CHAPTER IV

RESULTS AND DISCUSSION

4.1 Raw materials

In this experiment anthracite and palm-oil shell were used for the preparation of activated carbon by zinc chloride activation. The palm-oil shell char from carbonization was crushed and sieved to four different particle sizes of 0.25-0.50, 0.50-1.18, 1.18-2.36, 2.36-4.75 mm and 0.8-0.9 mm of anthracite before being treated. The proximate analysis of anthracite and palm-oil shell char are shown in **Table 4.1.**

Table 4.1 Proximate analysis of anthracite and palm-oil shell char.

Raw materials	Sizes (mm)	%M	On dry basis			
			BD (g/cm^3)	%Ash	%VM	%FC
Anthracite	0.8-0.9	2.77	0.8803	14.32	28.03	54.88
Palm-oil shell	0.25-0.50	1.25	0.6154	3.55	18.89	76.31
char	0.50-1.18	1.15	0.5869	2.45	18.38	78.02
	1.18-2.36	0.94	0.5604	2.83	15.71	80.52
	2.36-4.75	0.99	0.5310	2.81	16.46	79.74

4.2 Results and discussion of the experiments

4.2.1 The optimum temperature for activation

15 g of 0.80-0.90 mm of the anthracite and 1.18-2.36 mm of the palm-oil shell char were soaked in 40% zinc chloride solution and then were dried. These samples were used for each batch. The nitrogen gas was then allowed to flow through the tube reactor. The stainless tube reactor was heated until the temperature in the tube reactor was raised and fixed at the final temperatures 500, 600, 700, 750 and 800 °C. The nitrogen gas was continued, passing through the tube reactor for 3 hr. The results of these experiments are shown in **Table 4.2** and **Figures 4.1-4.6.**

Table 4.2 Deposition of zinc and characteristics of activated carbon from anthracite and palm-oil shell at different temperatures (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 3 hr for activation time, 40% zinc chloride).

Raw material	T (°C)	%Y	On dry basis			$S_{B.E.T}$ (m^2/g)	Deposition of zinc (%)
			BD (g/cm^3)	IA (mg/g)	MB (mg/g)		
Anthracite	500	61.11	0.7933	176.17	55.65	118.19	19.0
Palm-oil shell	500	64.23	0.5565	157.97	74.56	193.92	20.0
Anthracite	600	60.04	0.7629	214.10	78.34	253.59	14.0
Palm-oil shell	600	63.54	0.5465	188.04	96.09	206.97	15.0
Anthracite	700	53.76	0.7219	317.67	304.03	467.52	4.55
Palm-oil shell	700	58.95	0.5298	347.58	313.76	734.72	5.05
Anthracite	750	41.72	0.6050	852.12	450.09	986.64	0.40
Palm-oil shell	750	41.45	0.5078	1007.00	567.64	1080.23	0.70
Anthracite	800	30.13	0.5879	860.35	583.03	1026.99	0.20
Palm-oil shell	800	33.83	0.5063	1069.10	600.25	1099.10	0.20

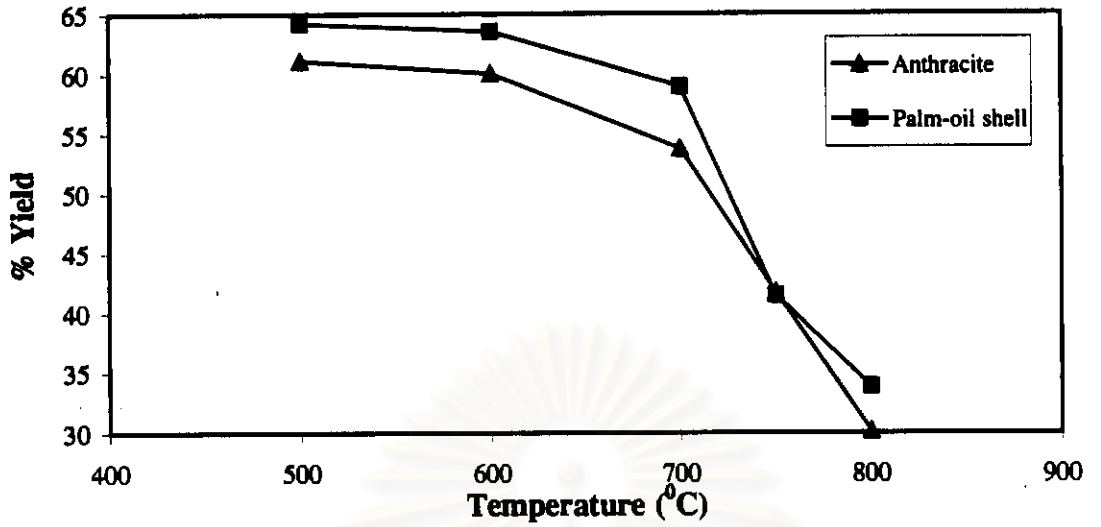

Figure 4.1 Effect of temperature on %yield at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 3 hr for activation time,40% zinc chloride).

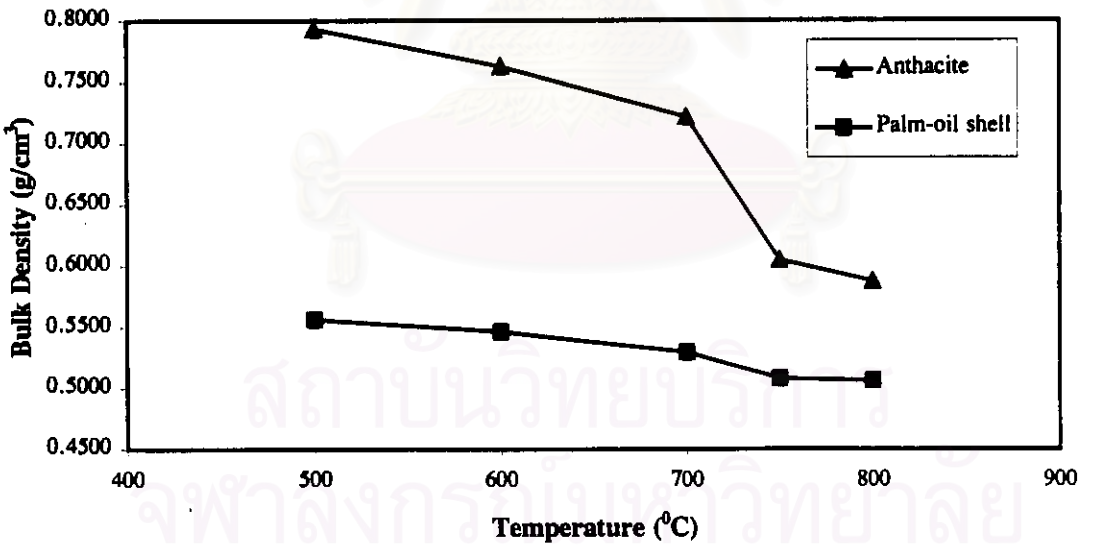

Figure 4.2 Effect of temperature on bulk density at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 3 hr for activation time, 40% zinc chloride).

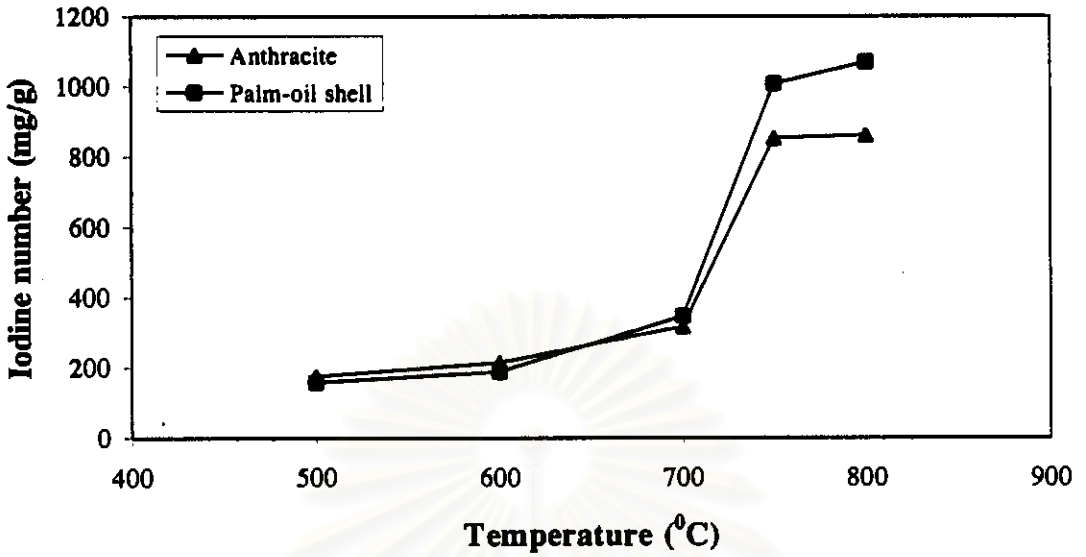

Figure 4.3 Effect of temperature on iodine number at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 3 hr for activation time, 40% zinc chloride).

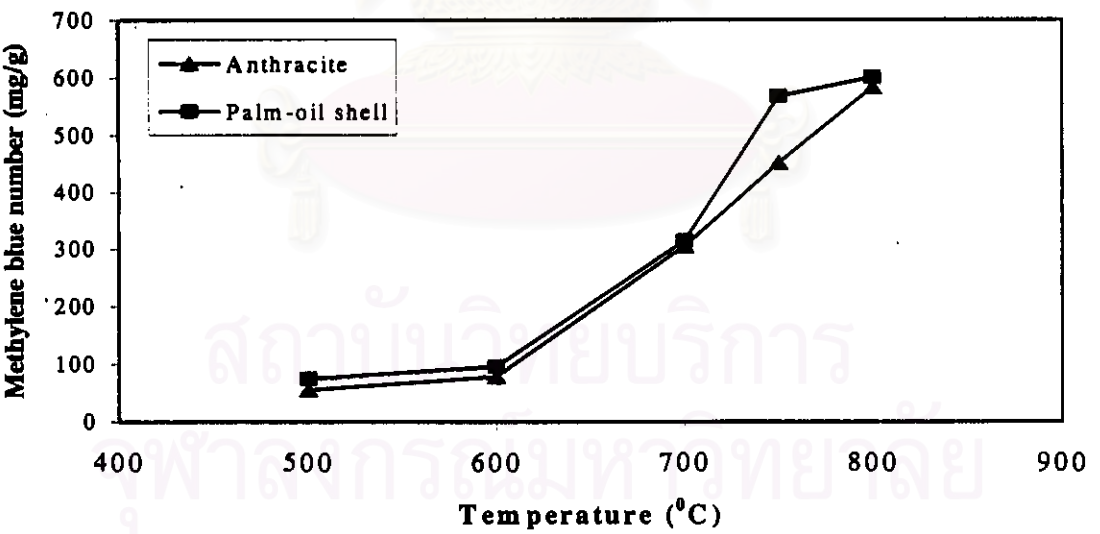

Figure 4.4 Effect of temperature on methylene blue number at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 3 hr for activation time, 40% zinc chloride).

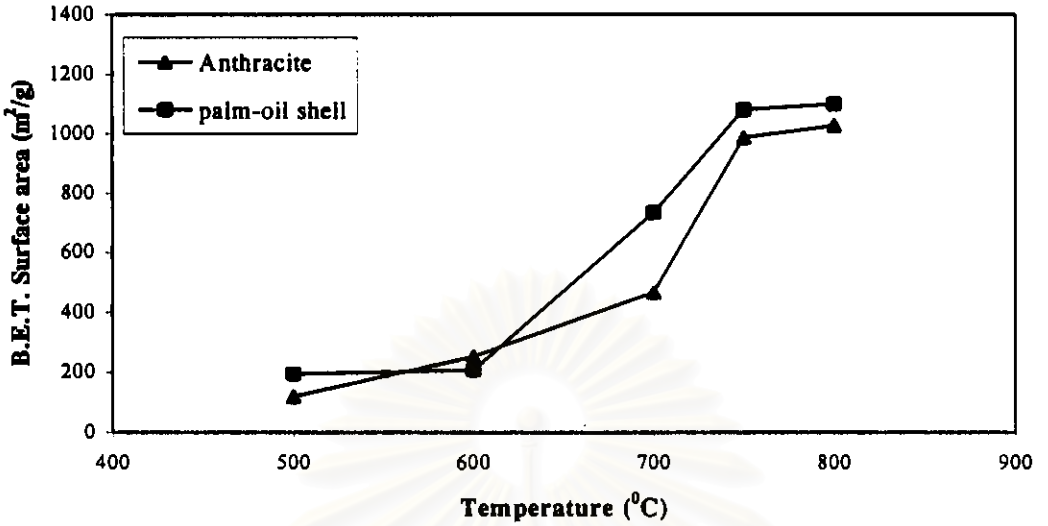

Figure 4.5 Effect of temperature on B.E.T. surface area at different raw materials (0.80-0.9 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 3 hr for activation time, 40% zinc chloride).

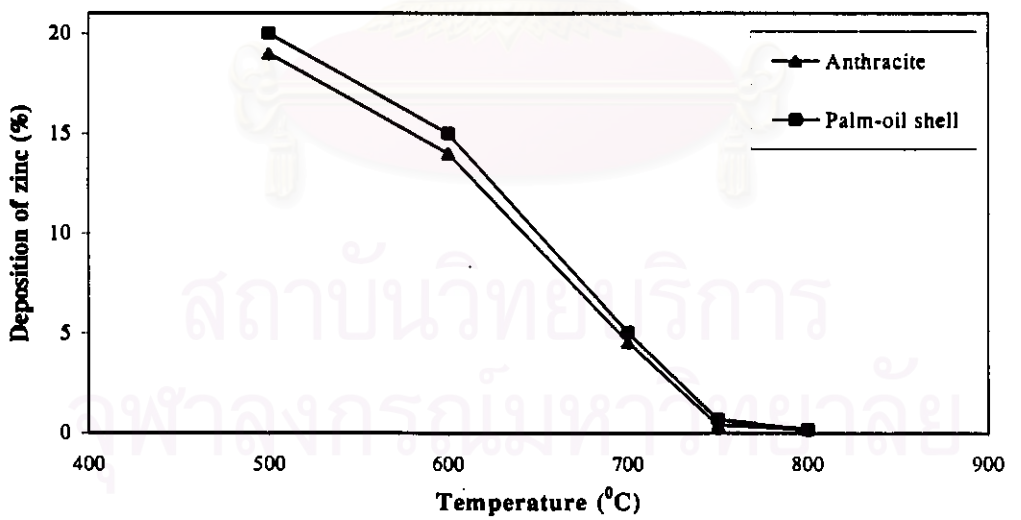

Figure 4.6 Effect of temperature on deposition of zinc at different raw materials (0.80-0.9 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 3 hr for activation time, 40% zinc chloride).

From **Table 4.2**, **Figure 4.1** and **Figure 4.2**, the %yield and the bulk density of activated carbon from anthracite and palm-oil shell decrease conformably as activation temperature increases. They decreased more slowly from 500 to 700°C than the range of 700 to 800° C. because at high temperature, loss of volatile matter was greater than at low temperature. The increasing of temperature leads to the increasing of porosity development, as a result, the weight of activated carbon decreases. Moreover, the % yield and the bulk density also decreased. The changes in the % yield of anthracite were about 12% from 500 to 700°C, 43%from 700 to 800°C and palm-oil shell were about 8 % from 500 to 700°C, 42 % from 700 to 800°C, and bulk density from two raw materials decreased totally 25 and 9 % as shown in **Table 4.3.**

Table 4.2 and **Figures 4.3 - 4.5**, showed that when the activation temperature increases from 500 to 700°C, the iodine number increased slightly about 1.5 time of one of 500°C and increased largely from 700 to 800°C and had a trend to be at the highest at 750°C for palm-oil shell. While the methylene blue number increased sharply at the beginning of 600 to 800°C. The B.E.T. surface area increased as the iodine number, because tar like matter and zinc chloride deposited in pores were removed or volatilized well by nitrogen gas from 600 to 800°C which generated porosity. The higher activation temperature, the more removal zinc chloride results, therefore the iodine number, the methylene blue number and the B.E.T. surface area increased quickly (see slope in **Figures 4.3, 4.4** and **4.5**). The % change of iodine number, methylene blue number and B.E.T. surface area were shown in **Table 4.3**.

Table 4.2 and **Figure 4.6**, showed the increasing of activation temperature leads to the decrease of deposition of zinc in the particle of activated carbon because the melting point and boiling point of zinc are 419°C and 907°C, respectively so zinc could be volatilized out of the particle at high temperature more than at lower temperature. The % removal of deposition of zinc in activated carbon was shown in **Table 4.3**.

Table 4.3 The % change of characteristics of activated carbon and deposition of zinc in activated carbon from anthracite and palm-oil shell when activation temperature increases from 500 to 800°C.

Raw material	T (°C)	%Y	BD (g/cm^3)	IA (mg/g)	MB (mg/g)	$S_{B.E.T.}$ (m^2/g)	Deposition of zinc (%)
Anthracite	500	61.11	0.7933	176.17	55.65	118.19	19.00
	↓	↓	↓	↑	↑	↑	↓
	700	53.76	0.7219	317.67	304.03	467.52	4.55
	%Change	*-12.02*	*-9.00*	*+80.32*	*+446.32*	*+295.56*	*-76.05*
	700	53.76	0.7219	317.67	304.03	467.52	4.55
	↓	↓	↓	↑	↑	↑	↓
	800	30.13	0.5879	860.35	583.03	1026.99	0.20
	% Change	*-43.95*	*-18.56*	*+170.83*	*+91.76*	*+119.66*	*-95.60*
Palm-oil shell	500	64.23	0.5565	157.97	74.56	193.92	20.0
	↓	↓	↓	↑	↑	↑	↓
	700	58.95	0.5298	347.58	313.76	734.72	5.05
	%Change	*-8.22*	*-4.79*	*+120.02*	*+320.81*	*+278.87*	*-74.75*
	700	58.95	0.5298	347.58	313.76	734.72	5.05
	↓	↓	↓	↑	↑	↑	↓
	800	33.83	0.5063	1069.10	600.25	1099.10	0.20
	% Change	*-42.61*	*-4.43*	*+207.58*	*+91.30*	*+49.59*	*-96.03*

↑ : increase ↓ : decrease

The experimental results showed that the optimum temperature of 800°C gave the maximum iodine number, methylene blue number, B.E.T.surface area and minimum deposition of zinc in activated carbon.

4.2.2 The optimum time for activation

Anthracite, 0.80-0.90 mm and palm-oil shell char 1.18-2.36 mm of particle size and mass of 15 g respectively were soaked in 40% zinc chloride solution and then were dried. Soaked char were used for each batch. Then it was treated at 750 °C for 1, 2, 3 and 4 hr as activation time with nitrogen gas by passing through the tube reactor. The results of this experiment were shown in **Table 4.4** and **Figures 4.7-4.12**.

Table 4.4 Deposition of zinc and characteristics of activated carbon from anthracite and palm-oil shell at different activation times (anthracite 0.80-0.90 mm and palm-oil shell char 1.18-2.36 mm of particle size, sample mass of 15g, temperature of 750°C, soaked in 40% zinc chloride solution).

Raw material	Time (hr)	%Y	On dry basis			$S_{B.E.T.}$ (m^2/g)	Deposition of zinc (%)
			BD (g/cm^3)	IA (mg/g)	MB (mg/g)		
Anthracite	1	66.77	0.7112	283.46	168.10	324.20	11.00
Palm-oil shell	1	68.92	0.6039	258.81	186.48	400.96	13.00
Anthracite	2	58.63	0.6553	360.84	300.99	589.11	3.50
Palm-oil shell	2	60.92	0.5454	389.98	317.46	572.00	9.00
Anthracite	3	41.72	0.6050	852.12	450.09	986.64	0.40
Palm-oil shell	3	41.45	0.5078	1007.00	567.64	1080.23	0.70
Anthracite	4	40.04	0.6002	849.38	451.33	986.00	0.40
Palm-oil shell	4	40.55	0.5006	1007.45	564.17	1039.56	0.65

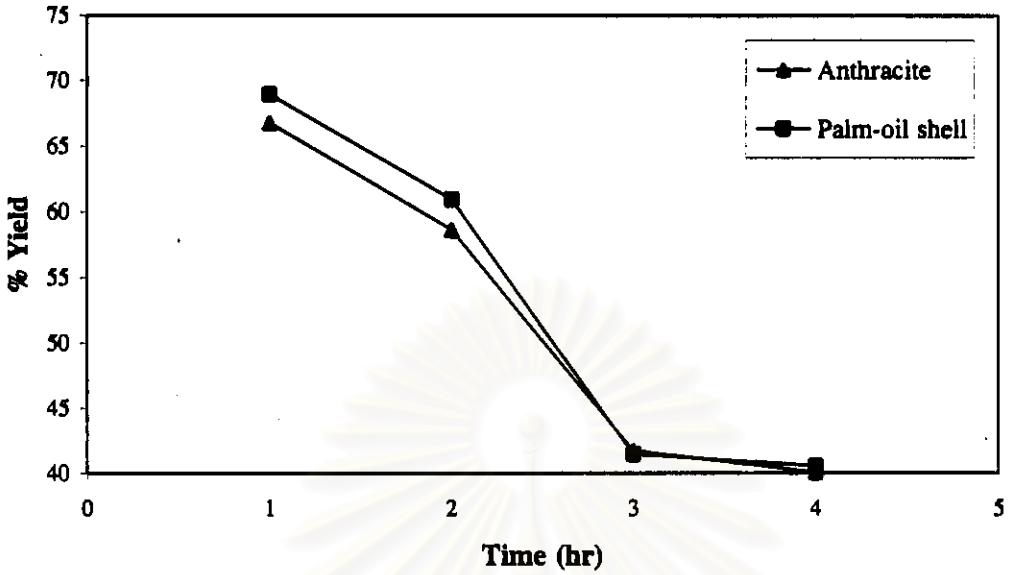

Figure 4.7 Effect of activation time on %yield at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 750°C, 40% zinc chloride).

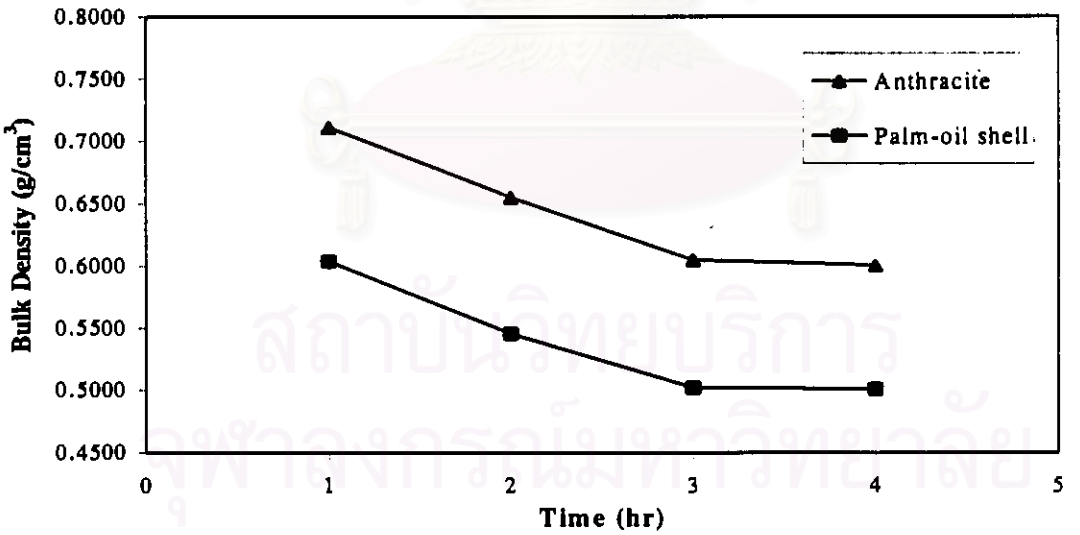

Figure 4.8 Effect of activation time on bulk density at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char 15 g, 750°C, 40% zinc chloride).

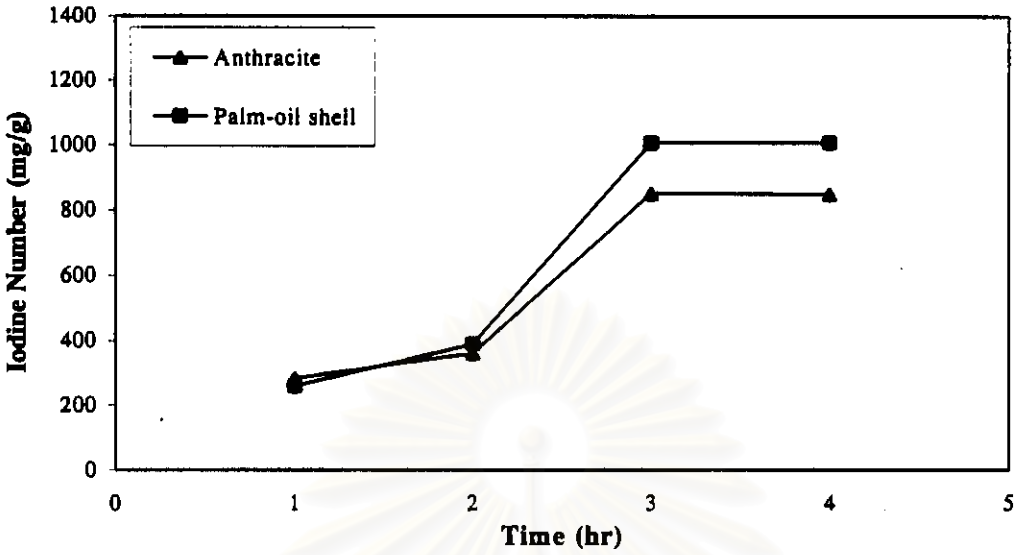

Figure 4.9 Effect of activation time on iodine number at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 750°C, 40% zinc chloride).

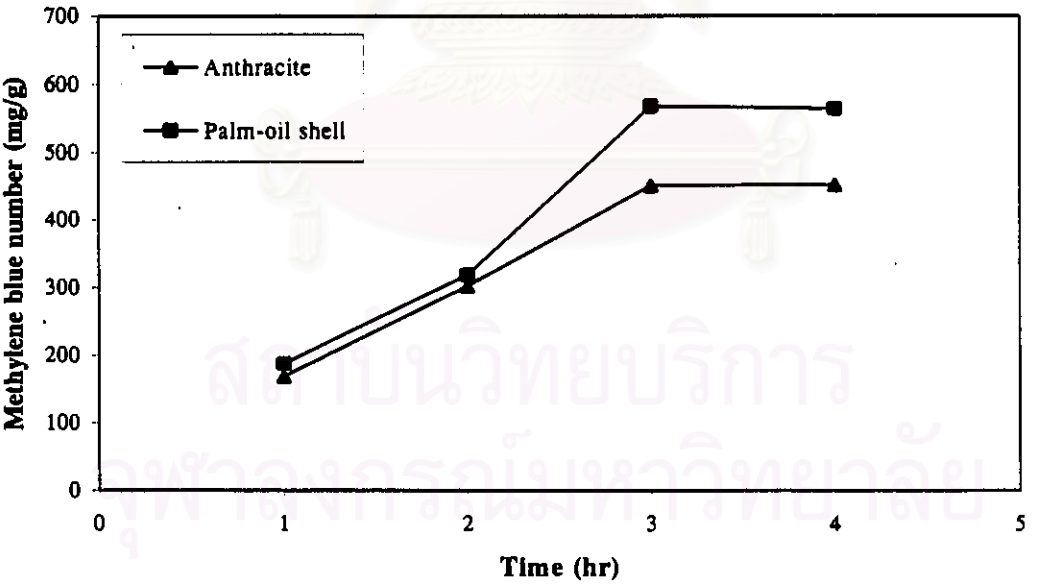

Figure 4.10 Effect of activation time on methylene blue number at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 750°C, 40% zinc chloride).

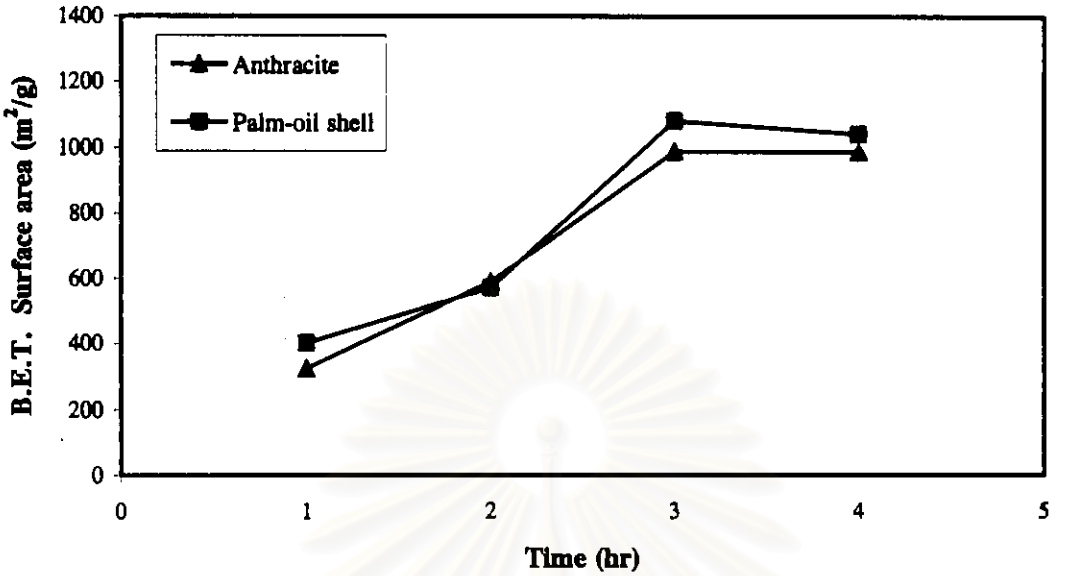

Figure 4.11 Effect of activation time on B.E.T. surface area at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 750°C, 40% zinc chloride).

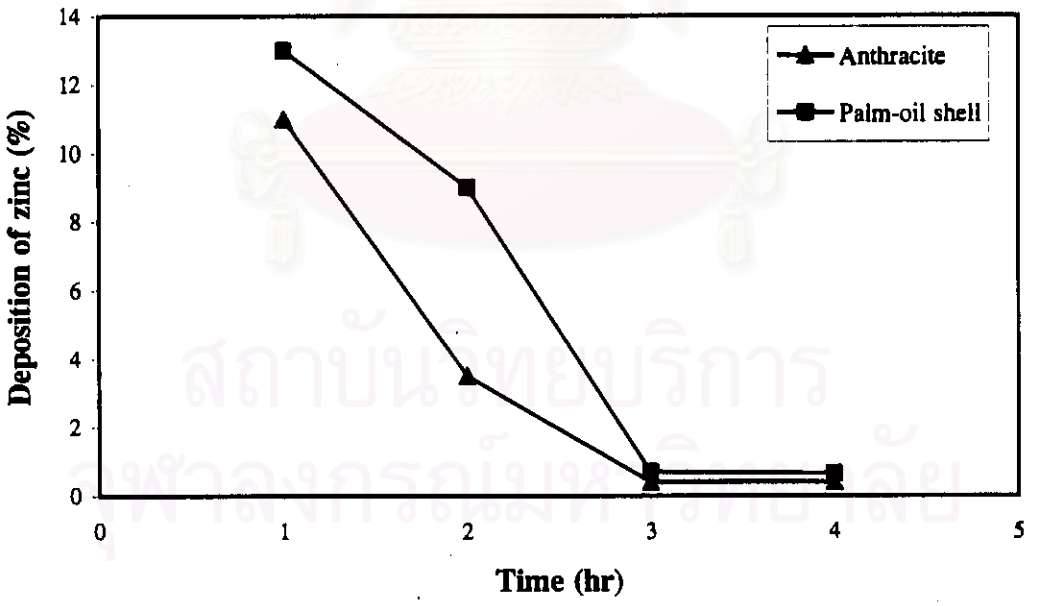

Figure 4.12 Effect of activation time on deposition of zinc in activated carbon at different raw materials (0.80-0.90 mm and 1.18-2.36 mm of palm-oil shell, 15 g, 750°C, 40% zinc chloride).

From **Table 4.4** and **Figure 4.7** the % yield of anthracite and palm-oil shell char decreases largely and conformably with increases in the time from 1 to 3 hr (about 37% change), and slightly decreased from 3 to 4 hr (4% change). Because the volatile matter outside and inside the particle and char were gasified itself by using zinc chloride as catalyst. The gaseous product, volatile matter and zinc chloride in majority diffused out of the particle in the beginning time more rapidly (see the slop) than longer activation time (from 3 to 4 hr) which less remained volatile matter being deeper in the particle diffused out only. The % bulk density of anthracite and palm-oil shell char **(Figure 4.8)** decreased in the same trend of the % yield namely, the % change of bulk density from 1 to 3 hr slightly more than from 3 to 4 hrs. This phenomena showed that porosity developed quickly in the first 3 hrs then more slowly after that. **Table 4.5** showed the change of % yield and the bulk density. In **Figure 4.8** it was noticed that anthracite had more bulk density than palm-oil activated carbon, because the arrangement of anthracite carbon structure was more tighter than palm-oil shell activated carbon.

Table 4.4 and **Figures 4.9-4.11**, showed the iodine number, methylene blue number and B.E.T. surface area of activated carbon from anthracite and palm-oil shell in function of activation time range of 1 to 4 hr. The iodine number, methylene blue number and B.E.T. surface area increased in the same trend namely, the high increasing rate covered in the range of 1 to 3 hr (from 200 to about 1000 mg/g for IA, 150 to about 600 mg/g for MB and to 300 to about 1100 m^2/g for specific surface area) which it could be explained in the same way as % yield that volatile matter and zinc chloride diffused out rapidly especially at the external surface at the initial time of activation, as a result, micropores, mesopores developed quickly in the form of surface area as well. After 3 hr iodine number seemed constant while methylene blue number still slightly increased because at this time the rate of increasing micropores equaled the rate of collapse of micropore as well, this phenomena could cause the small increasing

of mesopores. B.E.T. surface area confirmed the result of development of micropores and mesopores. Although iodine number (represents micropores) generated the increasing methylene blue number (represents mesopores) from collapse inside the particle, the specific surface area had a trend to decrease slightly because mesopores were less significant to generate inside surface area than micropores. The % changes of iodine number, methylene blue number and B.E.T. surface area were shown in **Table 4.5.**

Table 4.4 and **Figure 4.12,** showed the deposition of zinc in the particle of activated carbon. The deposition of zinc was sharply decreased from about 11.00 % to 0.40 % for anthracite and 13.00 % to 0.70 % for palm-oil shell in the initial time of activation from 1 to 3 hr which it confirmed the result of the rapid decreasing of % yield, owing to vaporization of zinc chloride and volatile matter. When the activation time passed from 3 to 4 hrs, this value (0.40 % zinc in anthracite and about 0.70 % zinc in palm-oil shell) seemed stable. It meant that some zinc chloride could not be removed because zinc chloride was so deep that it could not diffuse out. The% change of deposition of zinc in the particle of activated carbon in function of time was shown in **Table 4.5**.

Table 4.5 The % change of characteristics of activated carbon and deposition of zinc in activated carbon from anthracite and palm-oil shell when activation time increases from 1 to 4 hr.

Raw material	Time (hr)	%Y	BD (g/cm^3)	IA (mg/g)	MB (mg/g)	$S_{B.E.T.}$ (m^2/g)	Deposition of zinc (%)
Anthracite	1	66.77	0.7112	283.46	168.10	324.20	11.00
	3	41.72	0.6050	852.12	450.09	986.64	0.40
	% Change	*- 37.51*	*-14.93*	*+200.61*	*+167.75*	*+204.33*	*-96.36*
	3	41.72	0.6050	852.12	450.09	986.64	0.40
	4	40.04	0.6002	849.38	451.33	986.00	0.40
	% Change	*-4.02*	*-0.79*	*-0.32*	*+0.27*	*-0.06*	*0.00*
Palm-oil shell	1	68.92	0.6039	258.81	186.48	400.96	13.00
	3	41.45	0.5078	1007.00	567.64	1080.23	0.70
	% Change	*-39.85*	*-15.91*	*+289.08*	*+204.39*	*+169.41*	*-94.61*
	3	41.45	0.5078	1007.00	567.64	1080.23	0.70
	4	40.55	0.5006	1007.45	564.17	1039.56	0.65
	% Change	*-2.17*	*-1.41*	*+0.04*	*-0.61*	*-3.76*	*-7.14*

↑ : increase ↓ : decrease

The experimental results showed that the optimum time for activation was 3 hr because the activated carbon from anthracite and palm-oil shell gave the maximum of iodine number, methylene blue number, B.E.T.surface area and the minimum deposition of zinc in activated carbon.

4.2.3 The optimum size of the palm-oil shell char for activation

The influence of particle size was determined for different four sizes of palm-oil shell char. They were 0.25-0.50, 0.50-1.18, 1.18-2.36 and 2.36-4.75 mm and soaked in 40% zinc chloride solution. The mass of 15 g of each sample of the palm-oil shell char was carried out at 750°C while nitrogen gas was passed through the bed for 3 hr. The results of this experiment were shown in **Table 4.6** and **Figures 4.13-4.14**.

Table 4.6 Deposition of zinc and characteristics of activated carbon from palm-oil shell at different sizes (mass of sample 15 g, temperature 750°C, 3 hr for activation time, soaked in 40% zinc chloride solution).

Palm-oil shell char sizes (mm)	%Y	On dry basis			$S_{B.E.T.}$ (m^2/g)	Deposition of zinc (%)
		BD (g/cm^3)	IA (mg/g)	MB (mg/g)		
0.25-0.50	44.78	0.6596	401.11	339.58	615.87	19.50
0.50-1.18	43.53	0.5933	790.57	408.66	799.59	9.00
1.18-2.36	41.45	0.5078	1007.00	567.64	1080.23	0.70
2.36-4.75	52.21	0.5174	541.83	383.36	640.87	0.10

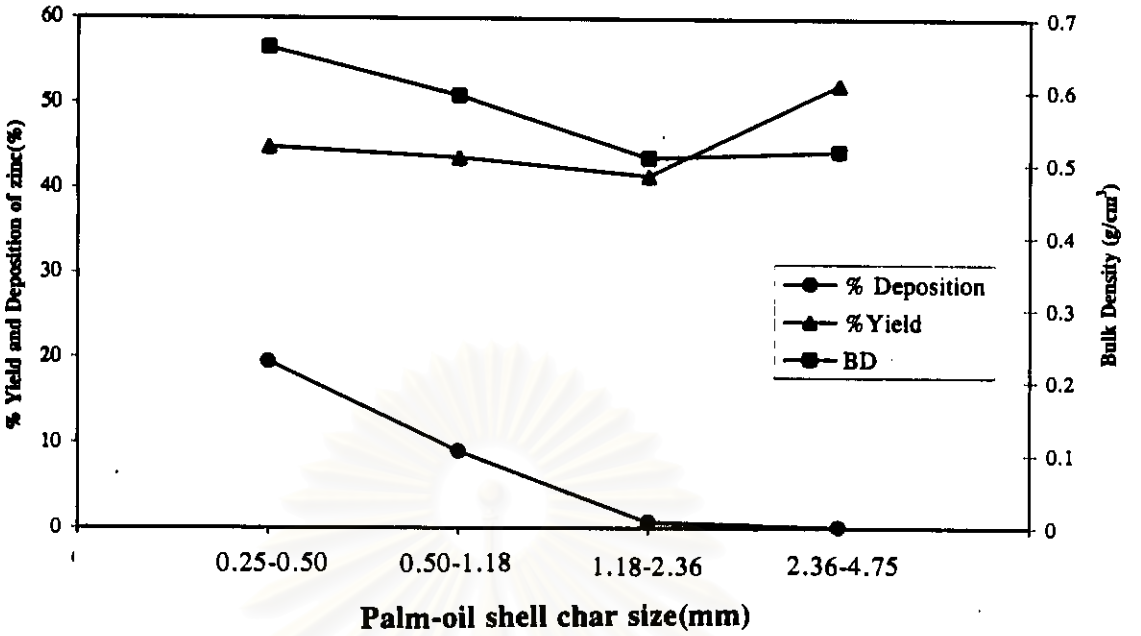

Figure 4.13 Effect of palm-oil shell char particle size on % yield, deposition of zinc and bulk density (mass of sample 15 g, temperature 750°C, 3 hr for activation time, 40 % zinc chloride solution)

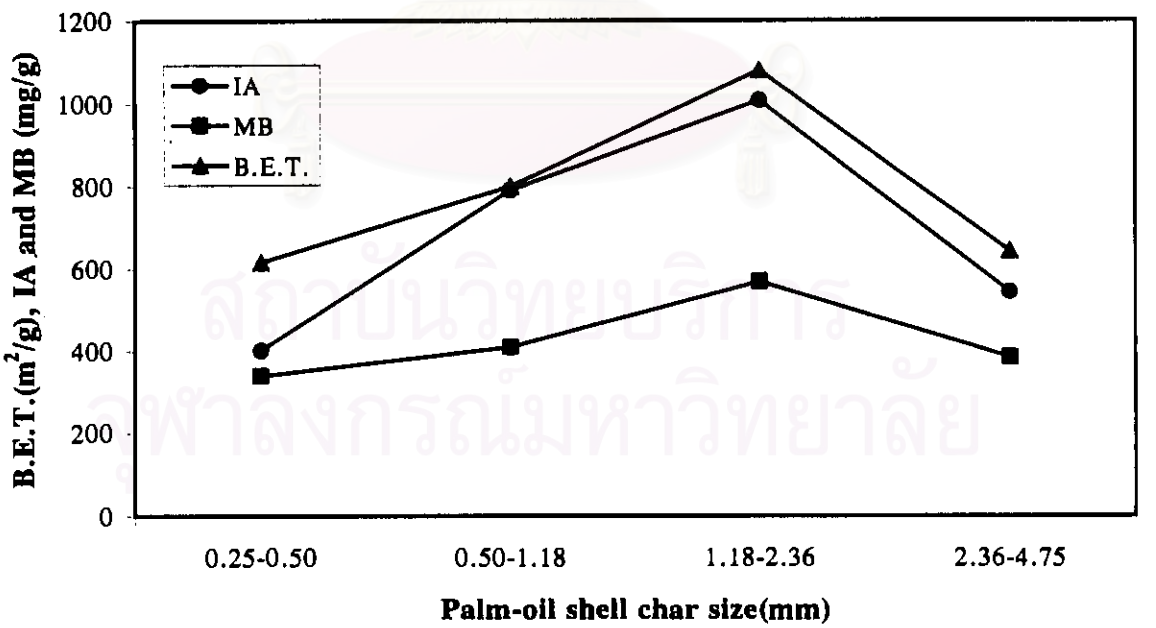

Figure 4.14 Effect of palm-oil shell char particle size on iodine number, methylene blue number and B.E.T.surface area (mass of sample 15 g, temperature 750°C,40 % zinc chloride solution)

Table 4.6 and **Figure 4.13** showed the %yield, bulk density and deposition of zinc in the particle. The %yield and bulk density had decreased as the increasing of particle size until both were the minimum at 1.18 2.36 mm and went upward again at 2.36-4.75 mm, especially % yield (from 44.78 to 41.45 %) while bulk density slightly decreased. The deposition of zinc also decreased largely (19.50 to 0.70% of zinc) until going to the size of 1.18-2.36 mm as was the same for both % yield and bulk density with small decreasing of deposition of zinc until particle size of 2.36-4.75 mm. In the contrary, the iodine number, methylene blue number and B.E.T surface area (**Figure 4.14**) increased with increasing of particle size approaching at the maximum at 1.18-2.36 mm and going down at 2.36-4.75 mm. These phenomena could be explained by the physical packing of the bed. When the small particles (range of 0.25-1.18 mm) were packed in the reactor, it seemed that they packed tightly; as result, the gaps between particles were narrow, so the volatile matter and zinc chloride were difficult to vaporize out of the fixed bed by flowing nitrogen gas. These caused the high % yield and low development of porosity which conformed high bulk density, low iodine number, methylene blue number and B.E.T surface area.

The particle size of 1.18-2.36 seemed appropriate for flowing of nitrogen gas and caused very well vaporization of zinc chloride and diffusion out of volatile matter from the surface of the particle and the bed, so the characteristic of the activated carbon was the best at this size.

The particle size of 2.36-4.75 mm was bigger about two times than the one of the optimum. They arranged themselves by packing loosly and causing big gaps between particles. The nitrogen gas could flow out rapidly without contact all of the particles or sometimes occurring a channeling (deposition of zinc at specific point at the upper surface of bed) was observed; low development of porosity causing higher % yield, bulk density but lower iodine number, methylene number and B.E.T.surface area.

The deposition of zinc conformed the optimum condition, namely; the particle size range of 0.25-1.18 mm giving the higher zinc deposited in the particle (9.00 to 19.50%), while the optimum size of 1.18-2.36 mm remaining less than 0.70%. This value decreased continuously at the minimum about 0.10% for the size of 2.36-4.75 mm, because the bed was loose so nitrogen gas could release very well and rapidly zinc chloride out of the bed causing low residence time of zinc chloride in the particle of char.

The experimental results showed that the optimum size of palm-oil shell char for activation was 1.18-2.36 mm because the characteristic of activated carbon gave the highest iodine number, methylene blue number and B.E.T. surface area. It's properties were yield of 41.45 %, bulk density of 0.5078 g/cm^3, iodine number of 1007 mg/g, methylene blue number of 567.64 mg/g, B.E.T. surface area of 1080 m^2/g and 0.70 % deposition of zinc.

4.2.4 The optimum concentration of zinc chloride for activation

The concentrations of zinc chloride solution at 20%, 30%, 40%, 50% and 60% were prepared. The char from anthracite and palm-oil shell were soaked by these different solutions for studying the influence of concentration of solution on characteristics of prepared activated carbon. The mass of 15 g of 0.8-0.9 mm of anthracite and 1.18-2.36 mm of palm-oil shell char were carried out at 750°C for 3 hr by passing nitrogen gas through the bed. The results of this experiment were shown in **Table 4.7** and **Figures 4.15-4.20**.

Table 4.7 Deposition of zinc and characteristics of activated carbon from anthracite and palm-oil shell at different concentrations of zinc chloride (anthracite 0.80-0.90 mm and palm-oil shell char 1.18-2.36 mm of particle size, sample mass 15 g, temperature 750°C, 3 hr for activation time).

Raw material	Concentration of $ZnCl_2$ (%)	%Y	On dry basis			$S_{B.E.T.}$ (m^2/g)	Deposition of zinc (%)
			BD (g/cm^3)	IA (mg/g)	MB (mg/g)		
Anthracite	20	48.33	0.6212	305.08	233.84	446.53	0.20
Palm-oil shell	20	48.98	0.5499	314.14	292.76	443.67	0.35
Anthracite	30	46.21	0.6100	418.15	300.73	764.58	0.35
Palm-oil shell	30	47.65	0.5237	697.30	329.09	776.76	0.30
Anthracite	40	41.72	0.6050	852.12	450.09	986.64	0.40
Palm-oil shell	40	41.45	0.5078	1007.00	567.64	1080.23	0.70
Anthracite	50	45.43	0.6199	850.97	408.56	873.84	2.00
Palm-oil shell	50	44.45	0.5694	852.22	400.01	999.10	2.30
Anthracite	60	47.75	0.6340	844.29	368.15	835.98	6.00
Palm-oil shell	60	49.56	0.5738	856.34	317.75	701.38	6.50

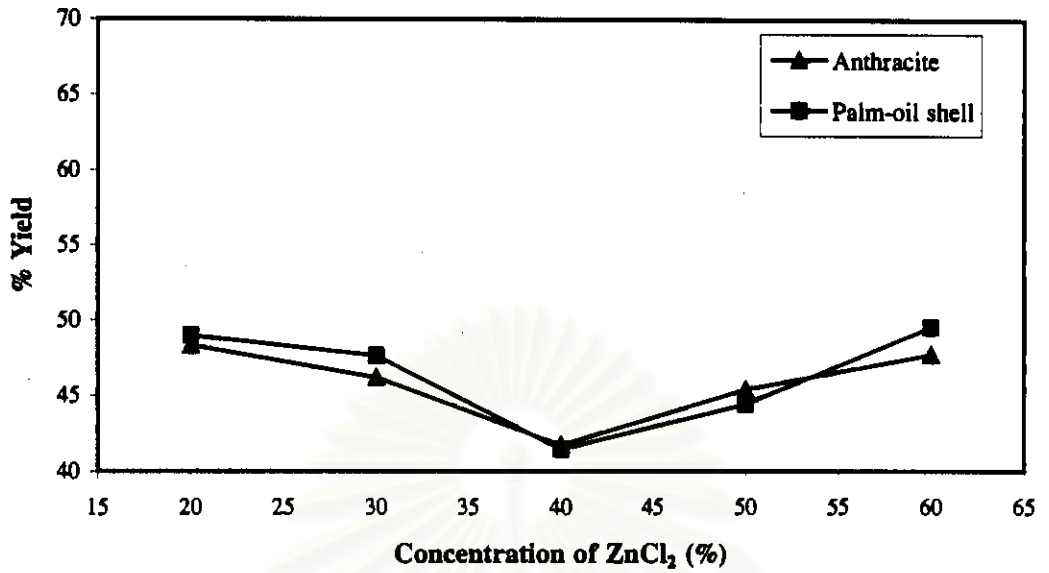

Figure 4.15 Effect of concentration of $ZnCl_2$ on %yield at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 750°C, 3 hr for activation time).

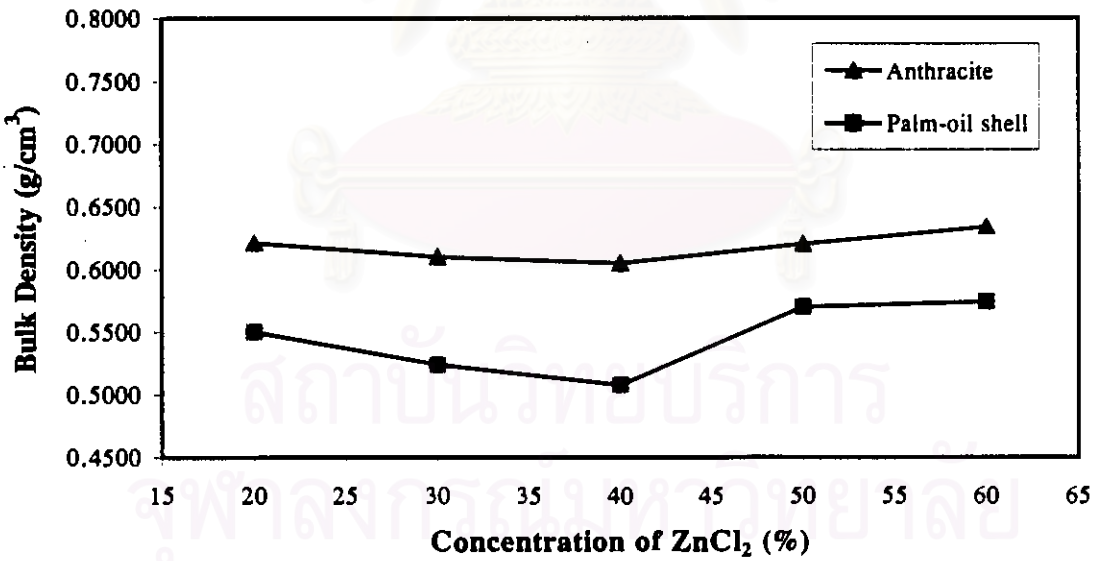

Figure 4.16 Effect of concentration of $ZnCl_2$ on bulk density at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 750°C, 3 hr for activation time)

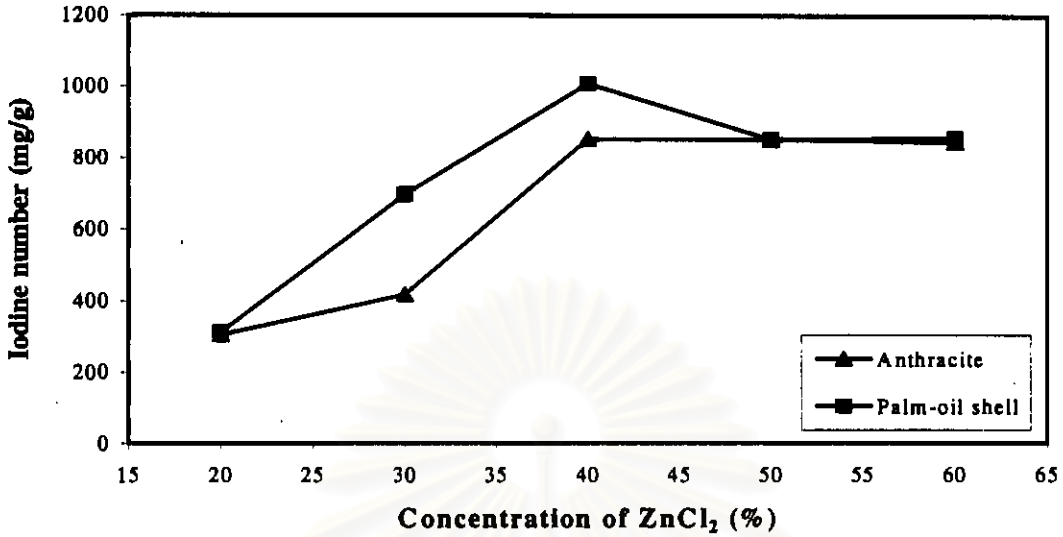

Figure 4.17 Effect of concentration of $ZnCl_2$ on iodine number at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 750°C, 3 hr for activation time).

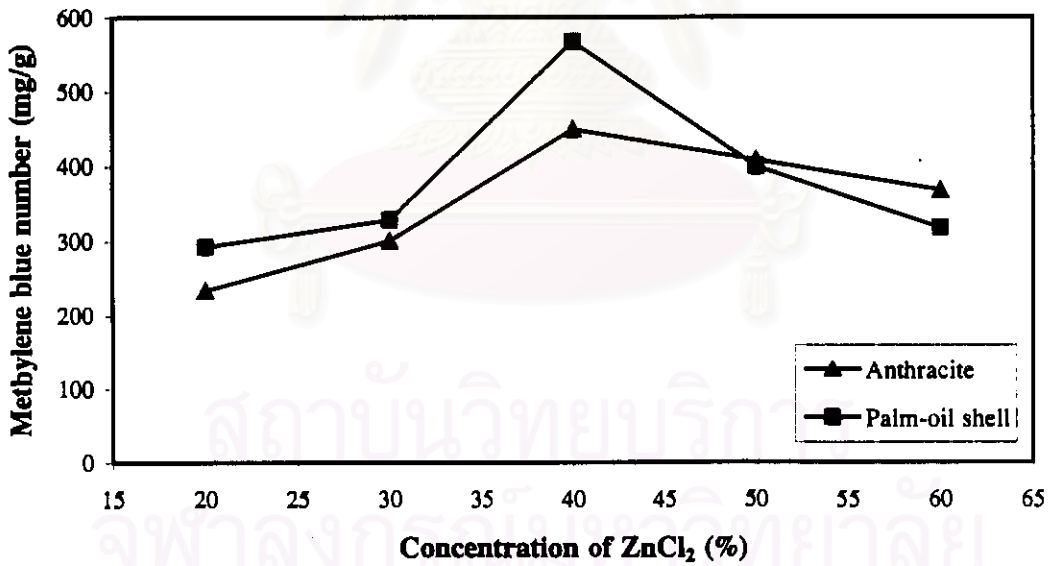

Figure 4.18 Effect of concentration of $ZnCl_2$ on methylene blue at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 750°C, 3 hr for activation time)

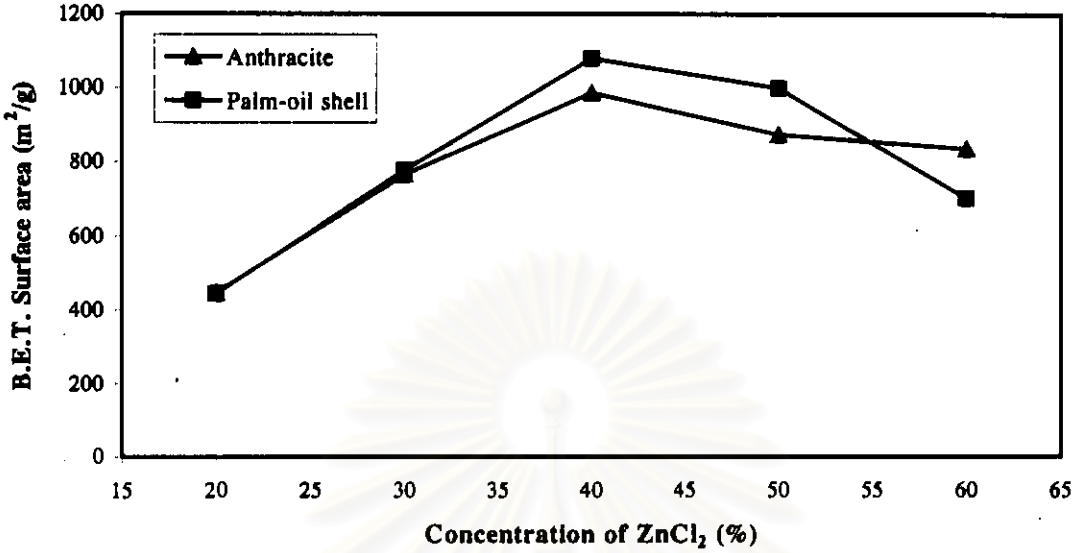

Figure 4.19 Effect of concentration of $ZnCl_2$ on B.E.T.surface area at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 750°C, 3 hr for activation time).

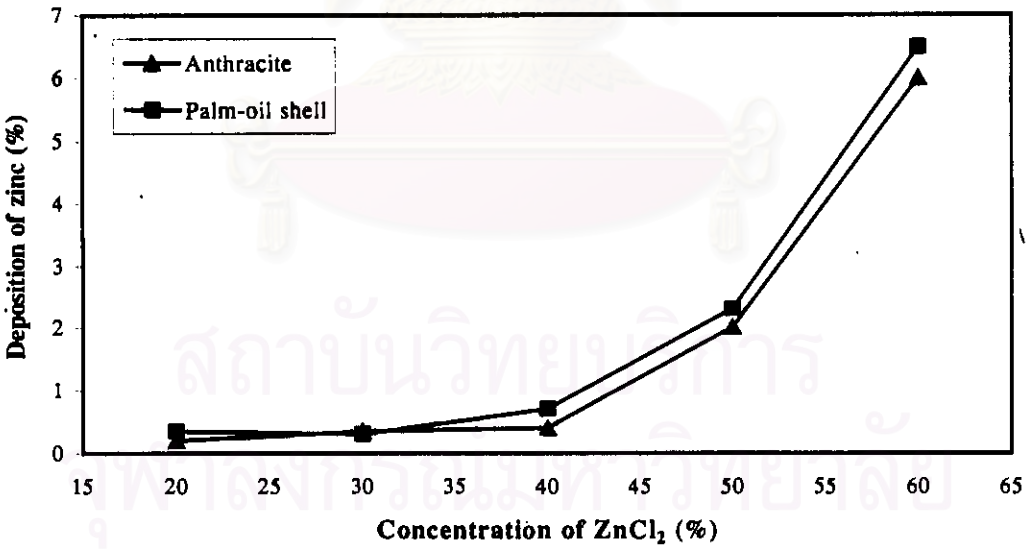

Figure 4.20 Effect of concentration of $ZnCl_2$ on deposition of zinc in activated carbon at different raw materials (0.80-0.90 mm of anthracite and 1.18-2.36 mm of palm-oil shell char, 15 g, 750°C, 3 hr for activation time).

From **Table 4.7** and **Figures 4.15-4.16**, the % yield and bulk density of activated carbon from anthracite and palm-oil shell decrease conformably when the concentration of zinc chloride increased and reached at the minimum of both values at 40 % of solution. Zinc chloride reacted more with char and volatile matter and diffused quickly out of the surface of particles, so the % yield and bulk density had decrease. However above 40 % of solution the % yield and bulk density increased. It might be that more zinc chloride of higher % concentration inside the particle which it would block volatile matter from gassing out to the surface (observed the higher % solution used) the more deposition of zinc from **Table 4.7.**

Table 4.7 and **Figures 4.17-4.19**, showed the increasing of iodine number methylene blue number and B.E.T.surface area with increasing of concentration of zinc chloride solution. They reached the maximum at 40 % of solution. It confirmed that when more reaction took place, more porosity developed as a result; % yield and bulk density decreased while iodine number, methylene blue number and B.E.T.surface area increased. It seemed that when the reaction took place at higher % solution of zinc chloride was not good which we have explained above concerning about the blockage of zinc chloride still remained inside the particle as a result; the increasing of % yield and bulk density, while the iodine number, methylene blue number and B.E.T.surface area were decreased. The % change of iodine number, methylene blue number and B.E.T.surface area were shown in **Table 4.8.**

From **Table 4.7** and **Figure 4.20**, the increasing of concentration of zinc chloride led to the increase of deposition of zinc in activated carbon from anthracite and palm-oil shell. **Table 4.7** and **Figure 4.20** showed the % deposition of zinc being nearly stable until 40 % and increasing sharply when the concentration of solution was increased from 40 to 60 % of solution. This figure confirmed the above explanation that there was too much zinc chloride which could not all be vaporized and it obstructed the diffusion of volatile matter out of the pores at the surface. The % change of deposition of zinc in activated carbon was shown in **Table 4.8.**

Table 4.8 The % change of characteristics of activated carbon and deposition of zinc in activated carbon from anthracite and palm-oil shell when concentration of zinc chloride increases from 20 to 60 % at the condition in **Table 4.7**.

Raw material	Concentration Of $ZnCl_2$ (%)	%Y	BD (g/cm^3)	IA (mg/g)	MB (m/g)	$S_{B.E.T.}$ (m^2/g)	Deposition of zinc (%)
Anthracite	20	48.33	0.6212	305.08	233.84	446.53	0.20
	↓	↓	↓	↑	↑	↑	↑
	40	41.72	0.6050	852.12	450.09	986.64	0.40
	% Change	*-13.67*	*-2.60*	*+179.31*	*+92.47*	*+120.95*	*+100.00*
	40	41.72	0.6050	852.12	450.09	986.64	0.40
	↓	↑	↑	↓	↓	↓	↑
	60	47.75	0.6340	844.29	368.15	835.98	6.00
	% Change	*+14.45*	*+4.79*	*-0.92*	*-18.20*	*-15.27*	*+1400.00*
Palm-oil shell	20	48.98	0.5499	314.14	292.76	443.67	0.35
	↓	↓	↓	↑	↑	↑	↑
	40	43.53	0.5174	1007.00	567.64	1080.23	0.70
	% Change	*-11.12*	*-5.91*	*+220.55*	*+93.89*	*+143.47*	*+100.00*
	40	43.53	0.5174	1007.00	567.64	1080.23	0.70
	↓	↑	↑	↓	↓	↓	↑
	60	49.56	0.5738	856.34	317.75	701.38	6.50
	% Change	*+13.85*	*+10.90*	*-14.96*	*+44.02*	*-35.07*	*+828.57*

↑ : increase ↓ : decrease

The experimental results show that the optimum concentration of zinc chloride was 40 %.because the activated carbon from anthracite and palm-oil shell gave the maximum of iodine number, methylene blue number and B.E.T. surface area.

4.3 Comparisons of this work with other works

The comparisons of this work with Terachai Suravattanasakul[28] (1998), Patra Panyawatanakit[26] (1997), in the condition of using palm-oil shell as raw material and comparing with Gergova, Klimkiewicz and Brown[22] (1995) by using anthracite were presented with respect to the maximum iodine number, methylene blue number and specific surface area obtained were shown in **Table 4.9** and **Table 4.10,** respectively.

Table 4.9 Comparisons of this work with Terachai Suravattanasakul (1998) and Patra Panyawatanakit (1997) (same raw material different activation procedures).

Description	This work (1999)	Terachai (1998)	Patra (1997)
Raw material	Palm-oil shell	Palm-oil shell	Palm-oil shell
Carbonization	400°C for 1 hr	750°C for 3 hr by add pyrolysis with air for 30 min before steam activation	400°C for 1 hr with air
Activation	800°C for 3 hr		900°C for 1 hr with air
Activation agent	Zinc chloride	Steam	Steam
% Yield	33.83 %	12.18 %	19.31 %
IA	1069.10 mg/g	766.99 mg/g	779.00 mg/g
MB	600.25 mg/g	189.20 mg/g	136.96 mg/g
$S_{B.E.T.}$	1099.10 m^2/g	669.75 m^2/g	670.10 m^2/g

Terachai produced the activated carbon from palm-oil shell by addition pyrolysis with air for 30 minutes before steam activation at 750°C for 3 hr and reported the maximum B.E.T.surface area of 669.75 m^2/g, iodine number of 766.99 mg/g, and methylene blue number of 189.20 mg/g. Patra produced the activated carbon from palm-oil shell by carbonization and followed by activation with steam at 900°C for 1 hr and reported the B.E.T. surface area of 670.10 m^2/g, iodine number of 779.00 mg/g and methylene blue number of 136.96 mg/g.

In this work with the same raw material but using the chemical activation, the B.E.T.surface area of 1099.10 m^2/g, iodine number of 1069.10 mg/g and methylene blue number of 600.25 mg/g were obtained by carbonization and also followed by activation with zinc chloride at 800°C and passing nitrogen gas for 3 hr. The iodine number, methylene blue number and surface area of this work was higher than Terachai's and Patra's. Although there was deposition of zinc chloride, but this quantity (0.20%) was so small that it could not release out of the particle.

Table 4.10 Comparisons of this work with Gergova, Klimkiewicz and Brown (1995) (same raw material and different activation procedures).

Description	This work (1999)	Gergova, Klimkiewicz and Brown (1995)
Raw material	Anthracite	Anthracite
Carbonization	400°C for 1 hr	-
Activation	800°C for 3 hr	850°C for 6 hr
Activation agent	Zinc chloride	Steam
% Yield	30.13 %	25.30 %
IA	860.35 mg/g	540.00 mg/g
MB	583.03 mg/g	-
$S_{B.E.T.}$	1026.99 m^2/g	720.00 m^2/g

The comparisons of this work to Gergova, Klimkiewicz and Brown experiments were carried out for the production of activated carbon from anthracite by using one-step steam pyrolysis activation, the result showed the iodine number of 540 mg/g and B.E.T.surface area of 720 m^2/g. In this work anthracite was activated by zinc chloride at 800°C and passing nitrogen gas for 3 hrs. The results gave the iodine number of 860 mg/g, methylene blue number of 583 mg/g and B.E.T. surface area of 1026 m^2/g. The comparisons showed that the iodine number and surface area of this work was higher than Gergova, Klimkiewicz and Brown's

From the comparisons of **Table 4.9** and **Table 4.10**, the energy requirement for activation was approximately equal for all processes which we have compared by consideration of almost the same reaction temperature. For zinc chloride activation (in this work) the iodine number, methylene blue number and surface area were higher

than physical activation of the other works. Zinc chloride activation was a directly catalytic process which affected on the formation of micropore and mesopore giving the higher iodine number, methylene blue number and surface area. One disavantage of this method was deposition of zinc. This work could minimize this value to 0.20 %, we could not release all of zinc chloride. This quantity was acceptable for using in commercial concerning about alimentation.