CHAPTER I

INTRODUCTION

1.1 Introduction

Palm-oil or *Elaeis guineensis* Jacq.[1] (**Figure 1.1**) belongs to the same family as the coconut. Its origin may be traced to the African continent. It can reach the height of 15 to 25 meters, growing wild. The palm-oil[2] can reach the age of 80 to 120 years; its fertility, however, comes to an end much earlier, namely about 60 years.

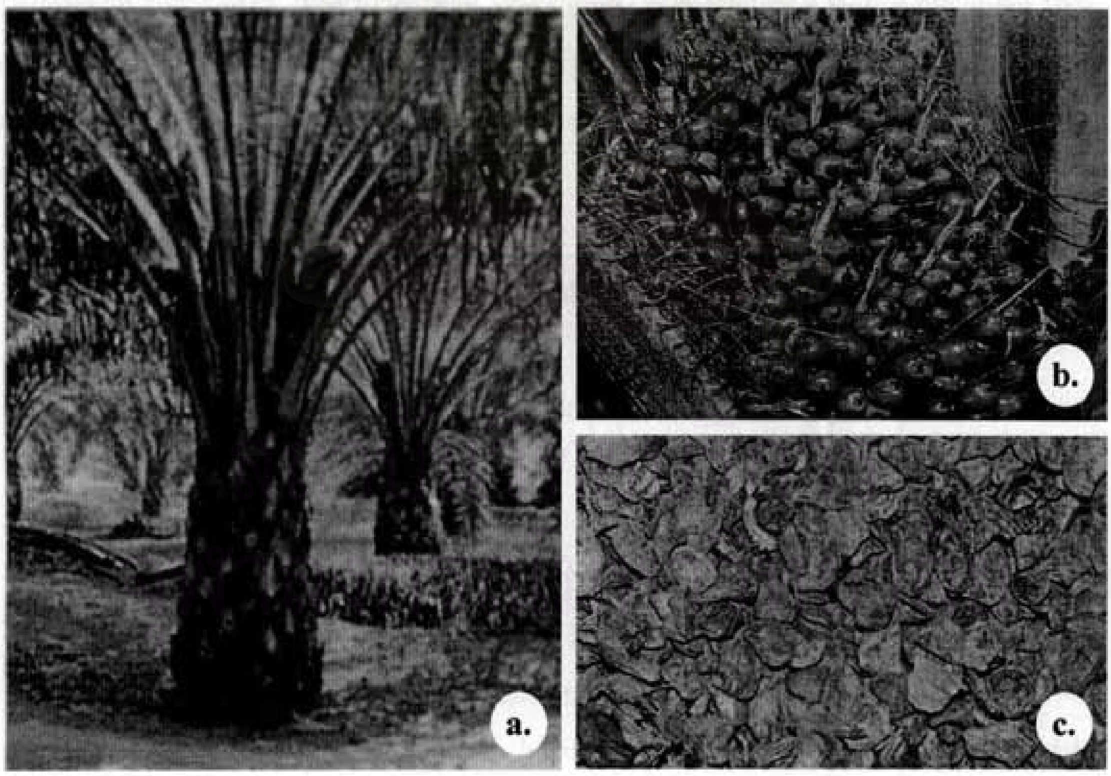
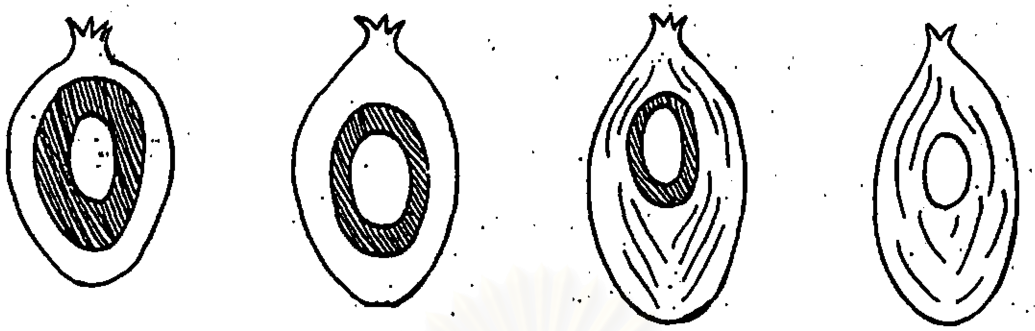


Figure 1.1 (a) palm-oil, (b) fresh bunches fruit and (c) palm-oil shells.

Fruit production[2] starts in the 3rd to the 4th years onwards and increases up to the 8-10th years, then remains at the same level with a certain amount of variation for a long time, but mostly falls off more or less rapidly from the 20th year, approximately. Beyond the 25th year, palm trees are too tall to be harvested economically and their yield are decline. Hence, on commercial basis they are replanted. The weight of an individual fruit varies between 4-20 grams according to local weather conditions, manuring and cultivation. The fruits vary very greatly in size, color, composition and shape, according to variety. An individual fruit consists of the outer exocarp or skin, the mesocarp of pulp, the endocarp or shell, and the kernel or seed.

Palm oil is extracted from the mesocarp, and kernel oil is obtained from the kernel after the endocarp has been removed. Because palm-oil grows well in hot zones where there is plentiful and regular rainfall throughout the year, the southern part of Thailand is ideal for it. It is grown mostly in the provinces of Krabi, Surat Thani, Chumphon and Satun. The plantation areas in these provinces account for about 95% of palm-oil growing area in Thailand. Other provinces where it is sporadically planted are Trang, Prachuab Khiri Khan, Phuket and Yala. Palm-oil strains[3] include the following (**Figure 1.2**) :

- *Macrocaya strain*. It is an old strain ; gives low yield and therefore is not often grown.
- *Dura strain*. It is similar to the old strain. The skin of the fruit is rather thick. It is commonly grown, but is preferred as a breeding strain for the improvement of new strains.
- *Pisifcra strain*. It has thick outer flesh (mesocarp) and high oil yield. However it is not commonly used in cultivation, though preferred as a breeding strain for the improvement of new strains.
- *Tenera strain*. It is a cross between Dura and Pisifera strains, with outstanding characteristics. It gives high yield of large fruits with thick outer flesh, thin inner flesh, thin skin and high oil content. This strain is therefore widely planted.



DURA		TENERA	PISIFERA
African	Deli		
Thick shell	Medium shell	Thin shell	No shell
45% pulp	60% pulp	75% pulp	92% pulp
40% shell	30% shell	15% shell	0% shell
15% kernel	15% kernel	10% kernel	8% kernel

Figure 1.2 Palm-oil strains in Thailand[1].

Palm-oil cultivation in Thailand has shown increasing economic signification with its expanding market demand at an average growth rate of 15% a year[4]. Estimates of the Bank of Thailand put palm-oil plantation areas in Thailand at 957,600 rai (1991), mainly concentrated in the southern part of Thailand. The market study revealed that palm oil production in Thailand during 1997[5] was about 449,796 tons/year. In 1998, it estimated that about 474,402 tons or 36,707 tons/month. Over 60% of market demand has been for direct consumption, with the remainder being used in various industries, i.e., soap, instant noodles, condensed milk, confectionery, margarine and shortening. Expansion of the palm oil industry was followed by the generation of enormous amounts of by-products at plantation grounds, oil press and refineries. It has been estimated that the pressing process produces about 292,367 tons of palm mesocarp fiber, 157,428 tons of palm-oil shells and 742,163 tons of empty fruit bunches as waste in 1997.

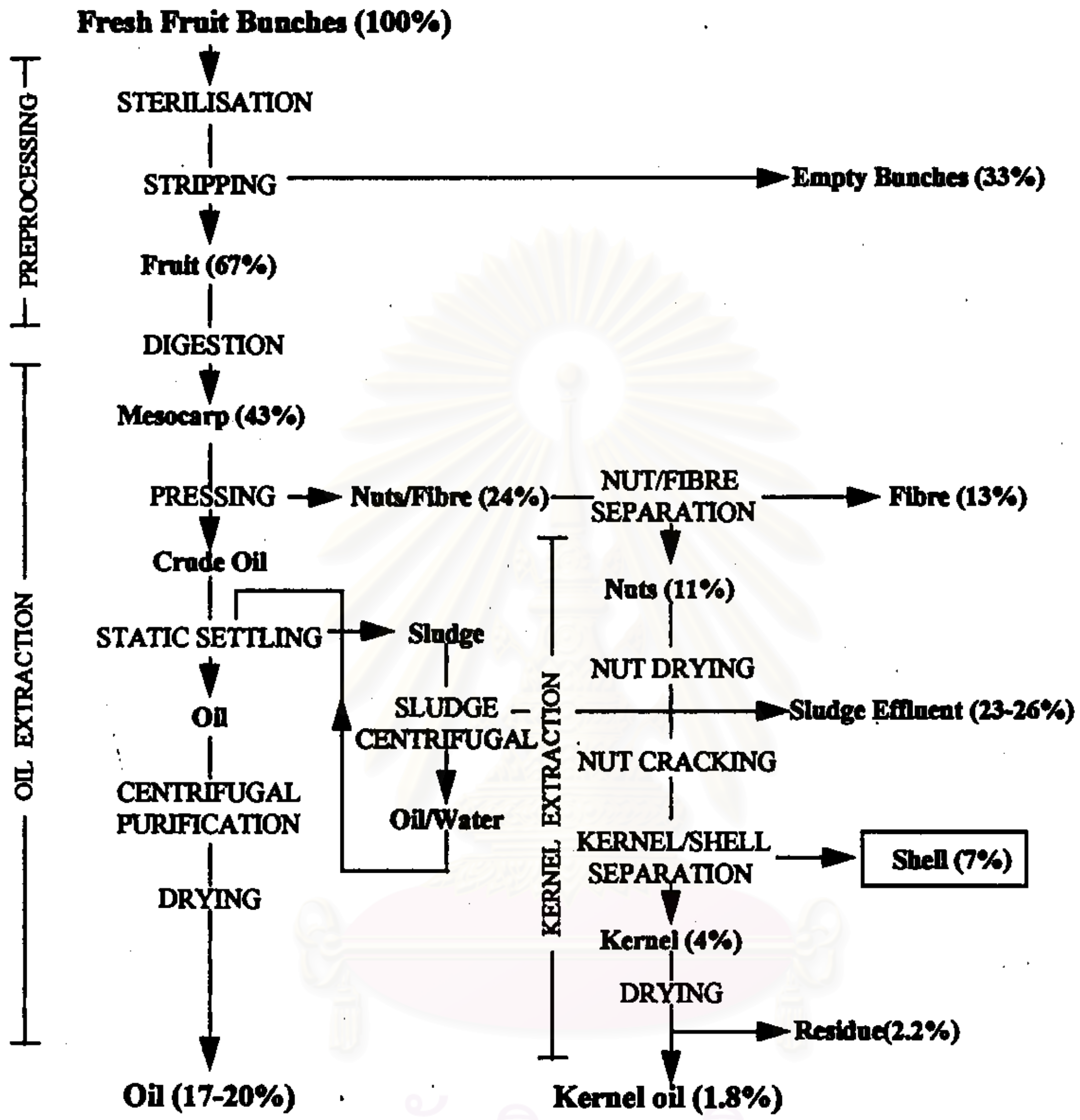


Figure 1.3 Flow chart of palm oil and kernel extraction process[2,6].

In the kernel extraction process (**Figure 1.3**), palm-oil shells are the by-product generated following the fuel or charcoal. Conversion of the palm-oil shell to value-added product such as activated carbon will directly solve part of the environmental problems and turning the by-product into a resource for another industry.

Activated carbon is widely used as adsorbents in gas and liquid-phase separation processes, purification of products and water cleaning operations. One of the most important fields in terms of consumption is in water and wastewater treatment, where activated carbon with a relatively high surface area and a well developed porosity is needed. Uses of activated carbon[7] are shown in **Figure 1.4**. To obtain activated carbon from cheap and readily available precursors becomes an interesting objective. Quantity and value of import and export of activated carbon in Thailand between 1988-1998 are shown in **Table 1.1** and **Figures 1.5-1.6.**

Table 1.1 Quantity and value of import and export of activated carbon between 1988-1998 (Activated carbon code 3802.100-004)[8].

Year	Import		Export	
	Quantity (kg)	Value (bath)	Quantity (kg)	Value (bath)
1988	1,932,203	52,327,284	260,802	8,118,737
1989	2,649,582	72,244,916	378,375	13,348,250
1990	2,321,914	75,358,548	663,917	25,001,383
1991	2,641,830	77,949,916	1,056,294	36,448,330
1992	2,706,967	101,418,463	1,027,131	34,008,219
1993	2,908,243	96,311,517	478,921	15,885,489
1994	2,816,400	103,186,178	522,068	18,246,436
1995	2,883,399	124,605,555	1,764,739	48,257,484
1996	3,047,195	100,836,897	2,937,245	75,682,676
1997	3,598,415	127,139,283	2,807,200	99,373,426
1998 (Jan.-Apr.)	1,090,437	40,559,567	1,160,900	54,840,113

source: Department of Business Economic, Finance Ministry.

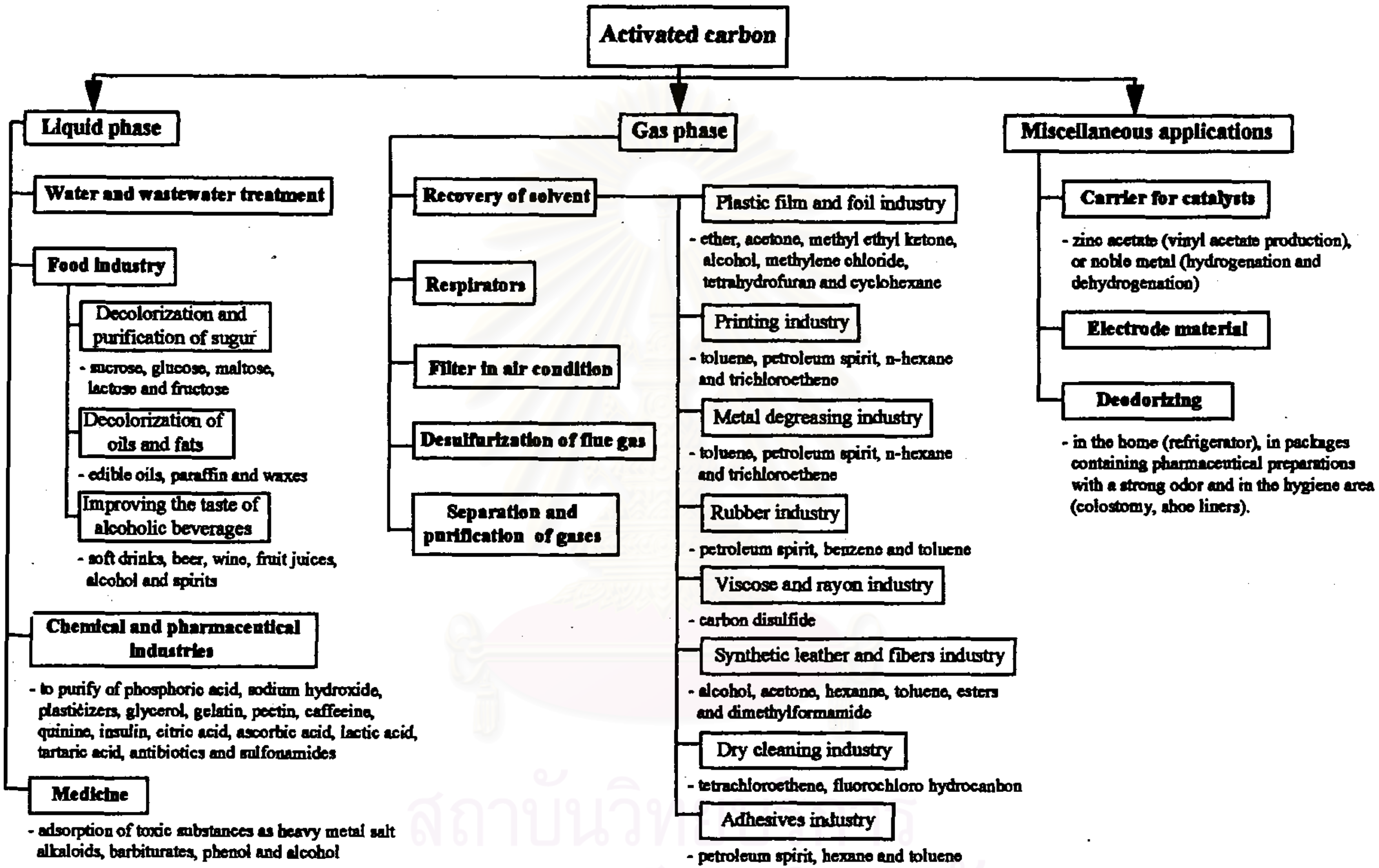


Figure 1.4 Uses of activated carbon[7].

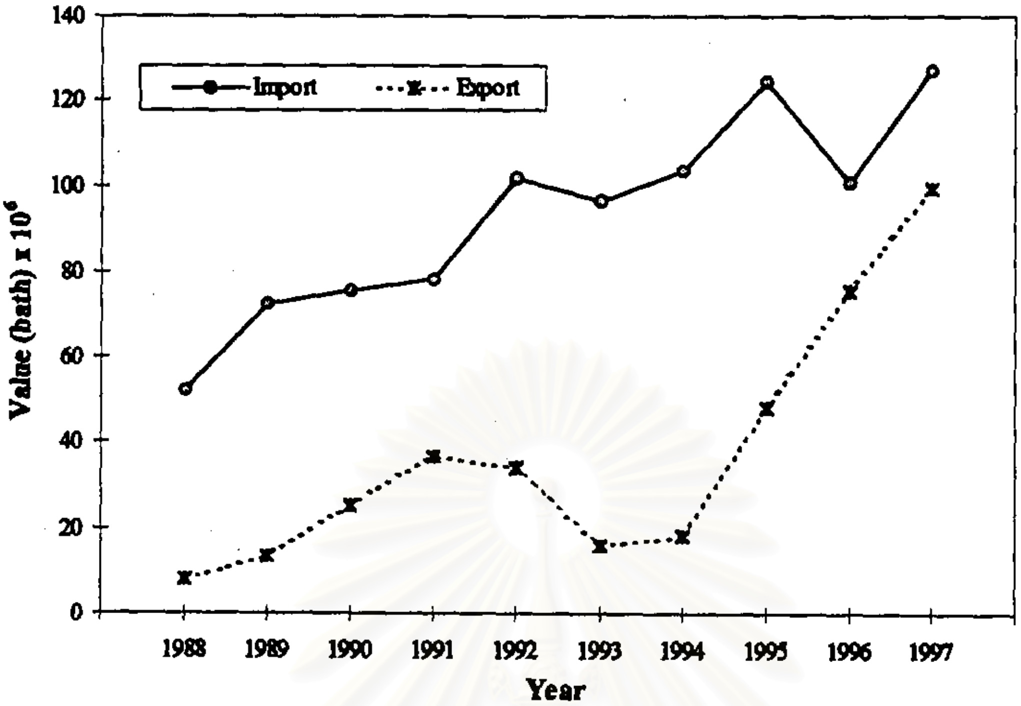


Figure 1.5 Value of import and export of activated carbon in Thailand between 1988-1998[8].

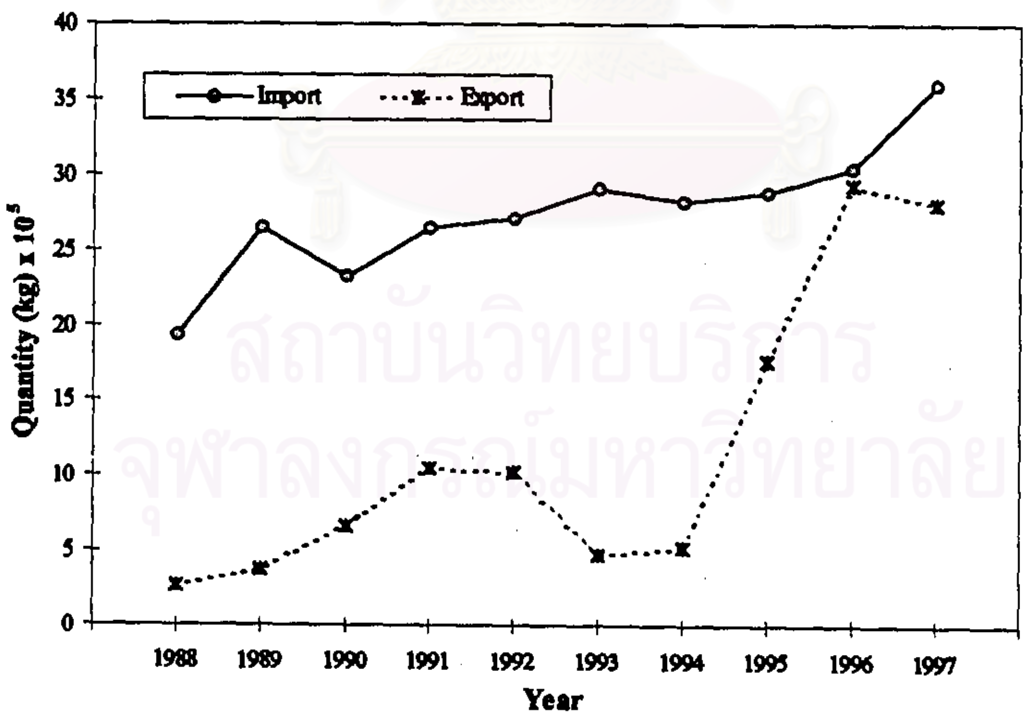


Figure 1.6 Quantity of import and export of activated carbon in Thailand between 1988-1998[8].

Commercial processes to produce activated carbon used a variety of raw material including peat, coal, wood and coconut shell. Among these, palm-oil shell is the interesting raw material because of its enormous amounts as by-products in palm oil industrial. From proximate analysis, it was observed that palm-oil shells have properties similar to coconut shell but palm-oil shells have more ash than coconut shells and B.E.T. surface area showed that palm-oil shells have higher number of pore than coconut shells, so palm-oil shells are likely to be a precursor for the production of activated carbon. The proximate analysis and the B.E.T. surface area compared with coconut shells and palm-oil shells are shown in **Table 1.2.**

Table 1.2 The proximate analysis and the B.E.T. surface area, compared with coconut shells and palm-oil shells.

Raw material	%VM	% Ash	% FC	IA (mg/g)	MB (mg/g)	Surface area (m^2/g)		
						S_{total}	S_{Micro}	$S_{External}$
Coconut shells	80.80	0.40	18.80	97.6	5.0	0.9	0.0	0.9
Palm-oil shells	79.66	2.05	18.29	-	-	12.2	0.0	12.2

1.2 Objectives

This work shows the studies of optimum condition in the production of activated carbon from palm-oil shells by one step pyrolysis and steam activation in a fixed bed reactor, which reduce problem from by-product in palm oil industry and a better solution from an environmental and economic standpoint. The objectives of this work are following:

1. To find effective parameters and optimum conditions for the production of activated carbon by pyrolysis and steam activation in a fixed bed reactor.
2. To study physical and chemical properties of the produced activated carbon.

1.3 Scope of the research

For the production of activated carbon from palm-oil shells by pyrolysis and steam activation, the appropriate condition such as temperatures, times, sizes of the raw material, flow rates of air and pyrolysis with air before steam activation were studied. The necessary procedures are follow:

1. Literature survey and in-depth study of this research work.
2. Proximate analysis of palm-oil shells.
3. Production of activated carbon from palm-oil shells by pyrolysis and steam activation by changing the following parameters so as to attain the optimum condition :
   - (a) The optimum temperature and time
   - (b) The optimum size of palm-oil shells
   - (c) The optimum flow rate of air
   - (d) The effect of pyrolysis with air before steam activation
4. Investigation of the properties of the activated carbon such as % yield, % ash, bulk density, iodine number, methylene blue number and B.E.T. surface area.
5. Summarizing the results.