 Palladium dispersion of Pd supported on carbon aerogel, spent Pd supported on carbon aerogel, Pd supported on granule activated carbon, and spent Pd supported on granule activated

Catalyst	Pd Dispersion (%)
Pd/carbon aerogel	48.34
Pd/granule activated carbon	15.81
Spent Pd/carbon aerogel	37.48
Spent Pd/granule activated carbon	15.36

SEM micrographs of carbon aerogel and granule activated carbon supports are shown in Figure 4.7. The SEM micrographs of carbon aerogel show the porous structure of carbon aerogel from the removal of the solvent. In the structure of the organic aerogel, the solid phase presents a smooth continuous polymer network incorporated with open mesopores. And micro porous structure of granule activated carbon is shown in Figure.4.7 (b).



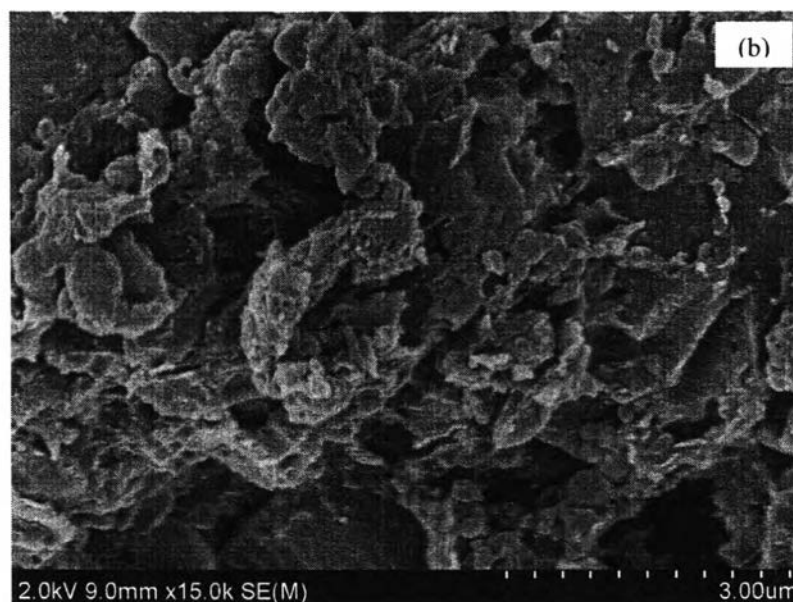
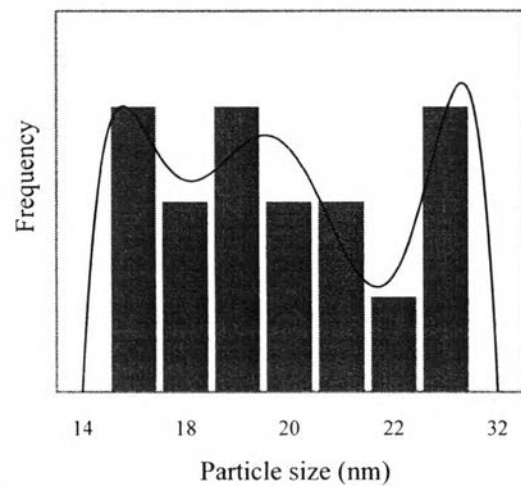
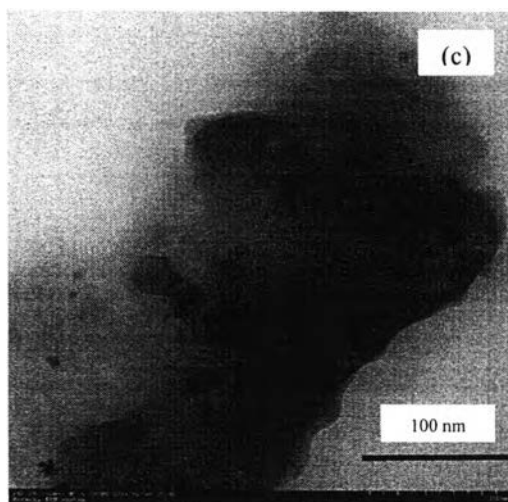
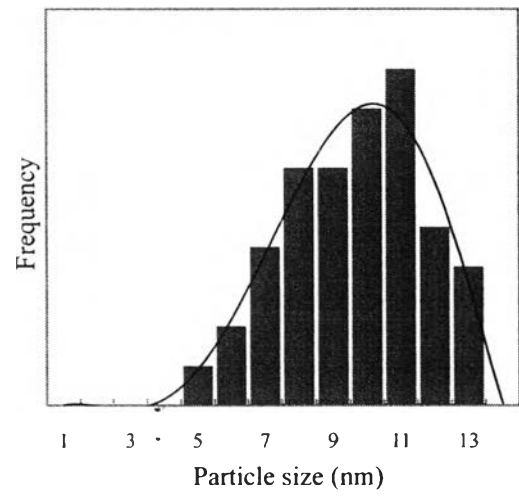
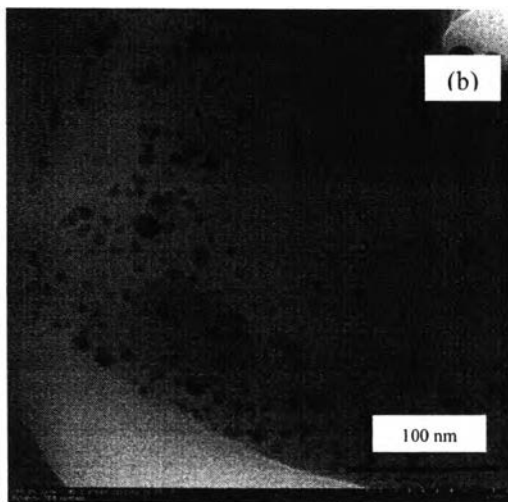
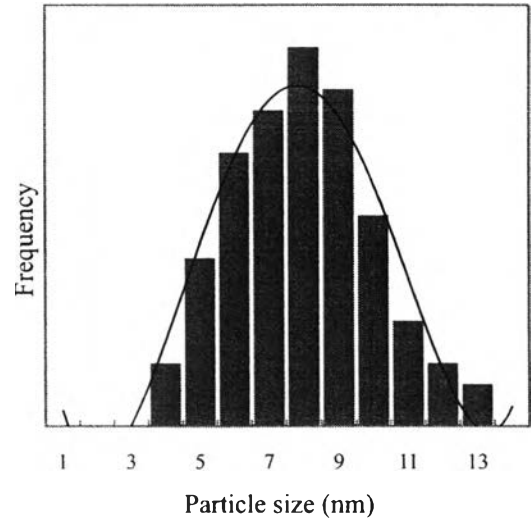
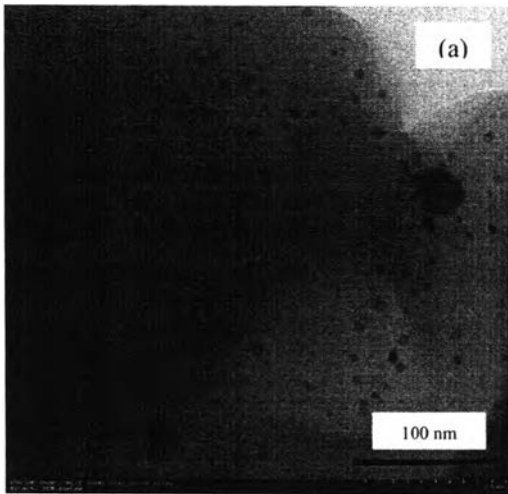


Figure 4.7 SEM micrographs of carbon aerogel, (a) and granule activated carbon, (b).

TEM micrographs of Pd/carbon aerogel, spent Pd/carbon aerogel, Pd/granule activated carbon, and spent Pd/granule activated carbon catalyst (Figure 4.8) revealed that the average Pd particle size close to the value obtained with XRD results. The average Pd particle size of Pd/carbon aerogel and spent Pd/carbon aerogel from TEM measurements was found in the range of 7 to 11 nm. And the average Pd particle size of Pd/granule activated carbon and spent Pd/granule activated carbon from TEM measurements was found in the range of 20 to 21 nm. This clearly indicates that the dispersion of Pd/carbon aerogel is high (Table 4.4), which resulted in lower particle size. Whereas, the Pd/granule activated carbon exhibited the formation of larger Pd particles. The TEM measurements also showed that granule activated carbon catalyst the size distribution of Pd particles is uniform and the average particle size of Pd is higher than Pd/carbon aerogel.



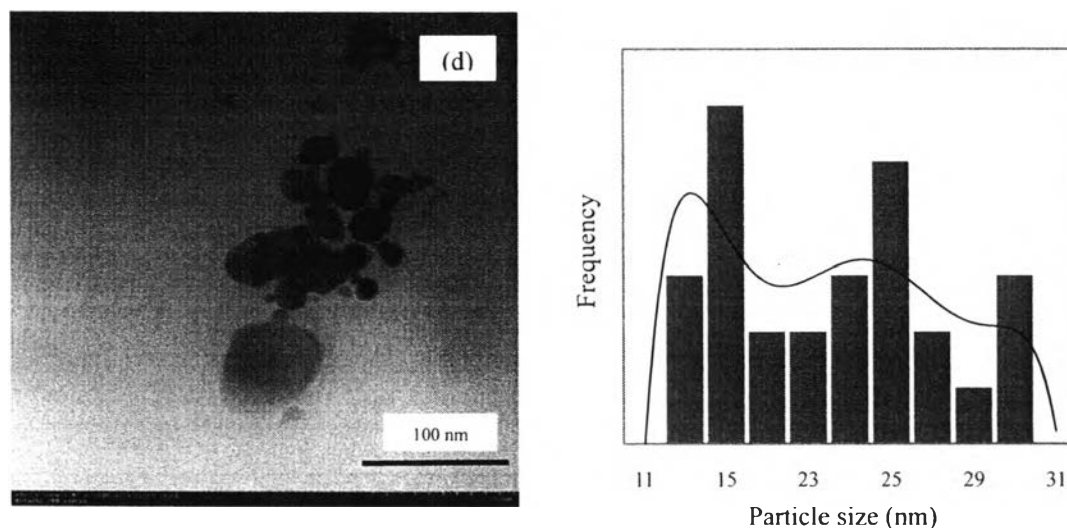


Figure 4.8 TEM micrographs and size distributions of Pd supported on carbon aerogel, (a) spent Pd supported on carbon aerogel, (b) Pd supported on granule activated carbon, (c) spent Pd supported on granule activated, (d).

4.3 Effect of Particle Size of Activated Carbon Support

In this section, the effects of particle size: activated carbon (40 μ m), granule activated carbon, and 850 μ m of granule activated carbon on the partial hydrogenation of polyunsaturated FAMES were studied. The catalytic activity of these catalysts was indicated by examining FAME composition in the partial hydrogenated biodiesel.

For the partial hydrogenation reaction using Pd/activated carbon (40 μ m) as a catalyst, the FAMES composition, as shown in Figure 4.9(a) of C18:2 and C18:1 rapidly reduce from 4.18% to 0% and from 26.50% to 3.68%, respectively, after 1.0 h of reaction; while C18:0 sharply increased from 0.14% to 27.77% after 1.0 h.

The partial hydrogenation reaction of Pd/activated carbon (850 μ m) activated carbon, shown in Figure 4.9(b), C18:2 decreased from 4.18% to 0.20% and C18:1 decreases from 26.50 to 10.86, whereas C18:0 rapidly increased from 0.14% to 19.93%, after 1.0 h of reaction. For the partial hydrogenation reaction using Pd/granule activated carbon as a catalyst, the FAMES composition shown in Figure

4.8(c), illustrated that C18:2 decreased from 4.18% to 0.26% and C18:1 decreased from 26.50% to 22.05%, whereas C18:0 increased from 0.14% to 8.60%, after 1.0 h of reaction.

According to these results, it can be concluded that the Pd/activated carbon (850 μ m) showed higher catalytic activity in term of complete hydrogenation than Pd/granule activated carbon because of its high dispersion, which resulted in higher catalytic activity on partial hydrogenation.

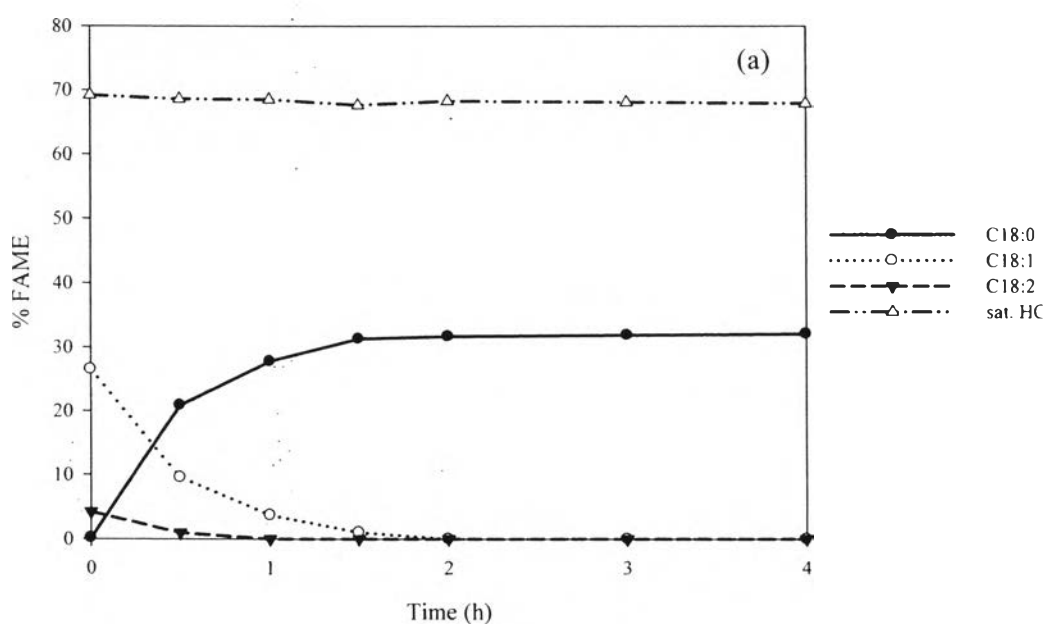


Figure 4.9 Effect of particle size of carbon support: (a) activated carbon (40 μ m), (b) activated carbon (850 μ m), (c) granule activated carbon on FAME composition of biodiesel after partial hydrogenation reaction.

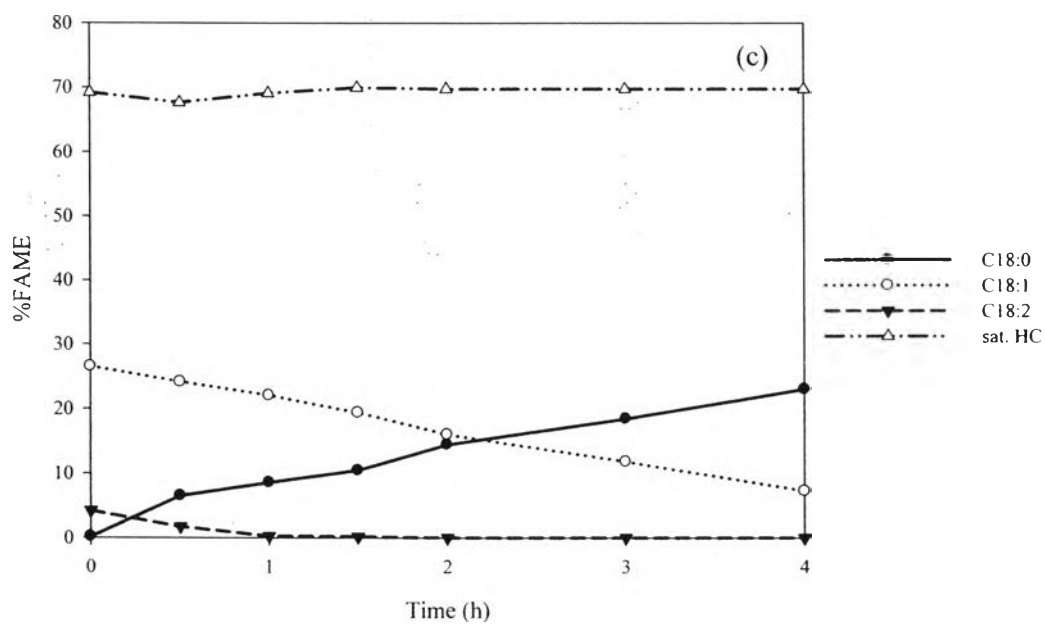
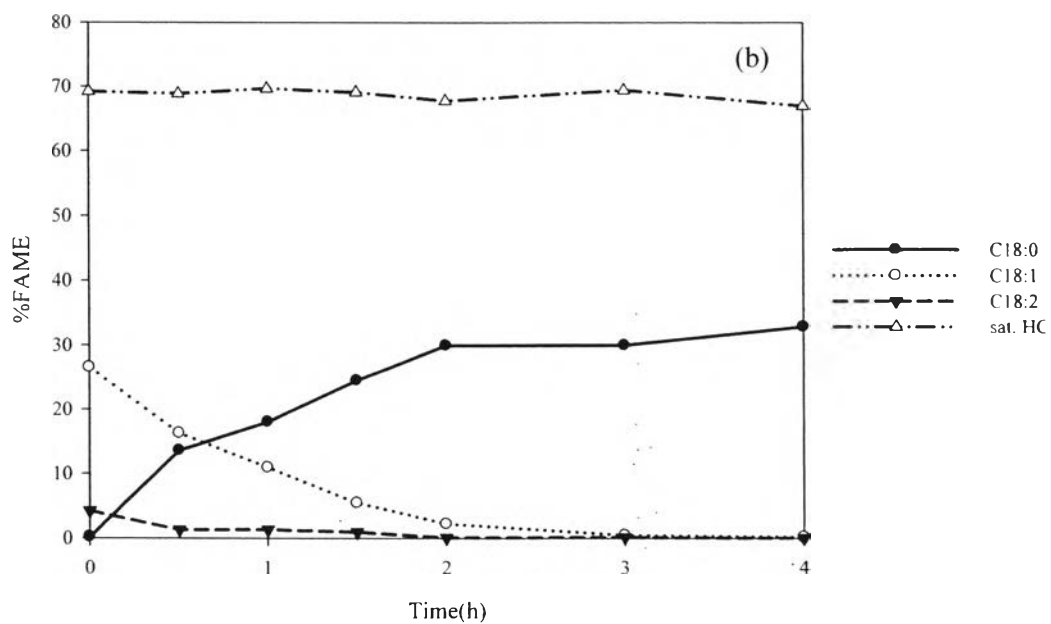


Figure 4.9 (cont.) Effect of particle size of carbon support: (a) activated carbon (40µm), (b) activated carbon (850µm), (c) granule activated carbon on FAME composition of biodiesel after partial hydrogenation reaction.

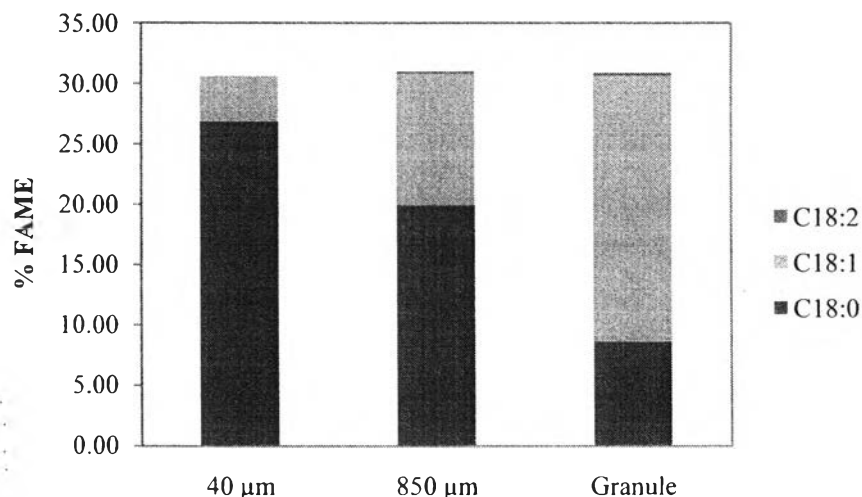


Figure 4.10 FAMES composition after 1 h of partial hydrogenation using activated carbon (40 μm), granule activated carbon, and 850 μm of granule activated carbon.

4.4 Effect of Hydrogen Partial Pressure

The effects of hydrogen partial pressure on the partial hydrogenation of polyunsaturated FAMES were studied by varying pressure from 1 to 2 and 4 bar. The catalytic activity of these catalysts was determined by examining FAME composition in the partial hydrogenated biodiesel. The reaction was operated at a condition of 120°C, 50 ml/min of hydrogen flow rate, 500 rpm of stirring rate, and 1.5 wt. % of catalyst compared to starting oil.

Firstly, the partial hydrogenation reaction was carried out under pressure 4 bar of hydrogen partial pressure using Pd/granule activated carbon as a catalyst; C18:2 decreased from 4.18% to 0.26% and C18:1 slowly decreased from 26.50% to 22.05%, whereas C18:0 increased from 0.14% to 8.60%, after 1.0 h of reaction, as shown in Figure 4.11(a). And after 2.0 h of reaction C18:2 were completely hydrogenated.

The FAMES composition after partial hydrogenation reaction under pressure 2 bar of hydrogen partial pressure using Pd/granule activated carbon as catalyst is shown in Figure 4.11(b). It showed that C18:2 decreased from 4.18% to 1.26% and C18:1 slowly decreases from 26.50% to 23.27%, whereas C18:0 increased from

0.14% to 6.18%, after 1.0 h of reaction. And the percentage of C18:2 were not completely hydrogenated after 4 h of reaction, 0.24% of C18:2 still remain.

At last, the FAMES composition after partial hydrogenation reaction under pressure 1 bar of hydrogen partial pressure using Pd/granule activated is shown in Figure 4.11(c) ; C18:2 decreased from 4.18% to 2.18% and C18:1 slowly decreases from 26.50% to 24.44%, whereas C18:0 increased from 0.14% to 4.95%, after 1.0 h of reaction. And percentage of C18:2 were not completely hydrogenated by after 4 h of reaction, and 0.50% of C18:2 still remain.

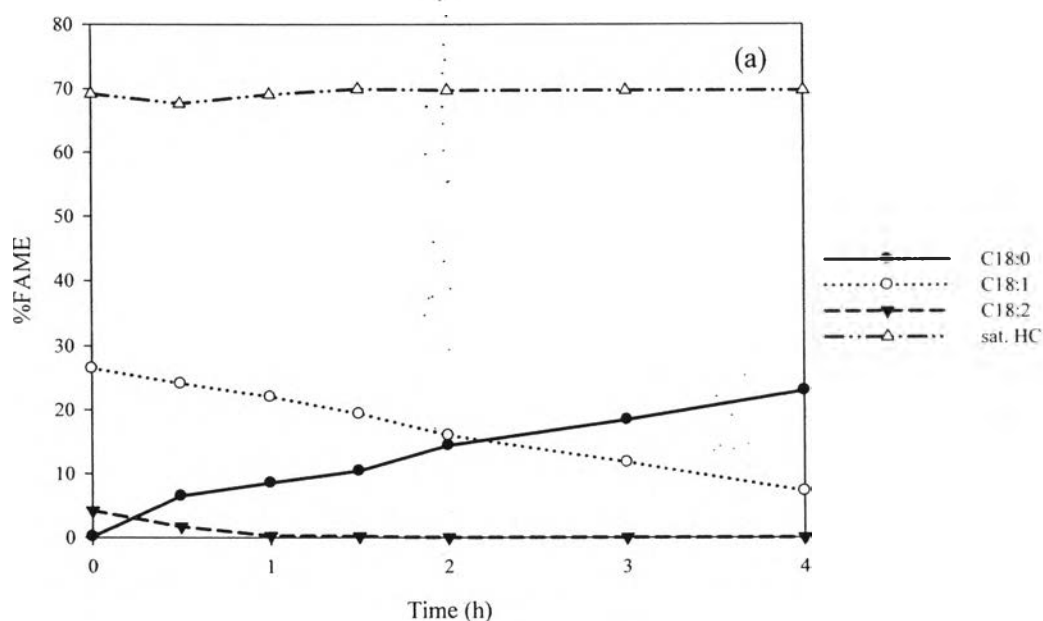


Figure 4.11 Effect of hydrogen partial pressure: (a) 4 bar, (b) 2 bar and (c) 1 bar on FAME composition of biodiesel after partial hydrogenation. (Reaction conditions: 120°C, 50 ml/min of H₂ flow rate, 500 rpm of stirring rate, and 1.5 wt. % of catalyst compared with starting oil).

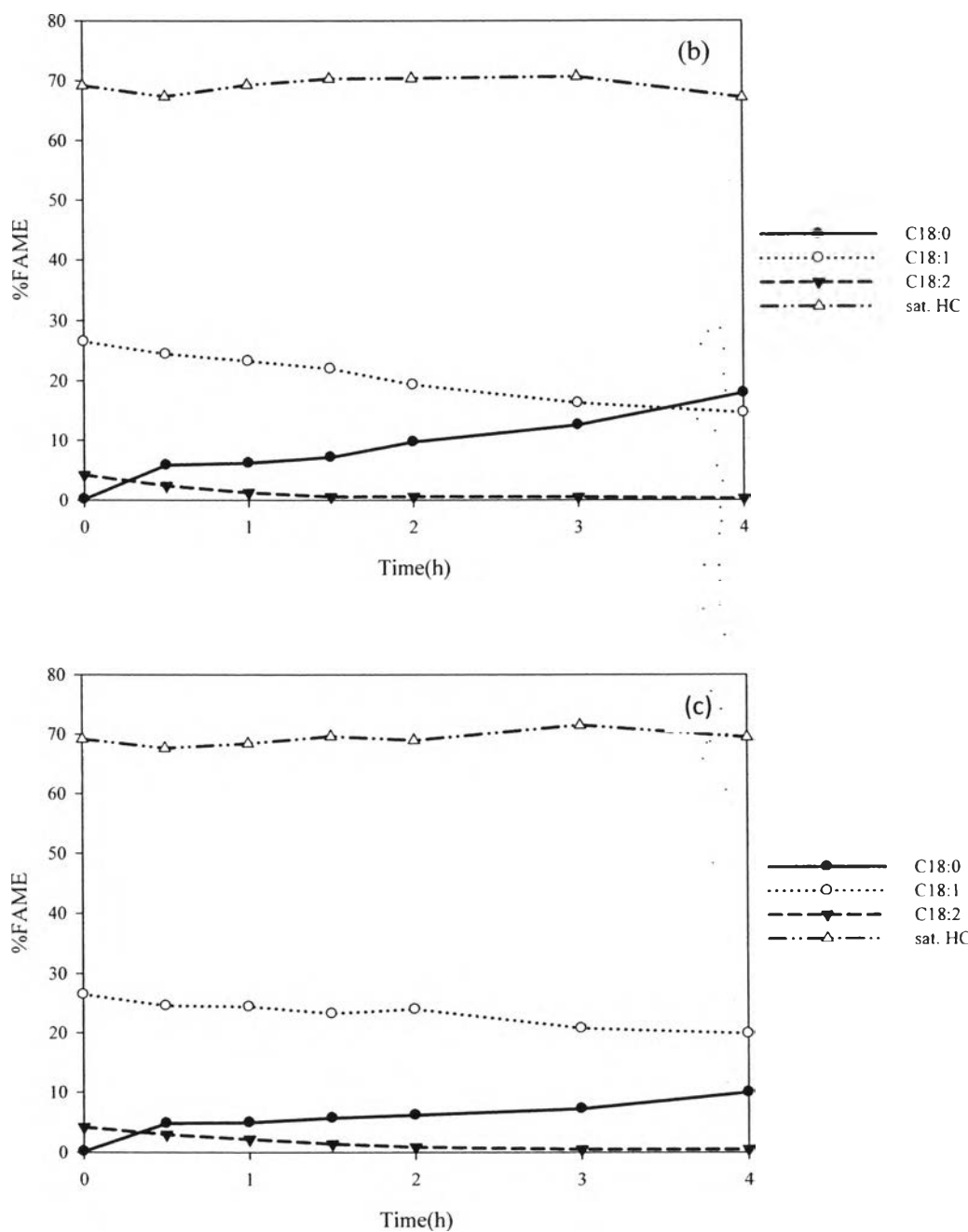


Figure 4.11 (cont.) Effect of hydrogen partial pressure: (a) 4 bar, (b) 2 bar and (c) 1 bar on FAME composition of biodiesel after partial hydrogenation. (Reaction conditions: 120°C, 50 ml/min of H₂ flow rate, 500 rpm of stirring rate, and 1.5 wt. % of catalyst compared with starting oil).

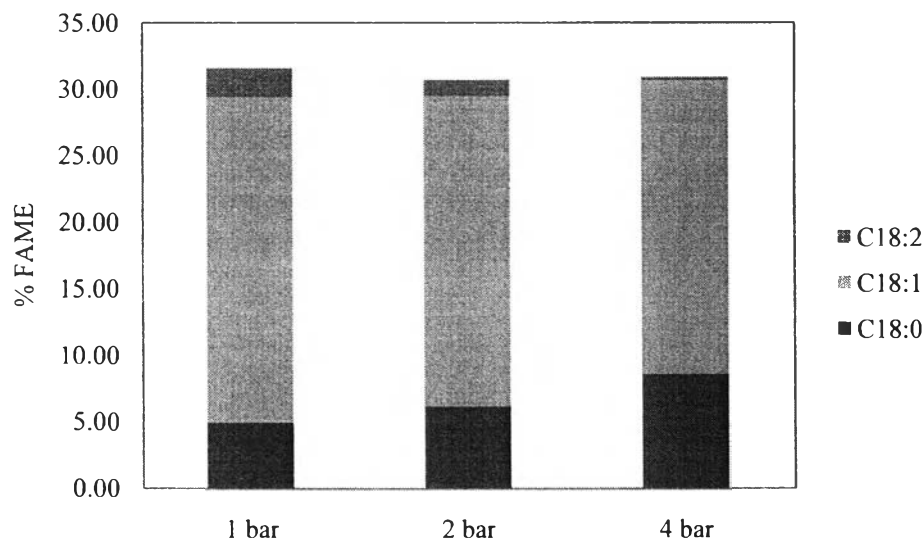


Figure 4.12 FAMES composition after 1 h of partial hydrogenation and operated at 1 bar 2 bar, and 4 bar (Reaction condition: 120°C, 50 ml/min of H₂ flow rate, 500 rpm of stirring rate, and 1.5 wt. % of catalyst compared with starting oil).

To confirm the results of effect of hydrogen partial pressure, the pressure was varied from 2 bar and 4 bar for the partial hydrogenation of biodiesel and hydrogen flow rate was kept constant at 30 ml/min.

The partial hydrogenation reaction was carried out at 4 bar of hydrogen partial pressure using Pd/granule activated carbon as a catalyst. The results showed that C18:2 decreased from 4.18% to 1.24% and C18:1 slowly decreased from 26.50% to 22.11%, whereas C18:0 increased from 0.14% to 7.41%, after 1.0 h of reaction, as shown in Figure 4.13(a). The FAMES composition after partial hydrogenation reaction under 2 bar of hydrogen partial pressure using Pd/granule activated carbon is shown in Figure 4.13(b), It was found that C18:2 decreased from 4.18% to 2.72% and C18:1 slowly decreased from 26.50% to 23.49%, whereas C18:0 increased from 0.14% to 5.68%, after 1.0 h of reaction, It can be seen that the percentage of FAME decreased when hydrogen partial pressure decreased from 4 bar to 2 bar.

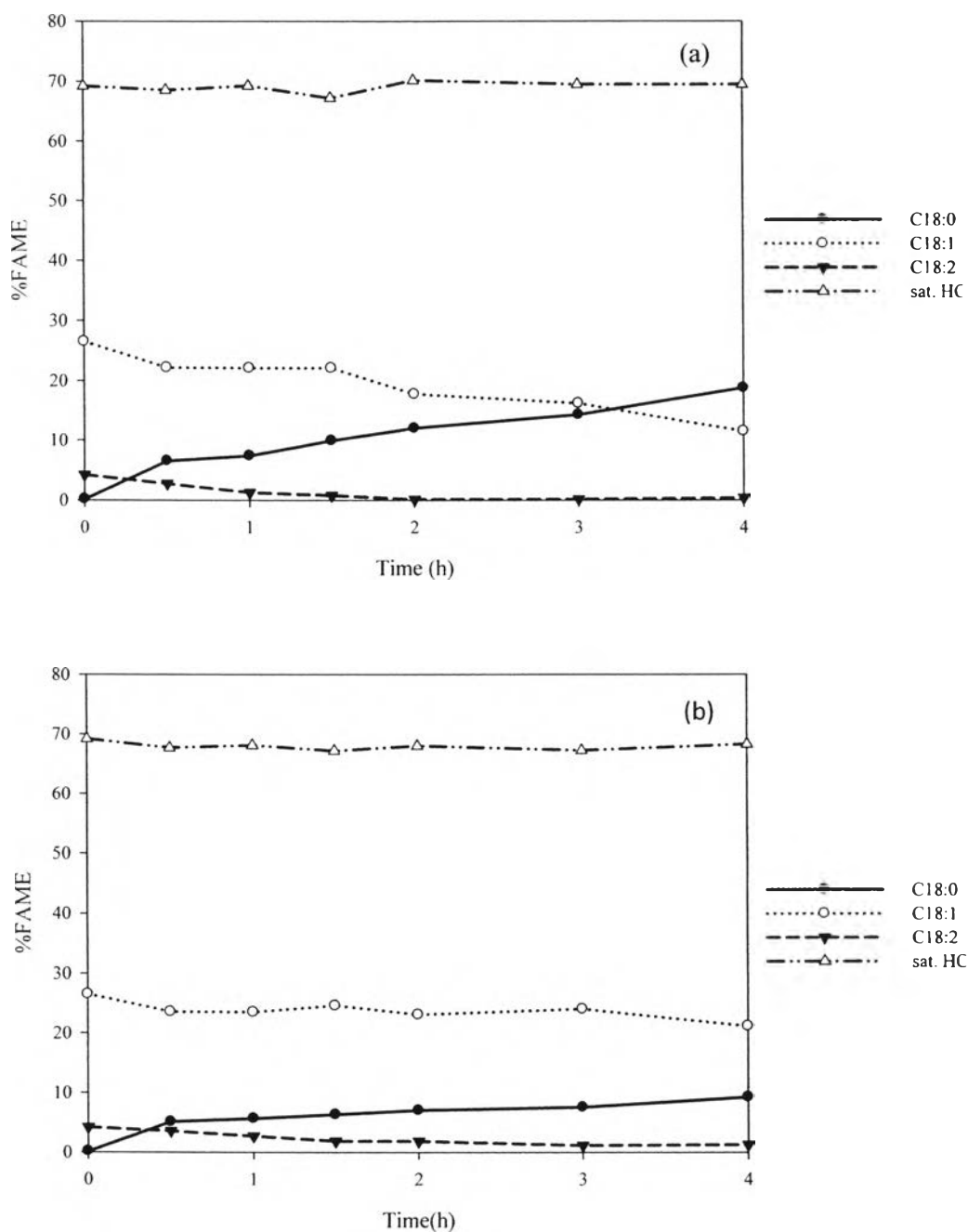


Figure 4.13 Effect of hydrogen partial pressure: (a) 4 bar and (b) 2 bar on FAME composition of biodiesel after partial hydrogenation reaction using 2 wt. % Pd/granule activated carbon calcined under N_2 at $500^\circ C$ (Reaction condition: $120^\circ C$, 30 ml/min of H_2 flow rate, 500 rpm of stirring rate, and 1.5 wt. % of catalysts compared with starting oil).

From these results, it could be suggested that at the same reaction time of partial hydrogenation reaction, the percentages of C18:1 in biodiesel product after partial hydrogenation reaction under difference partial pressure was observed amount of C18:0 in biodiesel product after partial hydrogenation reaction under pressure of 4 bar was higher than those of 2 bar and 1 bar, respectively. According to these results, it can be concluded that high hydrogen partial pressure during partial hydrogenation reaction leads to high conversion of C18:2 and C18:1.

4.5 Effect of Reaction Temperature

The effect of temperature was considered by varying from 120°C, 100 °C ,and 80°C on the partial hydrogenation of polyunsaturated FAMES. The reaction conditions were operated at 4 bar, 500 rpm of stirring rate, 1.5 wt. % of catalyst compared to starting oil, and 2 wt. % Pd/carbon support.

For the partial hydrogenation reaction, the FAMES composition carried out at 120°C shown in Figure 4.14(a) show that C18:2 decreased from 4.18% to 0.26 % and C18:1 slowly decreases from 26.50% to 19.16%, whereas C18:0 increased from 0.14% to 10.79%, after 1.0 h of reaction. And then the partial hydrogenation reaction by operated at 100°C, the FAMES composition is shown in Figure 4.14(b); C18:2 decreased from 4.18% to 0.83% and C18:1 decreases from 26.50 to 21.11, while C18:0 slowly increased from 0.14% to 9.67%, after 1.0 h of reaction. For the partial hydrogenation reaction, the FAMES composition operated under temperature 80°C is shown in Figure 4.14(c); C18:2 decreased from 4.18% to 0.92% and C18:1 decreases from 26.50% to 22.41%, while C18:0 increased from 0.14% to 8.35%, after 1.0 h of reaction.

Therefore, it can be concluded that higher temperature of partial hydrogenation of polyunsaturated FAMES leads to high conversion of C18:2 to C18:1 and C18:0.

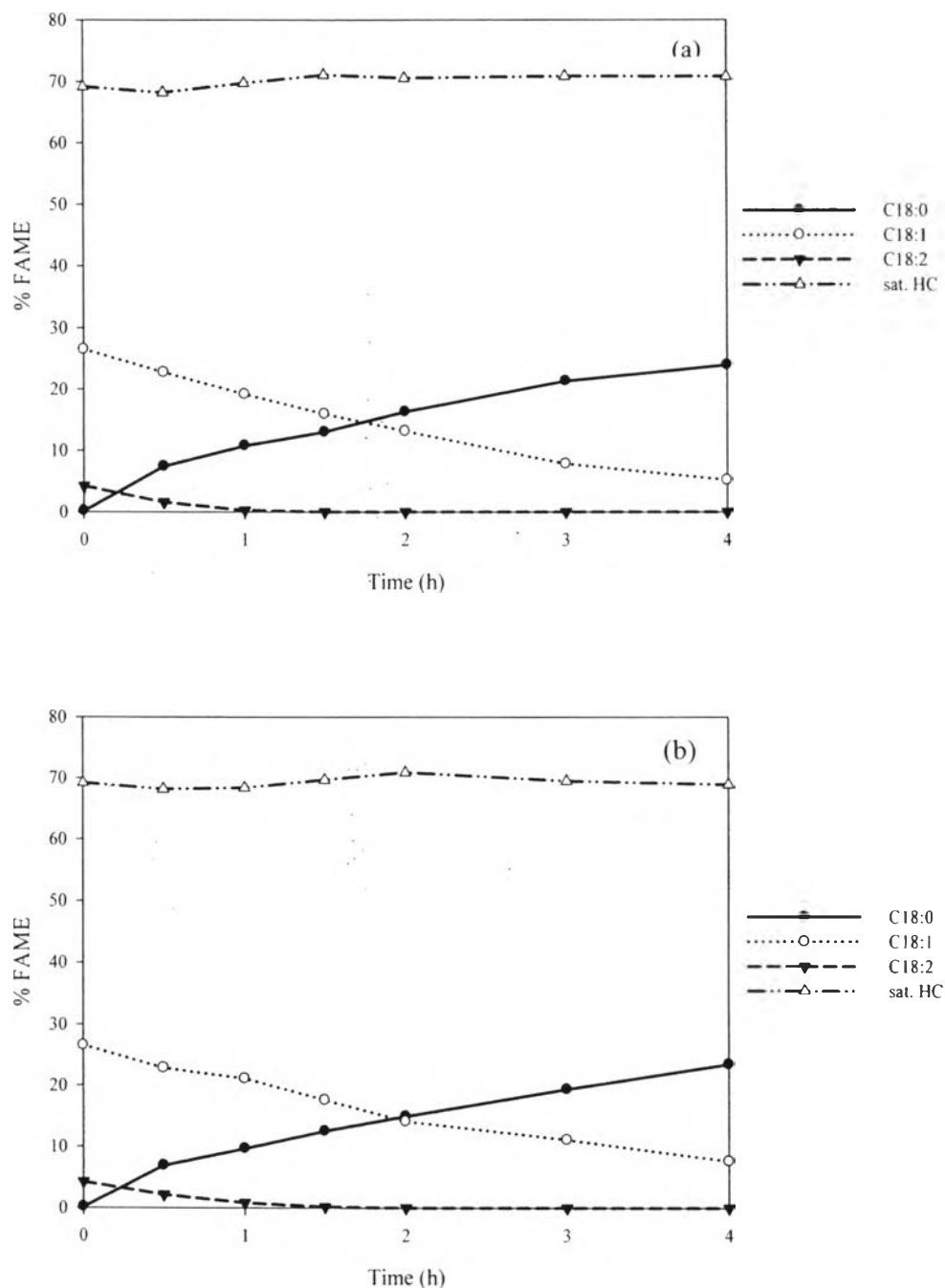


Figure 4.14 Effect of Reaction Temperature: (a) 120°C, (b) 100°C, and (c) 80°C on FAME composition of biodiesel after partial hydrogenation reaction using 2 wt. % Pd/granule activated carbon calcined under N₂ at 500°C.

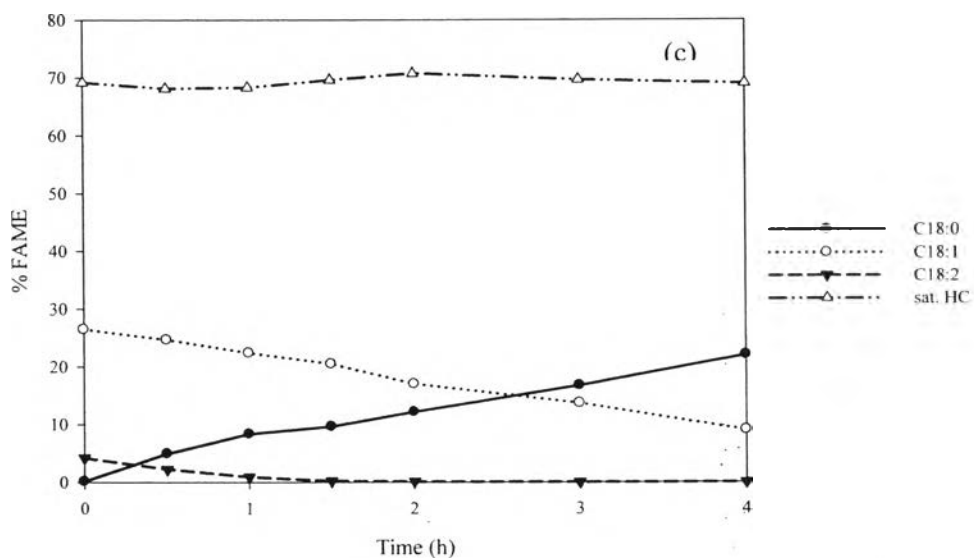


Figure 4.14 (cont.) Effect of Reaction Temperature: (a) 120°C, (b) 100°C, and (c) 80°C on FAME composition of biodiesel after partial hydrogenation reaction using 2 wt. % Pd/granule activated carbon calcined under N₂ at 500°C

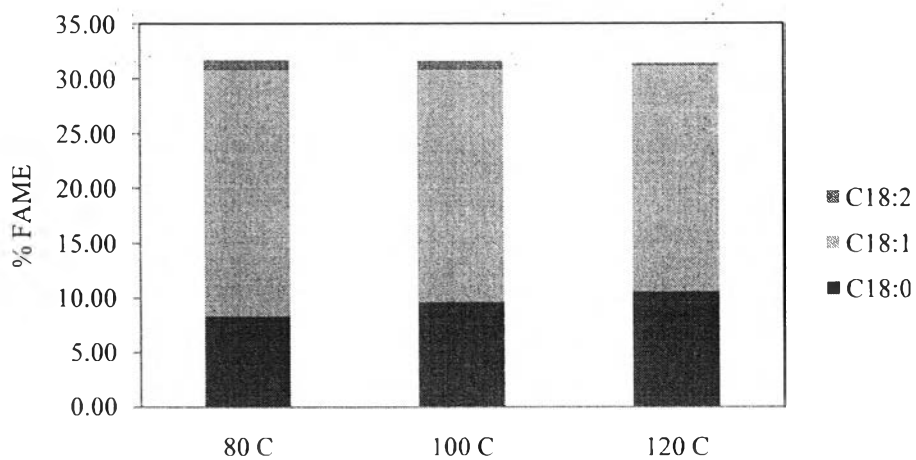


Figure 4.15 FAMES composition after 1 h of partial hydrogenation and operated under temperature 120°C, 100°C and 80°C.

4.6 Effect of Hydrogen Flow Rate

The effect of hydrogen flow rate was considered by varying flow rate from 100 ml/min to 50 ml/min and 30 ml/min on the partial hydrogenation of polyunsaturated FAMES. The reaction conditions were operated at 4 bar, 120°C, 500 rpm of stirring rate, 1.5 wt. % of catalyst compared to starting oil, and 2 wt. % Pd/carbon support.

For the partial hydrogenation using 100 ml/min of H₂ flow is shown in Figure 4.16(a); C18:2 decreases from 4.18% to 0.23% and C18:1 also slowly decreases from 26.50% to 20.82%, whereas C18:0 increased from 0.14% to 8.44%, after 1.0 h of reaction. And for the partial hydrogenation reaction by use 50 ml/min of H₂ flow, the FAMES composition shown in Figure 4.16(b) illustrated C18:2 decreased from 4.18% to 0.26% and C18:1 decreases from 26.50 to 22.05, while C18:0 slowly increased from 0.14% to 8.60%, after 1.0 h of reaction. Finally, FAMES composition by use 30 ml/min of H₂ flow was operated as shown in Figure 4.16(c); C18:2 decreased from 4.18% to 1.24% and C18:1 slowly decreases from 26.50% to 22.11%, whereas C18:0 increased from 0.14% to 7.41%, after 1.0 h of reaction.

It can be concluded that C18:2 and C18:1 decreased when hydrogen flow rate; however, amount of the saturated FAME (C18:0) was increased when hydrogen flow rate was increased.

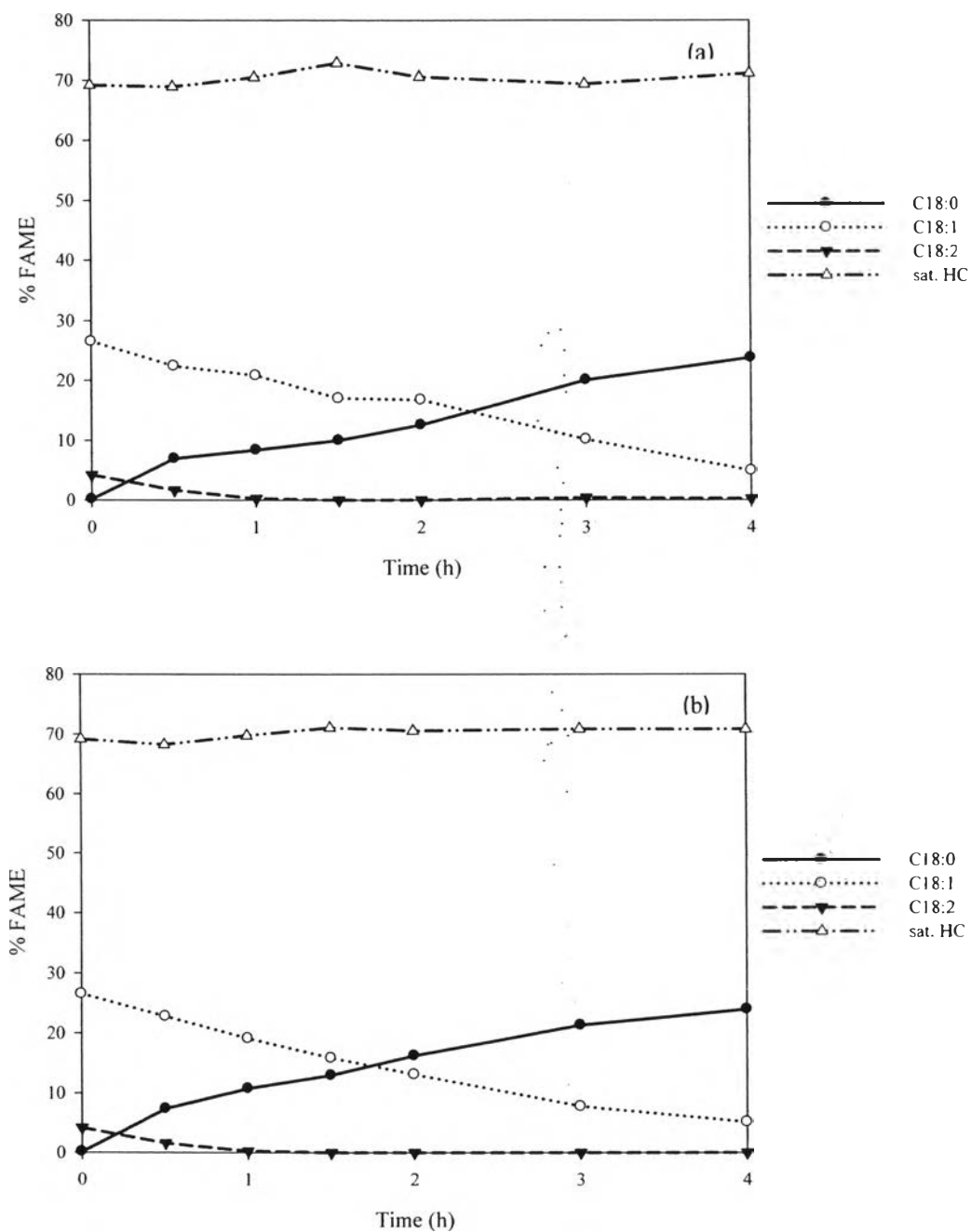


Figure 4.16 Effect of hydrogen flow rate: (a) 100 ml/min (b) 50 ml/min (c) 30 ml/min on FAME composition of biodiesel after partial hydrogenation reaction using 2 wt. % Pd on granules activated (Reaction conditions: 120°C, 4 bar, 500 rpm of stirring rate, and 1.5 wt. % of catalyst compared with starting oil).

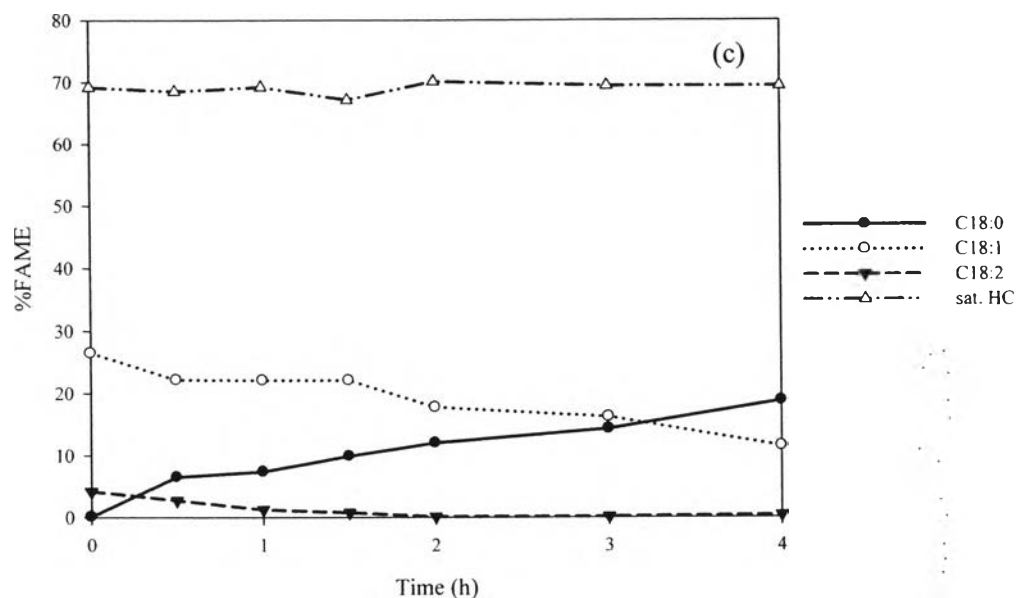


Figure 4.16 (cont.) Effect of hydrogen flow rate: (a) 100 ml/min (b) 50 ml/min (c) 30 ml/min on FAME composition of biodiesel after partial hydrogenation reaction using 2 wt. % Pd on granules activated (Reaction conditions: 120°C, 4 bar, 500 rpm of stirring rate, and 1.5 wt. % of catalyst compared with starting oil).

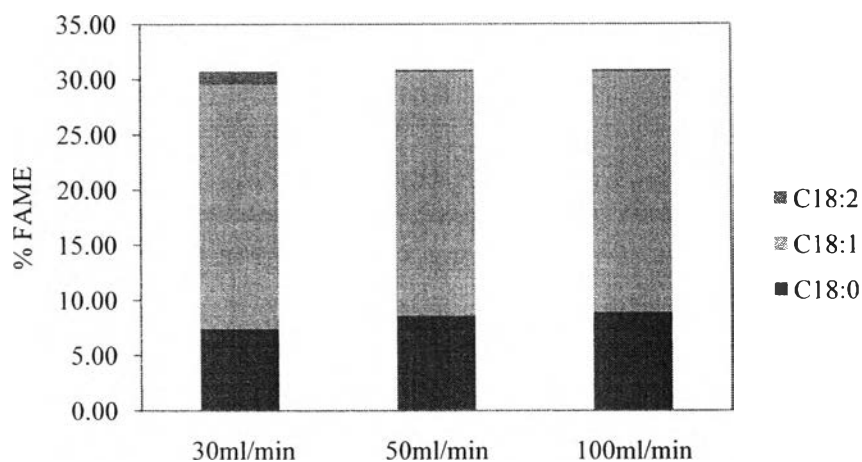


Figure 4.17 FAMES composition after 1 h of partial hydrogenation by use 30 ml/min, 50 ml/min and 100 ml/min of H₂ flow rate.

According to these results, it can be concluded that the Pd/activated carbon (0.5cm) exhibited better property in term of partial hydrogenation compared to Pd/activated carbon (850 μ m) by after 1.0 h of reaction and the reaction was operated under pressure 4 bar, 50 ml/min of H₂ flow rate, 120°C, 500 rpm of stirring rate, 1.5 wt. % of catalyst compared to starting oil and 2 wt. % Pd/granule activated carbon support. Figure 4.18 shows the comparison between the fresh biodiesel and partially hydrogenated biodiesel. The partially hydrogenate biodiesel had better biodiesel properties, especially oxidative stability and cold flow properties with a minimal decrease of C18:1.

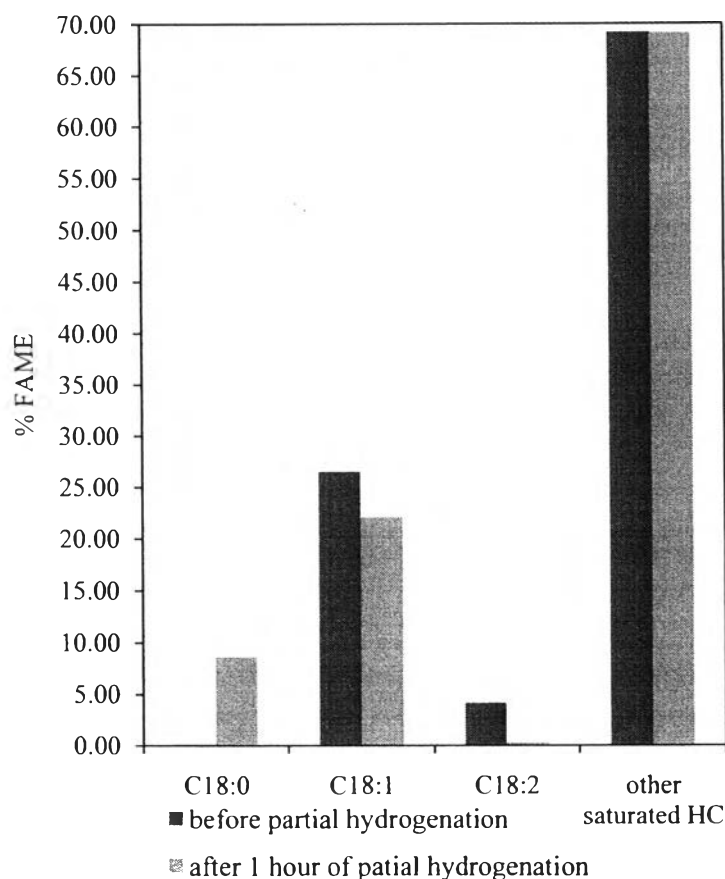


Figure 4.18 FAMES composition after 1 h of partial hydrogenation and operated at under pressure of 4 bar, 50 ml/min of H₂ flow rate, 120°C, 500 rpm of stirring rate, 1.5 wt. % of catalyst compared to starting oil and 2 wt. % Pd/granule activated carbon.