THE EFFECT OF PHYSICAL TREATMENT AND FERMENTATION ON CHEMICAL AND NUTRITIONAL COMPOSITION OF MALAYSIAN RUBBER SEED

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Abstrak

Biji getah (*Hevea brasiliensis)* merupakan produk sampingan dari pada ladang getah yang mengandungi nilai nutrisi yang boleh digunakan sebagai makanan untuk manusia, makanan ternakan untuk haiwan atau bahan api untuk menghasilkan tenaga. Analisis kimia dan penentuan untuk penghasilan tertinggi dari pada hasil pengepresan minyak getah dan hampas getah telah dilakukan dalam kajian ini. Kajian ini dilanjutkan dengan penentuan analisis kimia dari pada kondisi parameter yang terbaik, perlakuan detoksifikasi (nyah racun) untuk menurunkan kadar HCN keatas biji getah dilakukan dengan beberapa kaedah (perlakuan panas, penyimpanan, perendaman dan fermentasi.

Keputusan kajian menunjukkan bahawa biji getah boleh sebagai makanan ternakan alternatif dan sebagai tambahan yang baik untuk jagung sebagai makanan ternakan. Asid amino esensial biji getah menunjukkan biji getah tinggi Valine, tetapi rendah Metionin. Proses fermentasi adalah proses yang terbaik diantara proses lain untuk detoksifikasi kandungan HCN. Ada perbezaan yang signifikan antara perlakuan detoksifikasi, fermentasi merupakan perlakuan yang terbaik diantara perlakuan lain untuk mengurangi lebih banyak kandungan HCN.

Ada perbezaan yang signifikan diantara semua parameter dalam pemprosesan biji getah menjadi minyak dan hampas. Keadaan yang terbaik (saiz mulut paip 6 mm, kelajuan 20 rpm, dan skru jenis R-11) ialah keadaan yang boleh hasilkan efisiensi yang tinggi dan keadaan itu akan digunakan untuk kajian lebih lanjut.

Tempe biji getah mempunyai penampilan yang sama seperti tempe kacang soya, dengan adanya pembaikan pada kandungan asid amino esensial, seperti Valin, Isoleusin dan Leusin meningkat berbanding kepada biji getah baku.

THE EFFECT OF PHYSICAL TREATMENT AND FERMENTATION ON CHEMICAL AND NUTRITIONAL COMPOSITION OF MALAYSIAN RUBBER SEED

Abstract

Rubber seed (*Hevea brasiliensis*) as a by-product from rubber plantations contains nutritive values that can be harnessed as food for human, feed for animals or fuel for energy. Chemical analyses and the highest yield from the screw pressed rubber oil and rubber meal have been done in this study. The study continued to evaluate chemical analyses from the best conditions of press parameters, detoxification treatments to reduce HCN content on rubber seed using some methods (heat treatment, storage, soaking, and fermentation).

Results showed that rubber seed can alternatively be considered as potential feed stuff and good companion for maize as feed for animal. Essential amino acid of rubber seed showed rubber seed high in Valine but low in Methionine. Fermentation process is the best result to reduce HCN content among other treatments. There were significant differences among detoxification treatments, which is the fermentation process reduced more HCN content comparing other treatments.

There were significant differences among all parameters in processing rubber seed into oil and meal. The best condition/setting (nozzle size of 6 mm, speed of 20 rpm, and shaft screw of type R-11) was the highest yield (efficiency) of press and the setting were used for further study. Rubber seed tempeh had similar appearance as soybean tempeh, with an improvement on EAAs content, i.e. Valine, Isoleusine and Leusine were increased, compared to raw rubber seeds.

CHAPTER 1 - INTRODUCTION

1.1 Background

Rubber seed is an important by-product of rubber cultivation in many tropical countries. The rubber tree does not only produce latex, but also rubber seed, rubber honey and rubber wood. One of the by-products of rubber plantation, which should be more exploited, is rubber seed. In many countries, rubber seeds are only used for replanting.

A rubber plantation is estimated to be able produce about 1400-2000 kg rubber seeds per ha per year (DEPTAN, 2009) and these are normally regarded as waste. It is often included as a component of supplements fed to ruminants. From the composition of rubber seed itself, can be as food for humans. Some analyses have shown that the rubber seed contains useful nutrients such as protein and amino acids (Njwe *et al.*, 1988; Joseph, 2004 and Madubuike *et al.*, 2006). However, the seeds also contain HCN (hydrogen cyanide), posing as a hindrance to its use as a food source. Fresh rubber seeds and its kernel contain about 638 and 749 of hydrogen cyanide (HCN) mg per kg (George, *et al.,* 2000). Despite that, Njwe *et al.* (1988) reported that boiled and drained rubber seeds are eaten by Indian in the Amazon Valley of South America without adverse effects.

Solvent extraction and mechanical pressing are the leading methods for commercial oil extraction. Mechanical pressing is allowed by the organic food industry.

It is envisaged the rubber seed can be utilized as a source of oil and food. Adjusting pressing parameters can improve oil recovery, improve the flavor and also increase the protein content of the meal.

1.2. Rationale of study

As we know, seeds on the rubber plantation are not utilized and considered as waste. From its nutritive value, rubber seed can be used as protein source. We can utilize the rubber seed and change it from waste into something of value.

Currently there is no published data/study on the potential of rubber seed as a source of food and oil through optimum processing using screw press. Existing publications indicated that rubber seed meal has been evaluated and accepted as a good component of livestock feeds in other parts of the world especially South East Asia. The literature has shown that the source of rubber seed has significant impact on the composition of the rubber seed.

Screw press is one of the extraction methods for producing oilseed. Screw press method is safe and recommended for edible oilseed. And we can produce oilseed for home industry (small screw press cap 5 tons/hrs).

Tempeh is a traditional fermented food from Indonesia, based on soy bean. And Indonesia is the largest producers and consumer of tempeh in the world. Rubber seed tempeh is suggested as alternative food for human by detoxification the HCN content from rubber seed.

1.3. Objectives

Overall the main objective of this research is to study potential use of rubber seed as food, feed and fuel by evaluating the screw pressed rubber seed oil and meal.

More specifically, the objectives of this research were:

1. To determine the operating parameters of the screw press for high capacity and oil extraction efficiency.
2. To characterize of screw pressed rubber seed oil and meal obtained from screw press parameters which gave high yields.
3. To identify effective methods for detoxification of rubber seeds of its HCN content.
4. To produce tempeh from rubber seeds, and evaluate its nutritional value (proximate, mineral and EAA).

CHAPTER 2 - LITERATURE REVIEW

2.1. General

Hevea brasiliensis is the most important commercial source of natural rubber (NR). It is a native of the Amazon river basin of South America. It is one of the most recently domesticated crop species in the world and was introduced to tropical Asia through Kew Gardens in the UK, with the seeds brought from Brazil by Sir Henry Wickham. The tree is now grown in the tropical regions of Asia, Africa and America (Gowaricker, 1986).

The Para rubber tree (*Hevea brasiliensis*), often simply called rubber tree, belongs to the family Euphorbiaceace is most economically important member of the genus *Hevea*. It is of major economic importance because its sap-like extract (known as latex) can be collected and is the primary source of natural rubber.

The rubber tree (figure 2.1) can reach a height of over 30 m. The white or yellow latex occurs in latex vessels in the bark, mostly outside the phloem. These vessels spiral up the tree in a right handed spiral which form an angle of about 30 degrees with the horizontal. Once the trees are 5-6 years old, the harvest can begin: incisions are made orthogonal to the latex vessels, just deep enough to tap the vessels without harming the tree's growth, and the sap is collected in small buckets. Older trees yield more latex, but they stop producing after 26-30 years (FAO, 1977).

Figure 2.1. Rubber seed tree

2.2. Ancillary products from rubber plantation

There are three important by-products and ancillary sources of income from rubber plantations are rubber wood, rubber honey and rubber seed. Among the three by-products, the extent of commercial exploitation of rubber wood is relatively higher, compared to the other two, across the major NR (Natural Rubber) producing countries especially, Malaysia, Thailand, Indonesia, Sri Lanka and India, mainly due to the potential value addition and size of the world market for the rubber wood based finished products and household articles.

Thailand (35%), Indonesia (23%), Malaysia (12%), India (9%), and China (7%) are the world`s largest natural rubber producers. The main world importers are China (18% of total), United States (13%) and Japan (10%) (IRSG, 2010).

International Rubber Study Group (IRSG) reported world rubber production and consumption as shown in table 2.1.

Table 2.1. World rubber production and consumption

('000 tonnes)

Year	Production			Consumptiom		
	Natural Rubber	Synthetic Rubber	Total Rubber	Natural Rubber	Synthetic Rubber	Total Rubber
1998	6,634	9,880	16,514	6,570	9,870	16,440
1999	6,577	10,390	16,967	6,650	10,280	16,930
2000	6,762	10,870	17,632	7,340	10,830	18,170
2001	7,332	10,483	17,815	7,333	10,253	17,586
2002	7,326	10,877	18,203	7,556	10,874	18,430
2003	8,020	11,341	19,361	7,952	11,348	19,300
2004	8,746	11,961	20,707	8,718	11,840	20,558
2005	8,904	12,100	21,004	9,200	11,900	21,100
2006	9,791	12,653	22,444	9,677	12,691	22,368
2007	9,801	13,387	23,188	10,144	13,264	23,408
2008	10,036	12,743	22,779	10,173	12,603	22,776
2009	9,617	12,087	21,704	9,390	11,754	21,144
2010*	2,360	3,247	5,607	2,469	3,160	5,629

Source: International Rubber Study Group (IRSG, 2010)
*Note: Jan-Mar

2.2.1. Rubber wood

Rubber tree (*Hevea brasiliensis*) plantations form the second largest category of global tropical forest plantations by area, accounting for 18% of global forest plantations, after *Eucalyptus* spp. (24% of the total area) and *Pinus* spp. (18% of the total area) (ITTO, 2009). Rubber plantations produce two raw materials: rubber latex and wood. However, they are not normally regarded as a sustainable wood resource. While rubber latex has been extensively utilized in industrial manufacturing, wood from rubber plantations (rubber wood) has traditionally been regarded as waste (Hong 1995a; Arshad 1996) due to difficulties preserving the timber after milling.

Although industrial utilization of rubber wood has gradually increased in recent years (Sylva 1992; Hong 1995b; Yamamoto 1997; Kiam 2002; Varmola and Carle, 2002) with technological advances in rubber wood treatment methods (Killmann 2001; ITTO 2009), rubber plantations are still managed only for latex production with the wood regarded as an incidental by-product. Wood as a timber has not been sufficiently demonstrated; exploring the contribution of rubber wood products to industrial wood production is therefore essential.

The trend in the area planted to rubber worldwide and in Malaysia, Thailand, and the rest of Southeast Asia (Indonesia, Laos, Vietnam and Myanmar) from 1985 to 2005 is presented in Table 2.1. Malaysia has 1.47 million ha of rubber plantations and Thailand has 2.02 million ha (ITTO, 2009). Indonesia actually has the largest area planted rubber (3.28 million ha) (FAO, 2010), but the productive area is only 0.92 million ha (ITTO, 2009), and its utilization has been still limited.

Table 2.2. Planted area of rubber worldwide, in Asia, SE Asia, Malaysia and Thailand (Unit: million ha).

Year	World total	Asia							other regions
		Asia sub-total	Southeast Asia (SE Asia) (ha)					other Asia	
			SE Asia sub-total	Malaysia	Thailand	Indonesia	other SE Asia		
1985	6.04	5.67	4.95	1.54	1.41	1.69	0.31	0.72	0.37
1995	7.21	6.63	5.69	1.48	1.50	2.26	0.45	0.94	0.58
2005	8.81	7.94	6.87	1.23	1.69	3.28	0.67	1.07	0.87

Source: FAO (2010)

Figure 2.2. shows Malaysian export earning of Natural Rubber (NR), rubber products, rubber wood and other rubber from 2006-2010 (January-March).

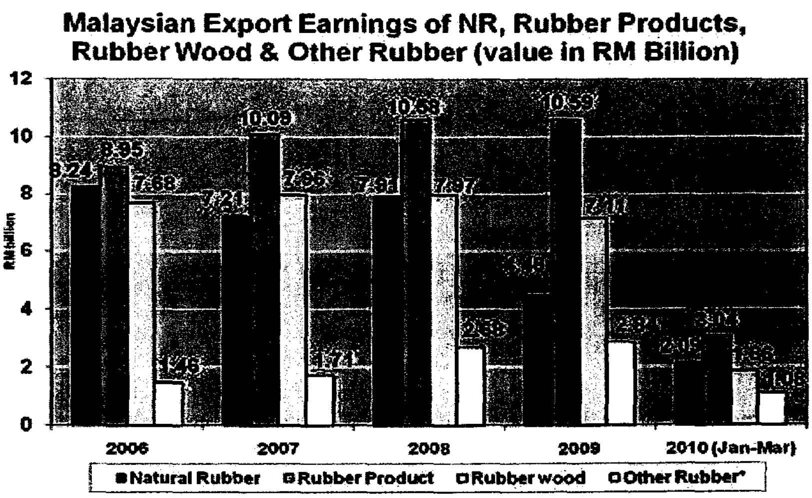

Figure 2.2. Malaysia rubber export (source: Malaysian Rubber Board, 2010)
*Other rubber: Synthetic rubber, reclaimed rubber, waste rubber.

2.2.2. Rubber honey

The rubber tree is a prolific source of honey, which is obtained from the extra floral nectars at the tip of the petiole and the honey flow period is between the months of January and March. According to BIS (Bureau of Indian Standard) specifications, honey is classified into three grades based on the moisture content. It prescribes less than 20% moisture for `special grade`, 20-22% for `grade A` and 22-25% for `standard grade`. Rubber honey belongs to medium grade (Grade A) with an average moisture content of 22% (Joseph, 2004)

2.2.3. Rubber seed

The rubber fruit as shown in figure 3 begins to produce fruit at 4 years of age. A fruit contains 3 to 4 seeds, which consist of brown or black with some white spots hard shell and a soft white kernel. The proportion of the kernel is about 51% of the total weight of the seed. The soft kernel is used to produce oil, and the by-product is rubber seed meal (RSM). A hectare of rubber trees gives 300 to 400 kg of seed per year (Gohl, 1981). Average rubber seed meal produced is about 60 to 70% of total seed weight. Therefore, one hectare of mature rubber trees can produces 180 to 280 kg of rubber seed meal.

Figure 2.3: Rubber seed

According to the Association of Natural Rubber Producing Countries, Kuala Lumpur, Malaysia has an estimated acreage of 1,229,940 hectares of rubber plantation in 2007 (Malaysian Rubber Board, 2010) Based on an estimated average of 1000 kg seeds per ha/ yr, the projected annual production of rubber seeds in Malaysia would be 1.2 million metric tons. Despite Malaysia being a major rubber growing country, to date, there is a dearth of information on the chemical composition of the Malaysia rubber seed. Eneh (1998) reported the crude protein in rubber seed to be about 32.98% (table 2.3). According to Bressani *et al* (1983), the rubber seed kernel (hull has been removed) contains 29.6% fat and 11.4% protein. Thus, it is estimated that Malaysia wastes about 355,200,000 kg fat and 136,800,000 kg protein per year. Even in countries such as Vietnam, there are 420,000 ha of rubber trees with density of 500 tree/ha. Based on an estimated production of approximately 300 kg rubber seed /ha, it is then possible to collect nearly 130,000 metric tons rubber seed equivalent to 65,000 metric tons of rubber seed meal without hulls every year from this level of rubber production.

Table 2.3. Proximate analysis of rubber seed

Parameter	rubber seed (%)	rubber kernel (%)
Moisture	10	3
Crude protein	24.1	23
Crude Fat	35	47
Ash	1	3.5
Total carbohydrate	29.9	23.5
HCN content (mg/kg)*	638	749

Source: Ukhun and Uwatse, (1988)
*George, *et al.* (2000)

In Indonesia, until now only latex and rubber wood are exploited. The present crisis in the rubber plantation industry in Indonesia could be overcome only if alternate source of income are identified for the growers. One of the by-products of rubber plantation, which should be more exploited, is rubber seed. In Indonesia, rubber seed is only used for replanting. As reported by Indonesian Ministry of Agriculture, Indonesia has about 3.3 million ha of rubber plantations in 2002. Based on to this value, the Indonesian rubber plantation is estimated to be able produce around 3.3 million tons rubber seeds per year.

2.3. Use of rubber seed

2.3.1. Rubber seed in the livestock

In view of their chemical composition and nutritive content, rubber seed kernels can alternatively be considered as potential feed stuff. Since it is well known that protein sources are the main constraint for the improvement of animal production in many tropical regions of the world, the seed with 11-25 % crude protein is a potential protein supplement for live stock. Rubber seed is an important by-product of rubber cultivation in many tropical countries, and is often included as a component of supplements fed to ruminants. It has a high content of semidrying oil which may be used in the paint industry, leaving the press cake as a potential source of high-protein food for cattle or sheep. However, heat treatment and storage are required to reduce the level of hydrocyanic acid (HCN) (UNIDO, 1987).

Rubber seed meal and the cake are higher in total digestible nutrients than soy-bean meal and are highly promising as a protein supplement. Rubber seed meal has a high level of lysine and tryptophan, making it a good complement for maize in poultry and pig rations (Ensminger and Olentine, 1978).

Farmers close to the location of rubber seed production in Vietnam have included rubber seed in diets for chickens and also pigs for a long time. According to these producers pigs can tolerate only about 7% of rubber seed in the diet due to the toxicity of the rubber seed. Even though farmers do not know exactly what the toxin is, the symtoms they describe indicate that the cause is probably HCN, as reported in the literature. The farmers reported that scavenging chickens do not show any serious symptoms of toxicity. However, consumers are often afraid of being poisoned through eating chickens which had been fed diets with rubber seed. This perception results in farmers not revealing the fact that they really feed their chickens diets with rubber seed. According to some rubber seed producers, even feed mills purchase rubber seed to mix into their complete feeds, but they never reveal this to the public (Gohl, 1981).

2.3.2. Rubber seed as a food

According to their chemical composition and nutritive value; rubber seed meal can be considered as very good potential food material for human. Rubber seed meals are higher in total digestible nutrients than soybean meal and are highly promising as a protein supplement.

Amino acids are joined together by peptide bonds form the primary structure of proteins. The amino acid composition establishes the nature of secondary and tertiary structures. These, in turn, are important factors in influencing the functional properties of food proteins and their behavior during processing. Of the 20 amino acids, only 8 are essential for human nutrition.

Essential amino acids are more important to life because the body cannot make these amino acids, and they have to come from food or amino acid supplements. The dietary requirement for protein will be the minimum intake which satisfies metabolic demands and which maintains appropriate body composition and growth rates, after taking into account any inefficiency of digestion and of metabolic consumption. To satisfy the metabolic demand, the dietary protein must contain adequate and digestible amounts of nutritionally indispensable or essential amino acids (FAO/WHO, 1991). The amounts of these essential amino acids present in a protein and their availability determine the nutritional quality of protein (Deman, 1976).

The Food and Drug Administration (FDA) of United States requires all food labels to include the percent Daily Value (%DV) for iron. DVs are reference numbers developed by the FDA to help consumers determine if a food contains a lot or a little of a specific nutrient. The percent DV indicates the percent of the DV that is provided in one serving. The DV for iron is 18 milligrams (National Institute of Health, 2007). A food providing 5% of the DV or less is a low source while a food that provides 10-19% of the DV is a good source. A food that provides 20% or more of the DV is high in that nutrient. In this light, a serving of 100 g rubber seed kernel has an iron content of 0.24 mg, or equivalent to 1.3 % of the DV. Thus, rubber seed is a poor source of iron. However, it is important to remember that foods that provide lower percentages of the DV or AI (Adequate Intake) may also contribute to a healthful diet.

Table 2.4. Amino acid composition appropriate for adult and whole egg

Amino acid	Adult[1] (%)	WE[2] (%)
Lys	5.5	7.0
Met+Cys	3.5	5.7
Thr	4.0	4.7
Ile	4.0	5.4
Trp	1.0	1.7
Val	5.0	6.6
Leu	7.0	8.6
His	0	2.2
Phe+Tyr	6.0	9.3

[1] Adult; FAO pattern

[2] WE: Whole Egg, according Hidvégi and Békés (1984)

2.3.3. Rubber seed in industry

2. 3.3.1. Rubber seed meal

Many countries produce use rubber seed as feed supplements for pig and earlier researchers have reported their work (Ong and Yeong, 1977; Ensminger and Olentine, 1978; Devendra, 1983; Ravindran, 1983; Pech, 2002) and as a diet for broilers in Malaysia (Yeong and Syed, 1979). Therefore, all countries make the animal feed industry for their own purposes even some countries that already export it.

Ong and Yeong (1977) and Devendra (1983) reported a reduction in growth when pigs were fed diets containing more than 20% rubber seed of the meal.

2. 3.3.2. Rubber seed oil

The world is confronted with the twin crises of fossil fuel depletion and environmental degradation. Indiscriminate extraction and increased consumption of fossil fuels have led to the reduction in underground-based carbon resources. Alternative fuels, promise to harmonize sustainable development, energy conservation, management, efficiency and environmental preservation. Ever since it was known that fossil fuels are finite and indeed will only suffice for a few generations, scientists have been looking for alternatives (Ikwuagwu, *et al.*, 2000; Ramadhas, *et al.*, 2005a; Chauchan, *et al.*, 2009).

Vegetable oil is a promising alternative to petroleum products. In the last few years, vegetable oils are increasingly being used in edible as well as non-edible applications such as surface coatings including paints, printing inks, rubber/plastic processing, pharmaceuticals, lubricants, cosmetics, chemical intermediates and diesel fuel substitute/extender. Recently, there has been growing interest in biodiesel, alternative fuel made from natural, renewable sources such as vegetable oils (Ramadhas, *et al.* 2005b).

Vegetable oil contains 97% triglycerides and 3% di- and monoglyserides and fatty acids. The process of removal of all glycerol and the fatty acids from the vegetable oil in the presence of catalyst is called transesterification. The vegetable oil reacts with methanol and forms esterified vegetable oil in the presence of sodium/potassium hydroxide as catalyst.

Studies have shown that rubber seed oil has many areas of potential applications amongst which are: as lubricant (Njoku and Ononogbu, 1995), as printing ink, foaming agent in latex foam (Reethamma *et al.*, 2005), fatice (Vijayagopalan, 1971; Fernando 1971), biodiesel (Perera and Dunn, 1990; Ikwuagwu *et al.*, 2000; Ramadhas, *et al.*, 2005a), paints and coatings (Aigbodion *et al.*, 2003) and others (Iyayi *et al.*, 2008). According to rubber seed composition, it is a potential source of oil and possible for industrial uses (Ikwuagwu, *et al.*, 2000). Concerning the commercial possibilities of rubber seed, Jamieson (1930) reported that the oil possesses less drying power than linseed oil and that the press cake is a useful cattle food, although care is required in its use for animals. When rubber seed oil was substituted for linseed in this binder the strength of the baked core was inferior by about one pound.

Biodiesel is metyl or ethyl ester of fatty acid made from vegetables oils (both edible and non-edible) and animal fat. The main non-edible oil resources for biodiesel production are *Jatropha curcas* (Ratanjyot), *Pongamia pinnata* (Karanji), *Calophyllum inophyllum* (Nagchampa) and *Hevea brasiliensis* (Rubber) (Chauchan, *et al.*, 2009).

Advantages of biodiesel:

1. Biodiesel
2. Biodiesel degrades four times faster than diesel
3. Pure biodoesel degrades 85-88% in water
4. Blending of biodiesel with diesel fuel increases engine efficiency.
5. The higher flash point makes the storage safer.
6. Biodiesel is an oxygenated fuel, thus implying that its oxygen content plays a role in making fatty compounds suitable as diesel fuel by "cleaner " burning.
7. Provides a domestic, renewable energy supply.
8. Biodiesel can be used directly in compression ignition engine with no substantial modifications of the engine.

Disadvantages of biodiesel:

1. Slight decrease in fuel economy on energy basics (about 10% for pure biodiesel).
2. Density is more than diesel fuel in cold weather, but may need to use blends in sub-freezing conditions.
3. More expensive due to less production of vegetable oil.

(Murugesan, 2009)

The important properties of biodiesel such as specific gravity, flash point, cloud point and pour point are shown in table 2.5.

Table 2.5. Biodiesel standard

Property	ASTM Method	Limit
Flash point (°C)	D93	130 min
Water & Sediment (vol%)	D2709	0.050 max
Kinematic Viscosity, 40°C (min2/s)	D445	1.9-6.0
Sulfated ash (% mass)	D874	0.020 max
Sulfur	D5453	-
S 15 grade (ppm)	-	15 max
S 500 grade	-	500 max
Cetane	D613	47 min
Cloud point (°C)	D2500	report
Acid number (mg KOH/g)	D664	0.50 max

Source: Murugesan, (2009)

Aigbodion and Pillai (2000) reported that rubber seed oil and its derivatives have been investigated for use in surface coatings. Rubber seed oil is naturally semi-drying oil, while heating 300 °C for 6 h confers reasonable drying ability on it.

Ramadhas, *et al.*, (2005a) reported that unrefined rubber seed oil as a viable alternative to the diesel fuel. Comparison rubber seed oil properties with diesel shown in table 2.6.

Table 2.6. Properties of rubber seed oil in comparison with diesel oil

Property	Rubber seed oil	Diesel
Specific gravity	0.91	0.835
Viscosity (mm^2/s)	76.4	7.50
Flash point (°C)	198	50
Caloric value (kJ/kg)	37,500	42,250
Saponification value	206	-
Iodine value	135.3	38.3
Acid value	53.0	0.062

Source: Ramadhas, *et al.* (2005b).

2.4. Processing of rubber seed into oil and meal

Generally rubber seed oil and meal are produced by mechanical processes (Aigbodion and Bakare, 2005; Iyayi *et al.*, 2008) and is not extracted, and usually contains 5 to 10% of tiny shell particles. These could damage the epithelial cells in digestive tract of swine. Fortunately, the chicken has a gizzard to grind and help to digest hard objects.

Solvent extraction and mechanical pressing are the leading methods for commercial oil extraction. Mechanical pressing is allowed by the organic food industry;

however, solvent extraction with petroleum distillates, such as hexane, is not allowed. Mechanical screw presses typically recover 86 – 92 % of the oil from oil seeds.

2.4.1. Screw press

2.4.1.1. Pressing principle

The operation principle of a screw press is rather simple to visualize although very difficult to model judging from attempts by Shirato, *et al.* (1971) and Vadke, *et al.* (1988). Therefore most improvements made to intuition rather than on the basis of physical principles (Vadke and Sosulski, 1988; Singh and Bargale, 2000). During the pressing process oil seeds are fed in a hopper and then transported and crushed by a rotating screw in the direction of restriction (sometimes referred to as die or nozzle). As the feeding section of a screw press is loosely filled with seed material the first step of the compression process consists of rolling, breaking and the displacement and removal of air from intermaterial voids. As soon as the voids diminish the seeds start to resist the applied force through mutual contact (Faborode and Favier, 1996). The continuous transport of material causes the oil to be expressed from the seeds.

There are two pressing forces; induced by the screw and friction between material and barrel. Material conveyance through the press is a result of the friction forces between material, screw and barrel. If the two friction forces are larger than the sum of other friction and pressure forces the material will be properly transported. When the friction between screw and seed material increase beyond the friction between material and barrel will occur and transport will reduce or even stop.

The oil is situated at different locations inside the cell, together with other constituents like proteins, globoids and nucleus. All these elements are contained within cell walls, which need to be ruptured to free the oil. A combined force of friction and pressure in the barrel causes the cell walls to rapture and oil to flow out of the liquid solid mixture inside the barrel. The separated oil is discharged through holes provided along the press barrel the compressed solid material or press cake is simultaneously discharged through the nozzle.

2.4.1.2. Screw press design

There are three main design of the screw press i.e. `strainer press`, `cylinder-hole press` and `twin-screw press`. They mainly differ in screw geometry, oil outlet and press cake restriction.

Strainer press. For this type the screw press rotates in a cage lined with hardened steel bars, resembling a strainer. Spacers placed between the steel bars permit oil outlet as the pressure on the feed material increases. The gaps between the bars form an adjustable oil outlet this adjustability allows the pressure to be optimized for different input materials. Figure 2.4 shows a schematic of the `strainer press`. The figure shows the increasing diameter of the screw in order to increase pressure in the direction of the choke. Instead of increasing the screw diameter cones on a constant diameter screw is a frequently applied alternative. The screw design causes the volume displacement at the feed and to be considerably larger than at the discharge end. The resulting pressure increase forces the oil through the strainer (Khan and Hanna, 1983). The cake is pressed out of the adjustable choke in the form of flat and often fractured flakes. To influence pressure, the shape and oil content of the cake; the choke gap can be adjustable. Ferchau (2000) reported that the `strainer presses` are available with capacities between 15-2000 kg/hour.

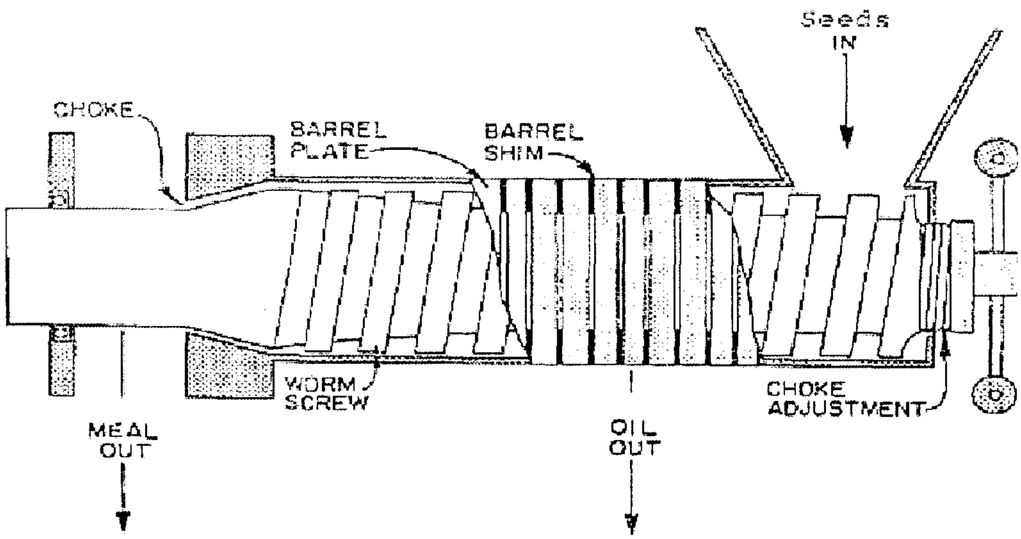

Figure 2.4. Strainer press (Ferchau, 2000)

Cylinder-hole press. The oil is pushed out through holes drilled in the cylinder tube. Increasing pressure forces the press cake through a circular nozzle at the end of the cylinder. To decrease the viscosity of the paste inside the press, press head is usually preheated before operation.

Beerens (2007) reported that the pressure level in the screw press is influenced by nozzle diameter, screw design and seed conditions. Pressure increases with decreasing nozzle size. This effect would suggest a small nozzle, in order to extract as much oil as possible.

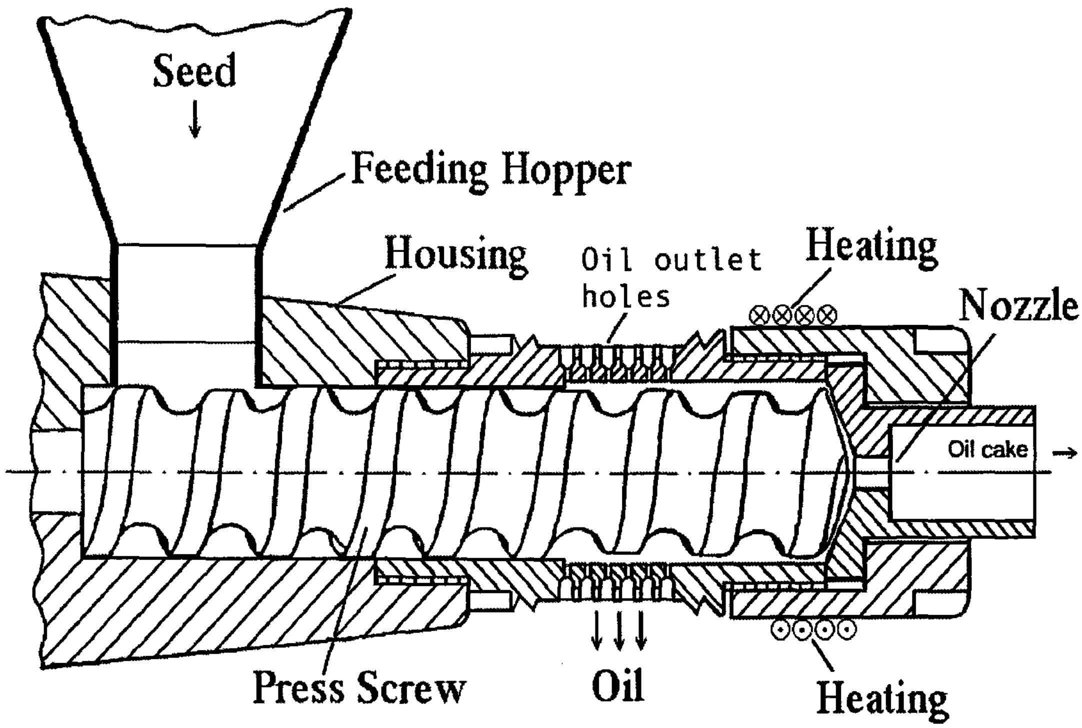

Figure 2.5. *Cylinder-hole press* (Ferchau, 2000)

Twin-screw press. A twin-screw press, one of single-screw press variation is widely used in various industries, including polymer processing, food processing, rubber compounding, and pharmaceutical development. Many researchers reported that the twin-screw press achieves very high yields on oilseeds compared to single-screw press (Amalia Kartika *et al.*, 2005; Ph.Evon, *et al.*, 2009)

The two press screws have tapered shafts and the screw pitch varies so that the picth, and thus the flight distance, is greatest at the thin end of the shafts (figure 2.6). The screws rotate in opposite senses. The material is fed in at the end where the shafts are thinner, and is carried towards the end where they are thicker. As can be seen the space for the material gradually reduces and, to compensate, liquid is passed out through the strainer plates surrounding the screws.

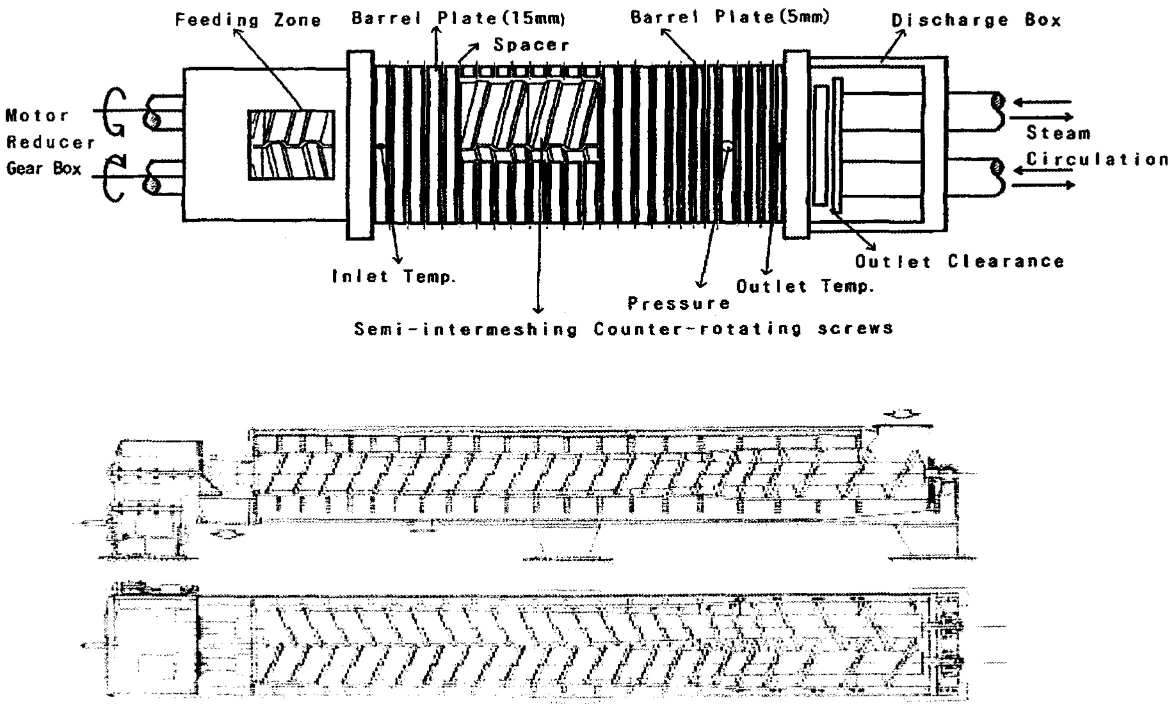

Figure 2.6. a. *Twin-screw press;* b. Cut view of *Twin-screw press*
Source: Ferchau, (2000)