RESULTS

The results are reported orderly in 2 major parts. Part I presents the effects of high carbohydrate and high fat diets on endurance performance in exercise rats. Part II is focusing on the assessment of appropriate proportion of carbohydrate and fat in the diet on endurance in trained rats.

Part I

Effects of High Carbohydrate Diet and High Fat Diet on Endurance Performance in Exercise Rats

The animal were divided into high carbohydrate diet (HC) and high fat diet (HF) groups which received eucaloric and isocaloric high carbohydrate (CHO 80%E, fat 0%E) and high fat (CHO 5%E, fat 75%E) diets, respectively, for 8 weeks. Simultaneously, all animals were performed running exercise 5 days per week. In addition to endurance performance, physical characteristics, cardiovascular parameters and changes of blood borne substrates were investigated.

A. Body Weight

Changes of body weight during 8 weeks of feeding high carbohydrate and high fat diets in combination with exercise are shown in Figure 1. The initial weights were not significantly different among

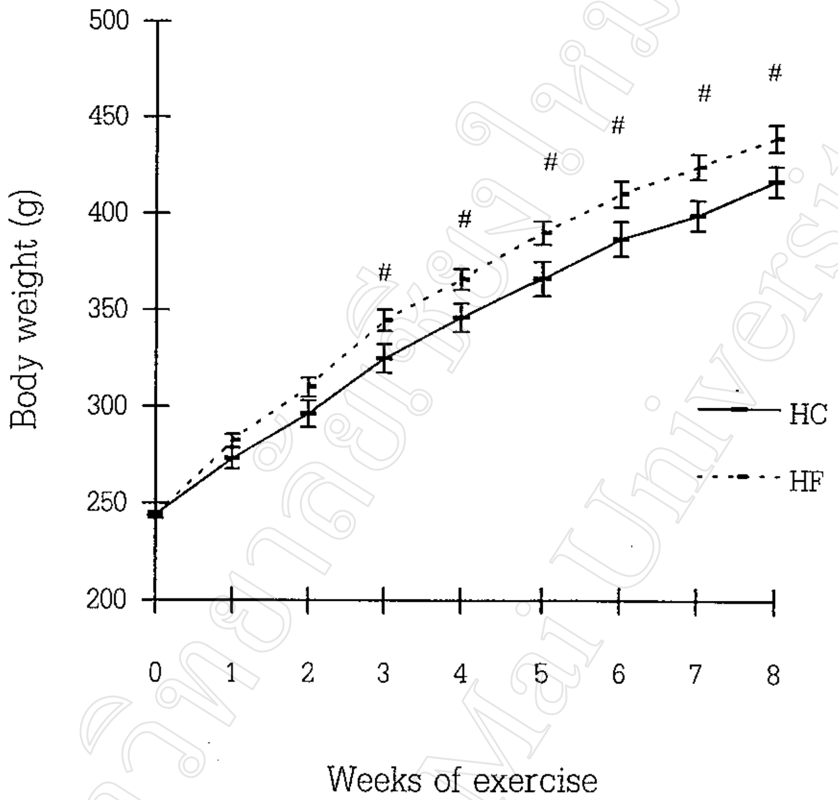

Figure 1. Effect of high carbohydrate (HC) and high fat (HF) diets on body weight changes during 8 weeks of exercise.

Each value represented mean ± SE from 40 rats

#; Significantly different from HC group, $p<0.05$

rats in all experimental groups. In HC group, the mean initial body weight was 244.12 $\pm$ 1.45 g and considerably increased, about 70%, to 417.12 $\pm$ 7.86 g at the end of the 8^{th} week. The weight gain in HF group was 80% (from 243.25 $\pm$ 1.16 to 439.62 $\pm$ 7.07 g), being 10% apparently greater than in HC group ($p<0.05$). Correspondingly, there were significant increased body weight in HC group as compared with HF group during 3^{rd} – 8^{th} weeks ($p<0.05$).

B. Cardiovascular Parameters

The values of mean systolic blood pressure recorded by the tail cuff method before and after consuming high carbohydrate and high fat diets in association with exercise are summarized in Table 3. The baseline value of systolic blood pressure in HC group was 164.87 $\pm$ 3.23 mmHg and significantly decreased, about 18%, to 132.87 $\pm$ 3.36 mmHg at the end of the 8^{th} week ($p<0.01$). Also in the HF group, there was an apparent reduction of systolic blood pressure, about 17% (from 160.68 $\pm$ 2.62 to 134.75 $\pm$ 4.12 mmHg) after 8 weeks of exercise ($p<0.01$). Initial resting heart rates of rats in HC and HF groups were 443.37 $\pm$ 4.49 and 448.25 $\pm$ 4.97 beats/min, respectively. After exercise for 8 weeks, the mean values of resting heart rates were significantly reduced in both HC and HF groups, 400.12 $\pm$ 5.24 and 411.12 $\pm$ 5.06 beats/min, respectively ($p<0.01$). The reductions of systolic blood pressure and resting heart rate indicated that 8 week - training caused fitness of rats in both HC and HF

Table 3. Effects of high carbohydrate (HC) and high fat (HF) diets in association with exercise on resting systolic blood pressure and heart rate.

Variable	Group	
	HC	HF
Systolic blood pressure (mmHg)		
Initial	164.87 ± 3.23	160.68 ± 2.63
End of week 8	132.87 ± 3.36★★	134.75 ± 4.12★★
Heart rate (beats/min)		
Initial	443.37 ± 4.49	448.25 ± 4.97
End of week 8	400.12 ± 5.24★★	411.12 ± 5.06★★

Each value represents mean ± SE from 40 rats.

★★; Significantly different from initial value, $p<0.01$.

groups. In addition, the type of diets did not cause significant difference in fitness of trained rats .

C. Blood Borne Substrates

Table 4 shows concentrations of plasma glucose, serum triglyceride and serum cholesterol before and after feeding with high carbohydrate and high fat diets together with exercise for 8 weeks. No significant difference in the means of initial plasma glucose concentrations was presented between HC and HF groups (94.73 ± 4.68 and 102.78 ± 5.71 mg/dl, respectively, $p<0.05$). After 8 weeks of dietary manipulation, there was an increased plasma glucose levels in HC group about 21% (from 94.54 ± 4.68 to 113.89 ± 5.12 mg/dl). The mean plasma glucose concentration in HF group was 99.41 ± 2.60 mg/dl, being significantly lower than in HC group at the end of the 8^{th} week.

The initial values of serum triglyceride concentration were similar in HC and HF groups. At the end of the 8^{th}week, mean serum triglyceride levels increased about 43% in HC (from 138.40 ± 7.39 to 199.15 ± 12.34 mg/dl) and 42% in HF groups (from 137.30 ± 7.11 to 195.20 ± 23.22 mg/dl). No significant difference in the serum triglyceride concentrations was observed between HC and HF groups at the end of the 8^{th} week ($p> 0.05$).

There were similar in the initial serum cholesterol concentrations in HC and HF groups. The serum cholesterol level in rats fed with high carbohydrate diet (HC group) decreased about 11% (from 86.87 ± 2.59 to

Table 4. Effects of high carbohydrate (HC) and high fat diets in associated with exercise on resting concentrations of plasma glucose, serum triglyceride and serum cholesterol before and after 8 weeks of exercise.

Substrate	Group	
	HC	HF
Glucose (mg/dl)		
Initial	94.73 ± 4.68	102.78 ± 5.71
End of week 8	113.89 ± 5.12★	99.41 ± 2.60#
Triglyceride (mg/dl)		
Initial	138.40 ± 7.39	137.30 ± 7.11
End of week 8	199.15 ± 12.34★	195.20 ± 23.22★
Cholesterol (mg/dl)		
Initial	86.87 ± 2.59	83.95 ± 2.95
End of week 8	76.74 ± 2.55★	97.55 ± 4.22★,#

Each value represents mean ± SE of duplicated measurement from 40 rats.

★; Significantly different from initial value, $p<0.05$.

#; Significantly different from HC group, $p<0.05$.

76.74 $\pm$ 2.55 mg/dl) at the end of the 8^{th} week. In contrast, an increased serum cholesterol concentration was noted in HF group (16%, from 83.95 $\pm$ 2.95 to 97.55 $\pm$ 4.22 mg/dl). There was a significant difference in the serum cholesterol levels at the end of the 8^{th} week between HC and HF groups ($p<0.05$).

D. Maximal Oxygen Consumption (Vo_{2max})

As shown in Figure 2, the maximal oxygen consumption (Vo_{2max}) through 8 weeks of exercise training in both HC and HF groups increased by a different magnitude. In HC group, high carbohydrate diet in combination with 8 weeks of exercise caused 95% increase of the Vo_{2max} (from 16.57 $\pm$ 0.29 to 31.66 $\pm$ 0.45 ml/kg/min). The magnitude of increment of Vo_{2max} in HF group was about 122% (from 16.15 $\pm$ 0.41 to 36.63 $\pm$ 0.49 ml/kg/min), being significantly greater in comparison with HC group ($p<0.01$). Correspondingly, there were significant differences in the Vo_{2max} at the 6^{th} and 8^{th} weeks between HC and HF groups ($p<0.01$).

E. Endurance Performance

Figure 3 demonstrated changes of endurance time, represented as the time to exhaustion, during 8 weeks of feeding high carbohydrate and high fat diets in combination with exercise. Initially, time to exhaustion were 28.55 $\pm$ 0.81 and 28.65 $\pm$ 0.94 min in HC and HF groups, respectively. Likewise the Vo_{2max}, time to exhaustion during 8 weeks of training in both HC and HF groups increased by a different magnitude.

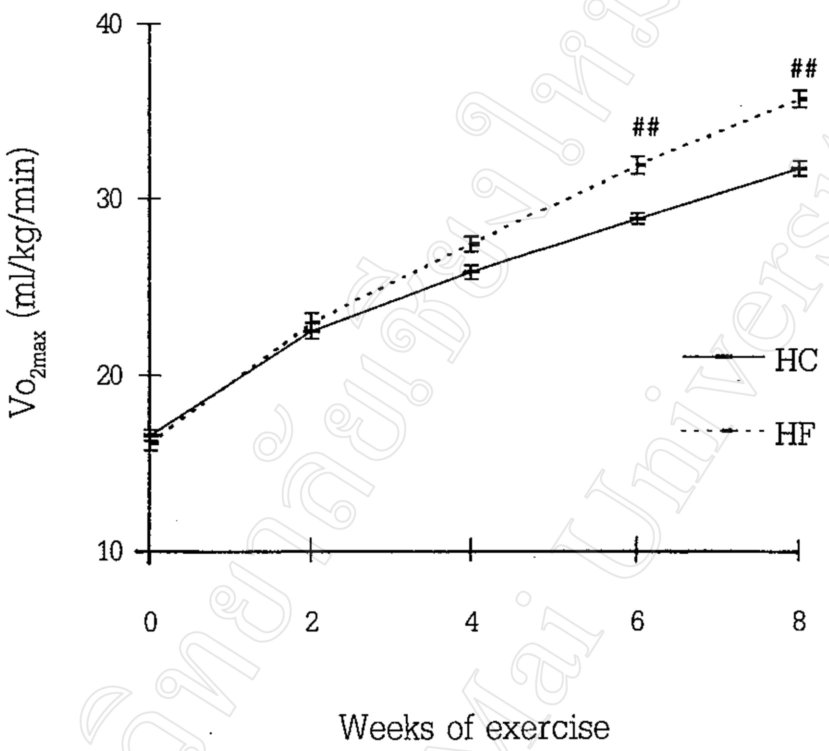

Figure 2. Effects of high carbohydrate (HC) and high fat (HF) diets on changes in the maximal oxygen consumption (Vo_{2max}) during 8 weeks of exercise in groups.

Each value is mean $\pm$ SE from 40 rats.

$^{\#\#}$; Significantly different from HC group, $p<0.01$.

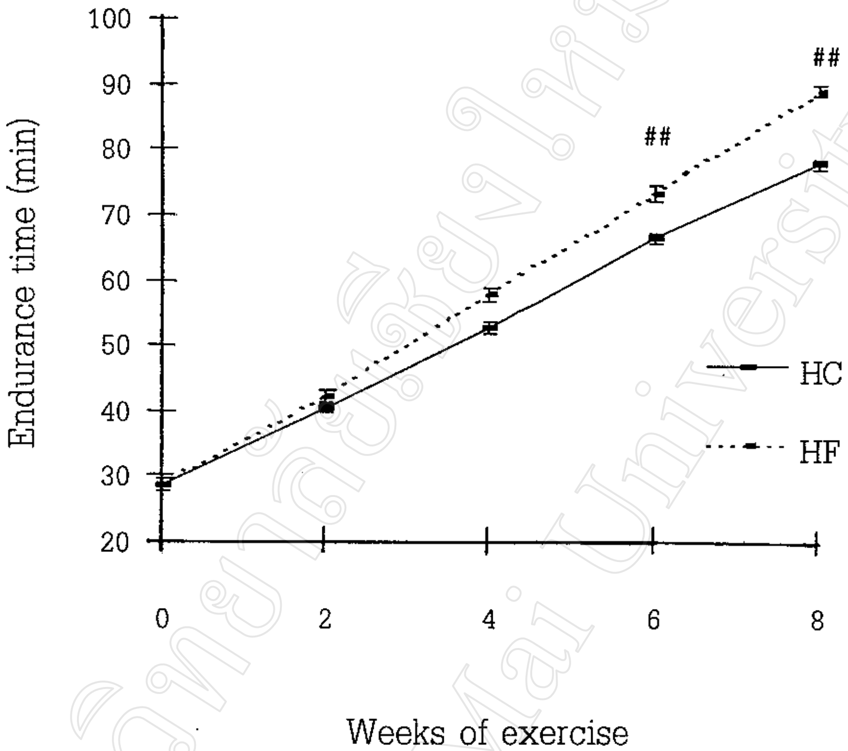

Figure 3. Effects of high carbohydrate (HC) and high fat (HF) diets on endurance time during 8 weeks of exercise.

Each value is mean ± SE from 40 rats.

##; Significantly different from HC group, $p<0.01$.

At the end of the 8th week, the time to exhaustion in HF group was increased about 210% (from 28.65 $\pm$ 0.94 to 88.77 $\pm$ 0.85 min), being significantly greater than that noted in HC group (175%, from 28.55 $\pm$ 0.81 to 77.52 $\pm$ 0.76 min) ($p<0.01$). Significant differences in time to exhaustion were also presented between HC and HF groups at the 4th, 6th and 8th weeks ($p<0.01$).

The results in part I demonstrated that trained rats in both HC and HF groups had increases in endurance performance as indicated by Vo_{2max} and endurance time. In addition, the increased endurance performance was higher in trained rats fed with high fat diet than those consumed high carbohydrate diet.

Part II

Assessment of Appropriate Proportion of Dietary Carbohydrate and Fat for Endurance Performance in Exercise Rats

At the end of the 8th week, rats in HC group were subdivided into 4 subgroups: HC, HCI, HCII and HCIII. The rats in HC subgroup were continually fed with high carbohydrate diet while those in HCI, HCII and HCIII subgroups received diets with formula I, II and III, respectively. Likewise, rats in HF subgroup were maintained on the same high fat diet while those in HFI, HFII and HFIII subgroups were fed with formula I, II and III diets, respectively. All diets were isocaloric but the proportion of fat to carbohydrate contents increased in the order of high carbohydrate diet < formula I diet < formula II diet < formula III diet < high fat diet, as shown in Table 1 in Materials and Methods. All animals were continually exercised for further 12 days. At the end of experiment, one - half of rats in each subgroup were run to exhaustion, whereas the remaining rats served as resting controls.

A. Endurance Performance

At the end of experiment, one-half of rats in each subgroup were subjected to run until exhausting. The time to exhaustion was measured and presented as endurance time in Table 5. No significant differences in endurance time before changing of the diet were noted among HC, HCI, HCII and HCIII subgroups (74.40 $\pm$ 2.33, 77.40 $\pm$ 1.40, 79.00 $\pm$ 1.26 and 77.40 $\pm$ 1.53 min, respectively). All subgroups showed significant increases of endurance time at the end of experiment (85.60 $\pm$ 2.30, 89.20 $\pm$ 1.59, 91.00 $\pm$ 2.02 and 94.80 $\pm$ 1.65 min in HC, HCI, HCII and HCIII subgroups, respectively, $p<0.01$). A significant difference in endurance time at the end of experiment was established between HC and HCIII subgroups ($p<0.05$). The magnitude of increased endurance time in HC subgroup (11%) was the lowest and was significantly different from the values noted in HCII and HCIII subgroups (17% and 22%, $p<0.05$) (Figure 4). In addition, a significant difference in magnitude of increased endurance time was observed between HCI and HCIII subgroups (15% and 22%, $p<0.05$). Endurance times in HFI, HFII, HFIII and HF subgroups before changing of the diet were similar (86.40 $\pm$ 3.54, 86.20 $\pm$ 2.05, 86.40 $\pm$ 1.28 and 86.00 $\pm$ 2.47 min, respectively) (Table 6). There were

Table 5. Effects of different proportion of fat to carbohydrate contents on endurance time in exercise rat pre-fed with high carbohydrate diet.

Variable	Subgroup			
	HC	HCI	HCII	HCIII
Endurance time (min)				
Week 8	74.40 ± 2.33	77.40 ± 1.40	79.00 ± 1.26	77.40 ± 1.53
At the end of experiment	85.60 ± 2.30★★	89.20 ± 1.59★★	91.00 ± 2.02★★	94.80 ± 1.65★★,#

Each value is mean ± SE from 10 rats.

HC; high carbohydrate diets, HCI; formula I diet, HCII; formula II diet and HCIII; formula III diet

★★; Significantly different from week 8 value, $p<0.01$.

#; Significantly different from HC subgroup, $p<0.05$.

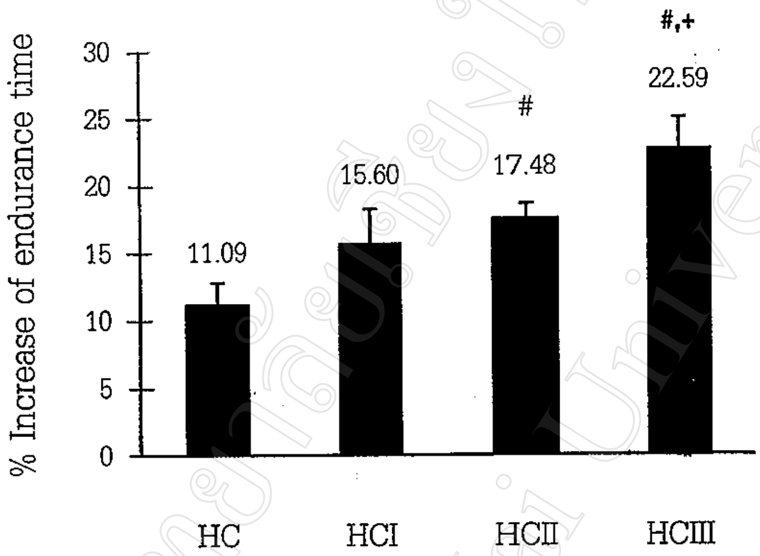

Figure 4. Effects of different proportion of fat to carbohydrate content on magnitudes of increased endurance time in exercise rats pre-fed with high carbohydrate diet.

HC; high carbohydrate diet, HCI; formula I diet, HCII; formula II diet and HCIII; formula III diet.

Each value is mean ± SE from 10 rats.

#; Significantly different from HC subgroup, $p<0.05$.

+; Significantly different from HCI subgroup, $p<0.05$.

Table 6. Effects of different proportion of fat to carbohydrate contents on endurance time in exercise rat pre-fed with high fat diet.

Variable	Subgroup			
	HFI	HFII	HFIII	HF
Endurance time (min)				
Week 8	86.40 ± 3.54	86.20 ± 2.05	86.40 ± 1.28	86.00 ± 2.47
At the end of experiment	99.60 ± 2.20★★	102.80 ± 1.82★★	112.40 ± 3.82★★,#,+,++	96.40 ± 1.32★★

Each value is mean ± SE from 10 rats.

HF: high fat diet, HFI: formula I diet, HFII; formula II diet and HFIII; formula III diet

★★; Significantly different from week 8 value, $p<0.01$.

#; Significantly different from HF subgroup, $p<0.05$.

+; Significantly different from HFI subgroup, $p<0.05$.

++; Significantly different from HFII subgroup, $p<0.05$.

significant increases of endurance time at the end of experiment in all subgroups (99.60 $\pm$ 2.20, 102.80 $\pm$ 1.82, 112.40 $\pm$ 3.82 and 96.40 $\pm$ 1.32 min in HFI, HFII, HFIII and HF subgroups, respectively). The rats in HF subgroup endurance time. The highest endurance time was noticed in rats consuming diet formula III. The endurance time decreased in rats fed with diets formula III, II and I in which fat contents were decreasing, respectively. In addition, the magnitude of increased endurance time in HFIII subgroup was 30%, being significantly greater than those found in HFII, HFI and HF subgroups (19%, 15% and 12%, respectively, $p<0.05$) (Figure 5). Table 7 and Figure 6 shows comparison of the endurance time after consuming diet with different proportion of fat to carbohydrate among rats pre-fed high carbohydrate (HC pre-fed) and high fat (HF pre-fed) diets. The results clearly demonstrated that neither high carbohydrate (HC) nor high fat (HF) diets gave rise to the optimal endurance performance. A diet that brought about the highest endurance contained an appropriate proportion of fat to carbohydrate content. This study showed that the highest endurance performance was observed in rats consuming the diet with 59% carbohydrate and 20% fat.

B. Maximal Oxygen Consumption (Vo_{2max})

Effects of dietary fat content on the Vo_{2max} in exercise rats pre-fed with high carbohydrate diet are presented in Table 8. No significant differences in the Vo_{2max} before transition from high carbohydrate to the formula I, II and III diets with increasing fat contents, among HC, HCI,

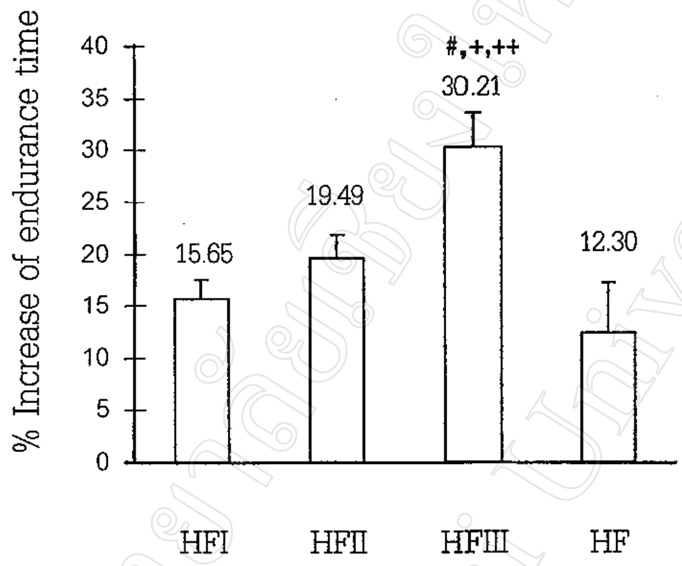

Figure 5. Effects of different proportion of fat to carbohydrate content on magnitudes of increased endurance time in exercise rats pre-fed with high fat diet.

HF; high fat diet, HFI; formula I diet, HFII; formula II diet and HFIII; formula III diet.

Each value is mean ± SE from 10 rats.

#; Significantly different from HF subgroup, p<0.05).

+; Significantly different from HFI subgroup, p<0.05).

++; Significantly different from HFII subgroup, p<0.05).

Table 7. Comparison of endurance time after switching to diets with different proportion of fat to carbohydrate contents among rats pre-fed with high carbohydrate (HC pre-fed) and high fat (HF pre-fed) diets.

Diet	Endurance time (min)	
	HC pre-fed subgroup	HF pre-fed subgroup
HC	85.60 ± 2.30	-
Formula I	89.20 ± 1.59	99.60 ± 2.20
Formula II	91.00 ± 2.02	102.80 ± 1.82
Formula III	94.80 ± 1.65	112.40 ± 3.82
HF	-	96.40 ± 1.32

Each value is mean ± SE from 5 rats.

HC; high carbohydrate diet containing 80%E CHO and 0%E fat, formula I; diet containing 66%E CHO and 14%E fat, formula II; diet containing 62%E CHO and 18%E fat, formula III; diet containing 59%E CHO and 20%E fat and HF; high fat diet containing 5%E CHO and 75%E fat.

Figure 6. Comparison of endurance time before and after switching to diets with different proportion of fat to carbohydrate contents among rats pre-fed with high carbohydrate (HC pre-fed) and high fat (HF pre-fed) diets

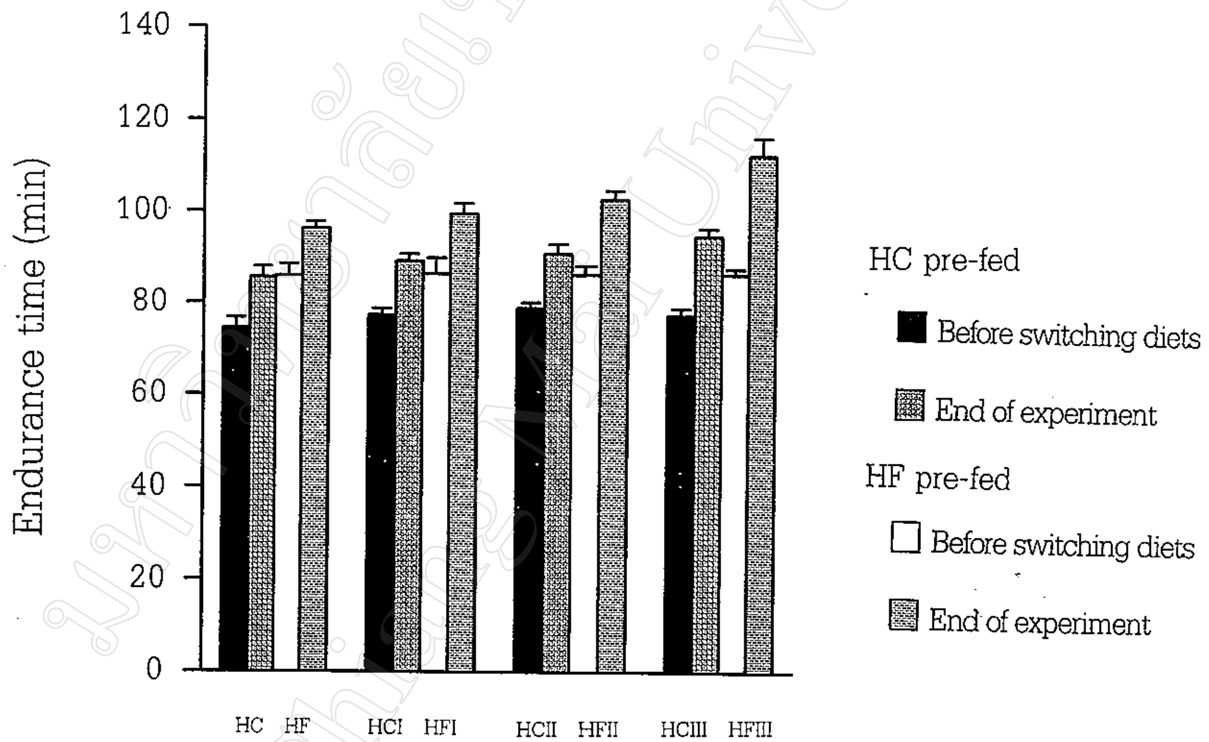

Table 8. Effects of different proportion of fat to carbohydrate contents on maximal oxygen consumption (Vo_{2max}) in exercise rat pre-fed with high carbohydrate diet.

Variable	Subgroup			
	HC	HCI	HCII	HCIII
Vo_{2max}(ml/kg/min)				
Week 8	32.20 ± 1.09	30.45 ± 0.86	30.70 ± 0.93	33.29 ± 0.51
At the end of experiment	35.18 ± 1.12★★	34.11 ± 1.01★★	35.21 ± 0.73★★	38.42 ± 0.75★★,#,+

Each value is mean ± SE from 10 rats.

HC; high carbohydrate diets, HCI; formula I diet, HCII; formula II diet and HCIII; formula III diet

★★; Significantly different from week 8 value, $p<0.01$.

#; Significantly different from HC subgroup, $p<0.05$.

+; Significantly different from HCI subgroup, $p<0.05$.

HCII and HCIII subgroups (32.20 ± 1.09, 30.45 ± 0.86, 30.70 ± 0.93 and 33.29 ± 0.51 ml/kg/min, respectively, $p<0.05$). After consuming diets with increasing fat content in combination with 12 days exercise, the values of Vo_{2max} were significantly increased in all HC's subgroup (35.18 ± 1.12, 34.11 ± 1.01, 35.21 ± 0.73 and 38.42 ± 0.75 ml/kg/min in HC, HCI, HCII and HCIII subgroups, respectively, $p<0.01$). The increase in the Vo_{2max} was obviously related to the increase of dietary fat content and was maximal in formula III diet containing 20% fat and 59% carbohydrate. Significant differences in Vo_{2max} at the end of experiment were noted between HC and HCIII subgroups and HCI and HCIII subgroups ($p<0.05$). As illustrated in Figure 7, the magnitude of increased Vo_{2max} in HC subgroup (9%) was lower as compared with those presented in HCI, HCII and HCIII subgroups which consumed higher dietary fat content (12%, 14% and 15%, respectively). A significant difference in the magnitude of increased Vo_{2max} was found between HC and HCIII subgroups or HC and HCII subgroups ($p<0.05$).

As illustrated in Table 9, the baseline values of Vo_{2max} before transition from high fat diet to the formula I, II and III diets were similar in HFI, HFII, HFIII and HF subgroups (34.04 ± 0.79, 34.31 ± 0.78, 35.44 ± 0.87 and 34.58 ± 0.69 ml/kg/min, respectively). After 12 days of consuming diet with reducing fat content and increasing carbohydrate content together with exercise training, the Vo_{2max} were significantly increased in all HF' s subgroups (38.90 ± 0.80, 40.36 ± 0.73, 42.23 ± 0.96

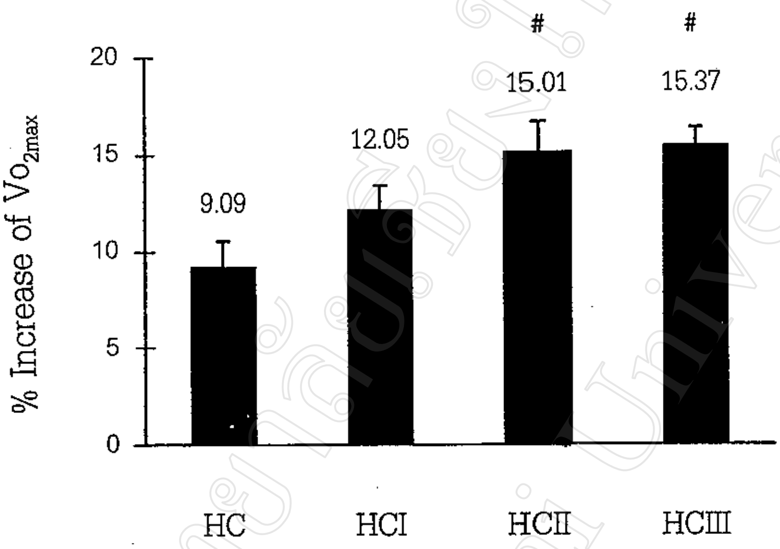

Figure 7 Effects of different proportion of fat to carbohydrate content on magnitudes of increased maximal oxygen consumption (Vo_{2max}) in exercise rats pre-fed with high carbohydrate diet. HC; high carbohydrate diet, HCI; formula I diet, HCII; formula II diet and HCIII; formula III diet.

Each value is mean ± SE from 10 rats.

#; Significantly different from HC subgroup, $p<0.05$.

Table 9. Effects of different proportion of fat to carbohydrate contents on maximal oxygen consumption (Vo_{2max}) in exercise rat pre-fed with high fat diet.

Variable	Subgroup			
	HFI	HFII	HFIII	HF
Vo_{2max}(ml/kg/min)				
Week 8	34.04 ± 0.79	34.31 ± 0.78	35.44 ± 0.87	34.58 ± 0.69
At the end of experiment	$38.90 \pm 0.80^{\star\star}$	$40.36 \pm 0.73^{\star\star,\#,+}$	$42.23 \pm 0.96^{\star\star,\#,+}$	$38.40 \pm 0.51^{\star\star}$

Each value is mean ± SE from 10 rats.

HF: high fat diet, HFI: formula I diet, HFII; formula II diet and HFIII; formula III diet

**; Significantly different from week 8 value, $p<0.01$.

$^{\#}$; Significantly different from HF subgroup, $p<0.05$.

$^{+}$; Significantly different from HFI subgroup, $p<0.05$.

and 38.40 ± 0.51 ml/kg/min in HFI, HFII, HFIII and HF subgroups, respectively, $p<0.01$). There were 11%, 14%, 18% and 19% increases of Vo_{2max} in HF, HFI, HFII and HFIII subgroups, respectively (Figure 8). The magnitudes of increased Vo_{2max} in HFII and HFIII subgroups were significantly greater than in HF and HFI subgroups ($p<0.05$). Figure 9 shows comparison of Vo_{2max} the after consuming diet with different proportion of fat to carbohydrate among rats pre-fed high carbohydrate (HC pre-fed) and high fat (HF pre-fed) diets. These results suggested that only fat in a diet was not enough for a rat to have maximal aerobic metabolism. A suitable diet for maximal aerobic metabolism should contain a certain proportion of carbohydrate and fat. The formula III diet containing 59% carbohydrate and 20% fat resulted in maximal aerobic metabolism in exercise rats in this study.

C. Blood Borne Substrates

The concentrations of resting plasma glucose, serum triglyceride and plasma lactate in HC's subgroups are summarized in Table 10. The resting plasma glucose concentrations of rats in HC, HCI, HCII and HCIII subgroups were not significantly different among experimental subgroups (140.00 ± 5.51, 149.60 ± 11.01, 139.00 ± 8.56 and 121.40 ± 8.48 mg/dl, respectively, $p>0.05$). At exhaustion, all subgroups showed significant decreases in plasma glucose levels (68.20 ± 6.50, 78.80 ± 5.34, 88.20 ± 10.87 and 88.00 ± 6.40 mg/dl in HC, HCI, HCII and HCIII subgroups respectively, $p<0.01$). The average blood glucose utilization rate was the

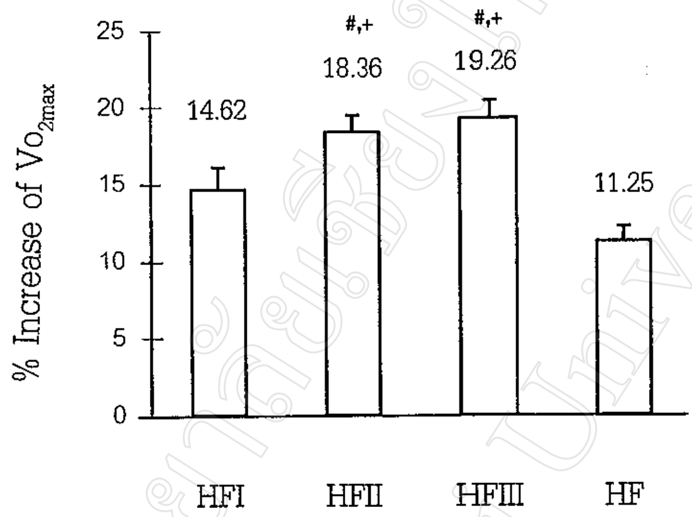

Figure 8. Effects of different proportion of fat to carbohydrate content on magnitudes of increased maximal oxygen consumption (Vo_{2max}) in exercise rats pre-fed with high fat diet.

HF; high fat diet, HFI; formula I diet, HFII; formula II diet and HFIII; formula III diet.

Each value is mean ± SE from 10 rats.

#; Significantly different from HF subgroup, $p<0.05$.

+; Significantly different from HFI subgroup, $p<0.05$.

Figure 9. Comparison of maximal oxygen consumption (Vo_{2max}) before and after switching to diets with different proportion of fat to carbohydrate contents among rats pre-fed with high carbohydrate (HC pre-fed) and high fat (HF pre-fed) diets

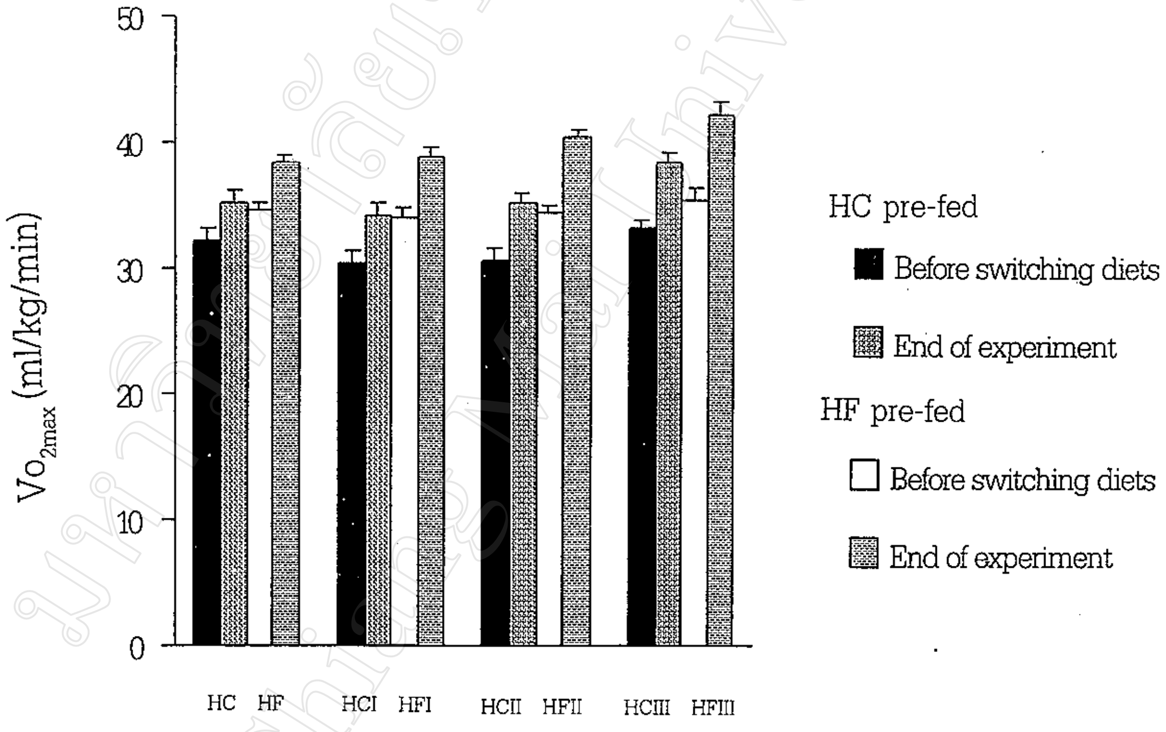

Table 10. Effects of different proportion of fat to carbohydrate contents on the concentrations of plasma glucose, plasma lactate and serum triglyceride in exercise rat pre-fed with high carbohydrate diet.

Substrate	Subgroup			
	HC	HCI	HCII	HCIII
Glucose (mg/dl)				
At rest	140.00 ± 5.51	149.60 ± 11.01	139.00 ± 8.56	121.40 ± 8.48
After exhausting exercise	68.20 ± 6.50**	78.80 ± 5.34**	88.20 ± 10.87**	88.00 ± 6.40**
Utilization rate (mg/dl/min)	0.83 ± 0.08	0.78 ± 0.05	0.54 ± 0.11$^{\#}$	0.34 ± 0.07$^{\#}$
Triglyceride (mg/dl)				
At rest	207.80 ± 21.70	193.50 ± 18.22	173.75 ± 34.87	200.00 ± 33.30
After exhausting exercise	150.00 ± 24.59*	157.25 ± 21.72*	111.06 ± 27.26*	118.00 ± 23.85*
Utilization rate (mg/dl/min)	0.43 ± 0.28	0.42 ± 0.23	0.68 ± 0.30	0.85 ± 0.24
Lactate (mmol/l)				
At rest	7.43 ± 0.69	6.71 ± 0.60	6.78 ± 0.45	7.88 ± 0.97
After exhausting exercise	11.02 ± 1.29*	9.51 ± 0.62*	9.36 ± 0.76*	9.83 ± 1.24*
Production rate (mmol/l/min)	0.04 ± 0.007	0.03 ± 0.012	0.02 ± 0.003	0.02 ± 0.002

Each value is mean ± SE from 5 rats.

*,**; Significantly different from corresponding resting value, $p<0.05$, $p<0.01$.

#; Significantly different from HC subgroup, $p<0.05$.

HC; high carbohydrate diet, HCI; formula I diet, HCII; formula II diet and HCIII; formula III diet.

Glucose and triglyceride utilization rates are expressed as average rate of use over time and did not necessarily reflect a linear relationship. Likewise, lactate production rate represented as average rate of production over time.

greatest in HC subgroup (0.83 ± 0.08 mg/dl/min) and the rate was lowering as the dietary fat content was increasing (0.78 ± 0.05, 0.54 ± 0.11 and 0.34 ± 0.07 mg/dl/min in HCI, HCII, HCIII subgroups, respectively). Significant differences in blood glucose utilization rate were established between HC and HCII subgroups and HC and HCIII subgroups (p<0.05).

No appreciable differences in the values of serum triglyceride were observed in the resting HC, HCI, HCII and HCIII subgroups (207 80 ± 21.70, 193.50 ± 18.22, 173.75 ± 34.87 and 200.00 ± 33.30 mg/dl, 157.25 ± 21.75, 111.06 ± 27.26 and 118.00 ± 23.85 mg/dl, respectively, p <0.05). The average blood triglyceride utilization rates in HC and HCI subgroups were similar (0.43 ± 0.28 and 0.42 ± 0.23 mg/dl/min). In comparison with HC subgroup, there were apparent increases in blood triglyceride utilization rates in HCII and HCIII subgroups in which the dietary fat contents were increased (0.68 ± 0.30 and 0.85 ± 0.24 mg/dl/min).

Dietary fat content had no influence on the resting plasma lactate concentrations in HC, HCI, HCII and HCIII subgroups (7.43 ± 0.69, 6.71 ± 0.60, 6.78 ± 0.45 and 7.88 ± 0.97 mmol/l, respectively). As a result of exercise, all exhausting subgroups showed significant increases in plasma lactate concentrations (11.02 ± 1.25, 9.51 ± 0.62, 9.36 ± 0.75 and 9.83 ± 1.24 mmol/l in HC, HCI, HCII and HCIII subgroups, respectively, p<0.05). The average blood lactate production rate in parallel with the rate of blood glucose utilization, was high in HC subgroup (0.04

$\pm$ 0.007 mmol/l/min). A trend of decrease in blood lactate production rate was noted in HCI, HCII and HCIII subgroups as dietary fat content was increased (0.03 $\pm$ 0.012, 0.02 $\pm$ 0.003 and 0.02 $\pm$ 0.002 mmol/l/min, respectively).

As demonstrated in Figure 10, rats consuming isocaloric diets of which the carbohydrate content decreased from 80%E to 59%E and the fat content increased from 0%E to 20%E showed a decrease in blood glucose utilization rate, a decrease in blood lactate production rate and an increase in the utilization rate of blood triglyceride.

Table 11 illustrates the plasma glucose, serum triglyceride and plasma lactate concentrations of rats in the HFI, HFII, HFIII and HF subgroups. The data were arranged orderly according to the increasing dietary fat content. In HF subgroup, though the rats consumed diets with the highest fat content and the lowest carbohydrate content, the mean resting plasma glucose level, 106.00 $\pm$ 13.60, was not significantly different from the values observed in other HF's subgroups, .i.e., HFI, HFII and HFIII subgroups (125.80 $\pm$ 7.81, 141.25 $\pm$ 6.87 and 124.25 $\pm$ 12.29 mg/dl, respectively). After exhausting exercise, plasma glucose concentrations decreased in all subgroups (81.00 $\pm$ 15.95, 108.25 $\pm$ 17.25, 90.25 $\pm$ 11.44 and 80.40 $\pm$ 13.47 mg/dl in HFI, HFII, HFIII and HF subgroups, respectively) as compared with their respective resting subgroupsalthough significant difference was noted only in the HF subgroup ($p<0.05$). The average blood glucose utilization rates were similar in HF and HFI subgroups (0.44 $\pm$ 0.14 and 0.42 $\pm$ 0.11 mg/dl/min,

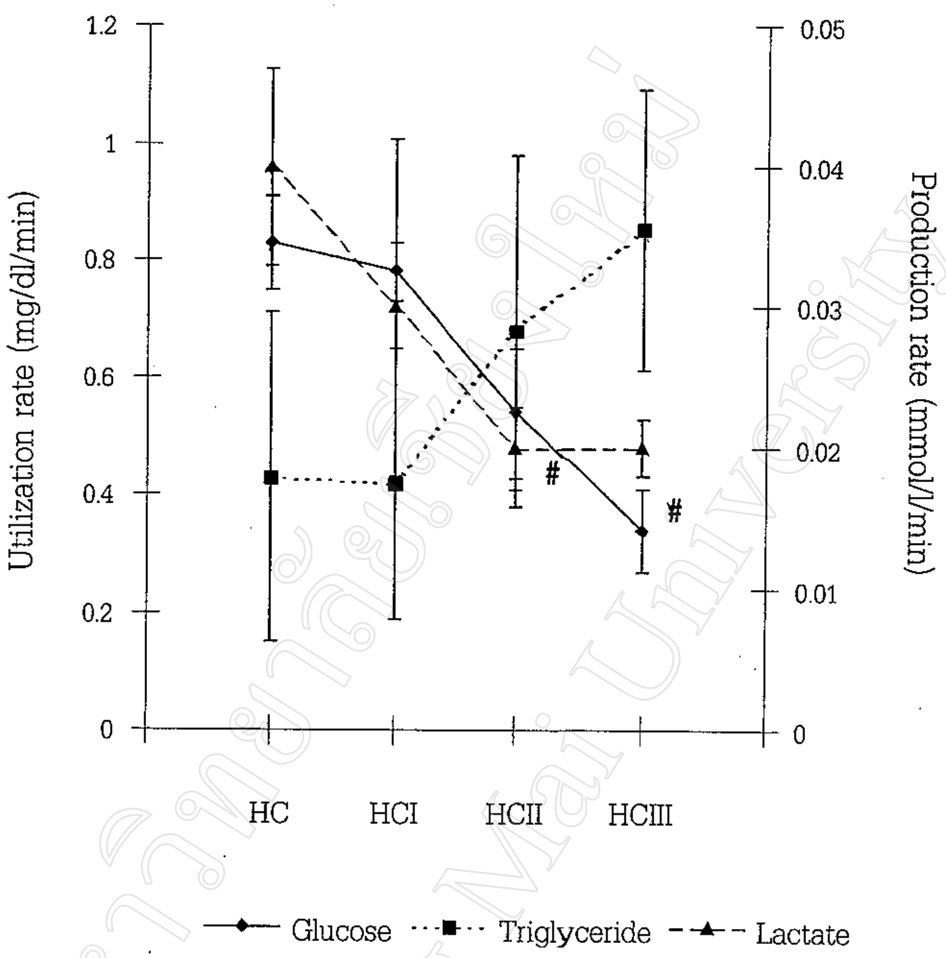

Figure 10. Effects of different proportion of fat to carbohydrate contents on blood glucose and triglyceride utilization rates and blood lactate production rate in exercise rats pre-fed with high carbohydrate diet.

HC; high carbohydrate diet, HCI; formula I diet, HCII; formula II diet and HCIII; formula III diet.

Each value is mean ± SE from 5 rats.

#; Significantly different from HC subgroup, $p<0.05$.

Table 11. Effects of different proportion of fat to carbohydrate contents on the concentrations of plasma glucose, plasma lactate and serum triglyceride in exercise rat pre-fed with high fat diet.

Substrate	Subgroup			
	HFI	HFII	HFIII	HF
Glucose (mg/dl)				
At rest	125.80 ± 7.81	141.25 ± 6.87	124.25 ± 12.29	132.20 ± 20.14
After exhausting exercise	81.00 ± 15.95	108.25 ± 17.24	90.25 ± 11.44	80.40 ± 13.47★
Utilization rate (mg/dl/min)	0.30 ± 0.10	0.42 ± 0.11	0.44 ± 0.14	0.25 ± 0.14
Triglyceride (mg/dl)				
At rest	153.00 ± 30.49	153.80 ± 12.00	177.20 ± 23.97	185.60 ± 52.30
After exhausting exercise	81.60 ± 15.30★	80.40 ± 15.49★	89.40 ± 12.85	115.60 ± 31.66
Utilization rate (mg/dl/min)	0.72 ± 0.11	0.72 ± 0.15	0.71 ± 0.14	0.73 ± 0.29
Lactate (mmol/l)				
At rest	6.06 ± 0.09	6.43 ± 0.20	6.49 ± 1.04	7.00 ± 1.28
After exhausting exercise	8.87 ± 0.42★	8.51 ± 0.23★	10.28 ± 1.36★	8.06 ± 1.12★
Production rate (mmol/l/min)	0.03 ± 0.012	0.02 ± 0.002	0.02 ± 0.003	0.01 ± 0.007

Each value is mean ± SE from 5 rats.

★; Significantly different from corresponding resting value, $p<0.05$.

HF; high fat diet, HFI; formula I diet, HFII; formula II diet and HFIII; formula III diet.

Glucose and triglyceride utilization rates are expressed as average rate of use over time and did not necessarily reflect a linear relationship. Likewise, lactate production rate represented as average rate of production over time.

respectively) and the rates decrease as the dietary fat contents increased in HFIII and HF subgroups (0.30 ± 0.10 and 0.25 ± 0.14 mg/dl/min) (Figure 11). Comparison of blood glucose utilization rates after switching to formula I, II and III diets between rats pre-fed with high carbohydrate (HC pre-fed) and high fat (HF pre-fed) diets during exhausting exercise is showed in Table 12. The results showed that the rats in HF pre-fed subgroups combusted plasma glucose with rates slower than in HC pre-fed subgroups.

Dietary fat contents in HFI, HFII, HFIII and HF subgroups did not significantly affect the resting serum triglyceride concentrations (153.00 ± 30.49, 153.80 ± 12.00, 177.20 ± 23.97 and 185.60 ± 52.60 mg/dl, respectively). At exhaustion, serum triglyceride levels in all subgroups (81.60 ± 15.30, 80.40 ± 15.49, 89.40 ± 12.85 and 115.60 ± 31.66 mg/dl in HFI, HFII, HFIII and HF subgroups, respectively) were apparently reduced and significant differences were noted in HFII and HFIII subgroups ($p < 0.05$). However, there were no statistical differences in blood triglyceride utilization rate among HFI, HFII, HFIII and HF subgroups (0.71 ± 0.14, 0.72 ± 0.15, 0.75 ± 0.11 and 0.73 ± 0.29 mg/dl/min), respectively, $p < 0.05$). As presented in Table 13, the utilization rate of blood triglyceride was slow in rats consuming high carbohydrate diet, 80%E CHO and 0%E fat. As the fat content increased and carbohydrate content decreased, the HC pre-fed rats which received formula III diet showed higher triglyceride combustion as compared with those HC's subgroups consuming higher carbohydrate contents. In addition, there was no difference in utilization

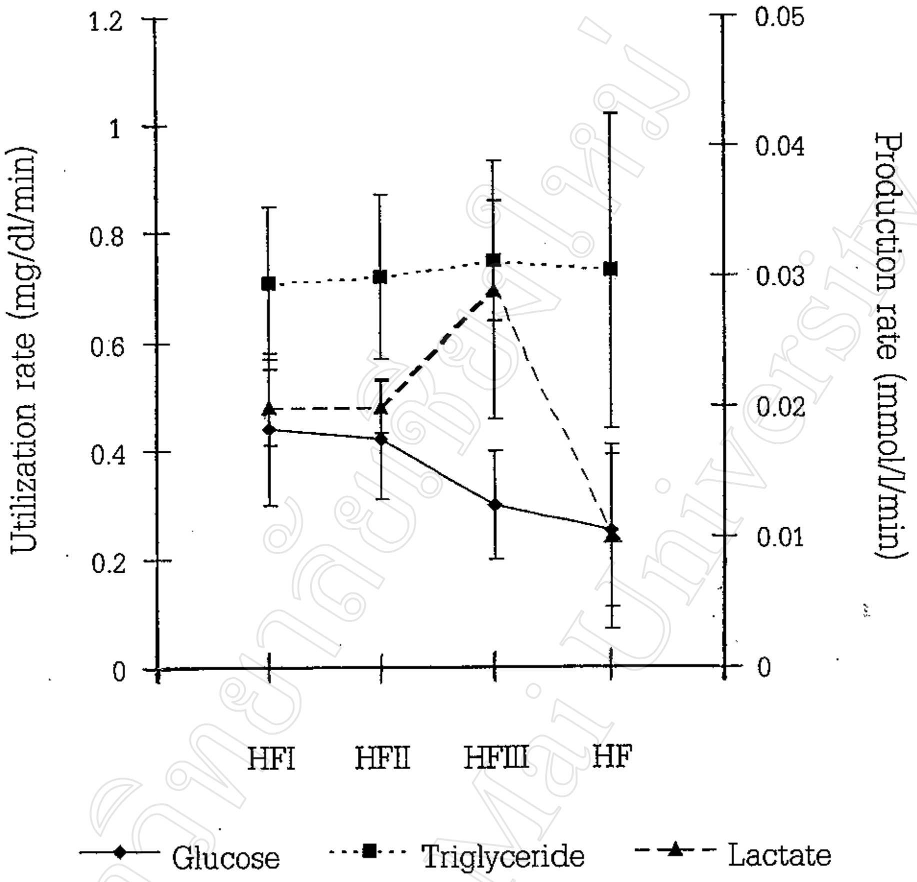

Figure 11 Effects of different proportion of fat to carbohydrate contents on blood glucose and triglyceride utilization rates and blood lactate production rate in exercise rats pre-fed with high fat diet.

HF; high fat diet, HFI; formula I diet, HFII; formula II diet and HFIII; formula III diet.

Each value is mean ± SE from 5 rats.

Table 12. Comparison of blood glucose utilization rate after switching to diets with different proportion of fat to carbohydrate contents among rats pre-fed with high carbohydrate (HC pre-fed) and high fat (HF pre-fed) diets.

Diet	Blood glucose utilization rate (mg/dl/min)	
	HC pre-fed subgroup	HF pre-fed subgroup
HC	0.83 ± 0.08	-
Formula I	0.78 ± 0.05	0.44 ± 0.14
Formula II	0.54 ± 0.11	0.42 ± 0.11
Formula III	0.34 ± 0.07	0.30 ± 0.10
HF	-	0.25 ± 0.14

Each value is mean ± SE from 5 rats.

HC; high carbohydrate diet containing 80%E CHO AND 0%E fat, formula I; diet containing 66%E CHO and 14%E fat, formula II; diet containing 62%E CHO and 18%E fat, formula III; diet containing 59%E CHO and 20%E fat and HF; high fat diet containing 5%E CHO and 75%E fat.

rates of blood triglyceride among HF pre-fed rats consuming diets with different proportion of fat to carbohydrate contents. In addition, there were no difference in utilization rates of blood triglyceride among HF pre0fed rats consuming diet with different proportion of fat to carbohydrate contents.

The resting plasma lactate concentrations were comparable among HFI, HFII, HFIII and HF subgroups (6.08 ± 0.09, 6.43 ± 0.20, 6.49 ± 1.04 and 7.00 ± 1.28 mmol/l, respectively). As a result of exhausting exercise, significant elevations of plasma lactate level were found in all subgroups (8.87 ± 0.42, 8.51 ± 0.23, 10.28 ± 1.36 and 8.06 ± 1.12 mmol/l in HFI, HFII, HFIII and HF subgroups, respectively, $p<0.05$). The average lactate production rate·was the lowest in HF subgroup which consumed the highest fat diet (0.01 ± 0.007 mmol/l/min). There were slightly increased lactate production rate in HFI, HFII and HFIII subgroups (0.02 ± 0.003, 0.02 ± 0.002 and 0.03 ± 0.012 mmol/l/min, respectively).

Table 13. Comparison of blood triglyceride utilization rate after switching to diets with different proportion of fat to carbohydrate contents among rats pre-fed with high carbohydrate (HC pre-fed) and high fat (HF pre-fed) diets.

Diet	Blood triglyceride utilization rate (mg/dl/min)	
	HC pre-fed subgroup	HF pre-fed subgroup
HC	0.43 ± 0.28	-
Formula I	0.42 ± 0.23	0.72 ± 0.15
Formula II	0.68 ± 0.30	0.71 ± 0.14
Formula III	0.85 ± 0.24	0.72 ± 0.11
HF	-	0.73 ± 0.29

Each value is mean ± SE from 5 rats.

HC; high carbohydrate diet containing 80%E CHO AND 0%E fat, formula I; diet containing 66%E CHO and 14%E fat, formula II; diet containing 62%E CHO and 18%E fat, formula III; diet containing 59%E CHO and 20%E fat and HF; high fat diet containing 5%E CHO and 75%E fat.