

ENERGY VALUE OF RUBBER PLANTATION RESIDUES

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ABSTRACT

Fallen leaves and branches from a rubber plantation were collected during the fall season (March-April) in order to study the energy potential of the rubber plantation residues. Rubber trees produced 1420 kg/ha and 98 kg/ha of dry leaves and fallen branches, respectively. Energy from the rubber plantation residues is about 5.8283×10^{10} MJ/year which is equivalent to 4.7% of total 1990 energy consumption of the country. The amount obtained showed that rubber plantation residues rank fifth in terms of both quantity and energy value compared with other major agricultural residues in Thailand. The bulky leaves can be transformed into a manageable form by carbonizing followed by briquetting.

1. INTRODUCTION

Thailand, with the rubber plantation area of 1717.56×10^3 hectares⁽¹⁾, is one of the major rubber producing countries. It is well known among rubber tree growers that during the fall season the rubber trees generate a great deal of dry leaves. The dry leaves are harmful since they can cause fire and therefore damage the trees.

Residues from rubber plantation have never drawn attention before, although they could be a source of energy. It is anticipated that residues from rubber plantation are energy-intensive wastes because, unlike other kinds of leaves, rubber leaves contain dry latex which is a good combustible ingredient. High heating value can be expected then. There is a need to carry

out a preliminary study to perceive the energy value of these residues. This paper reports the energy value of the residues from a rubber plantation. It also proposes a possible method that transforms the bulky residues into a manageable form.

2. MATERIALS AND METHODS

The rubber plantation in the Rubber Research Center, Hatyai, Southern Thailand was selected as the study site. The rubber trees were planted in rows of 7 m apart and the distance between the trees (in the same row) is 3.5 m. Three sampling sites with area of $7 \times 14 \text{ m}^2$ were cleared before the start of the fall season. Each sampling area covered eight trees along the perimeter and one tree in the middle. The rubber trees were

about 20 years old of RRIM 600 variety, the most popular variety planted in Thailand. Rubber trees can be tapped after 6-7 years of planting and their economic life time is 25-30 years.

Falling residues in the sampling areas were collected every week. The types and amount of the residues were recorded. Heating values of the gatherings were determined by an adiabatic bomb calorimeter with the cooperation of the Department of Science Service, Ministry of Science, Technology and Environment. At the end of the residue collection programme, top soil samples both within and outside the sampling areas were collected. A comparative study on the effects of residue collection on the soil moisture was carried out.

Dry leaves were carbonized by indirect firing method. The leaves were filled in a steel cylinder of 2.5 in diameter and 8 in long. Two circular plates tightly closed both ends by means of a pass-through bolt and nut. A small hole was drilled in the middle of the cylinder for the insertion of a thermocouple wire and served as a vent for the volatile matter to escape. Carbonized leaves were achieved by placing the stuffed cylinder in a fire place.

One hundred gram of dry leaves was densified by a hydraulic press under pressure of 345-1,335 bars. Cylindrical dies used had diameters of 89 and 57 mm. The strength of the compacted leaves was evaluated by drop tests at 1 meter height. Compaction of carbonized leaves

was performed under pressure of 380 bars having 10% (by weight) of casava starch as a binding agent. The densified mass was heated for 2 minutes in a microwave oven and subsequently oven dried at 45°C to determine moisture content.

3. RESULTS AND DISCUSSION

3.1 Quantity of the residues

The falling rate of the residues is shown in Table 1. The average weight of 50 dry leaves was 0.196 g. The average length and width of rubber leaves were 8.19 and 4.17 cm, respectively. The amount of residues per sampling area was found to be 14.883 kg consisting of 13.92 kg of leaves and 0.962 kg of branches. The average bulk density of the dry leaves is 22.8 kg/m³ which is, perhaps, the bulkiest residue compared with other agricultural residues ever reported in Thailand⁽²⁾. The total per-ha residues was calculated as 1518 kg of which 1420 kg (93.5%) were dry leaves. Taking the plantation area of the whole country as 1717.56x10³ ha⁽¹⁾, the amount of 2,439,000 tons of dry rubber leaves a year can be expected. This figure ranks fifth in term of quantity in all major agricultural residues in Thailand (after paddy straw 33,151,359 tons, bagasse 9,168,728 tons, paddy husk 5,037,800 tons and cassava stalk 4,106,368 tons⁽²⁾). It must be noted that this could be an over estimated figure since not every trees are as mature as the trees in this investigation. However, as the rubber growing area is increasing, the relative ranking with other kinds of residues should still be valid.

This work did not present data for the

amount of rubber seeds since the rubber trees did not produce seed during the period of investigation. However, the amount of seeds can be derived from other published papers^(3,4) that about 132.2×10^3 tons per year of seeds are presently

scattering all over the planted area in the country.

3.2 Energy from rubber plantation residues

The samples of the fallen leaves and branches were analysed for the composition, elements and heating value. Table 2 gives the

Table 1
Falling Rate of the Residues (g/wk)

Week	Sampling area*			Average accumulative residues (g/site)
	1	2	3	
1**	781	929	868	859
2	963	574	2,095	2,070
3	963(251)#	1,492 (150)	1,591 (364)	3,410 (255)
4	5,819(604)	5,554(508)	5,378(653)	8,993(843)
5@	4,951(98)	6,177(153)	3,656(106)	13,921(962)
Total	13,450 (953)	14,726(811)	13,588(1,122)	13,921(962)

* Each sampling area is 98 m²

** Starting March 1, 1991

Figures in parentheses are weight of branches

@ After week 5 no residue was found on the sampling areas; buds, new leaves and only few yellow leaves were seen on the trees

Table 2
Analysed Data of the Rubber Plantation Residues

Components	Leaves	Branches
Proximate analysis		
Moisture (%)	6.7	8.8
Ash (%)	6.2	4.1
Volatile matter (%)	75.2	70.2
Fixed Carbon (%)	11.9	16.9
Ultimate analysis		
Carbon (%)	50.8	44.5
Hydrogen(%)	7.7	6.5
Oxygen (%)	33.9	44.2
Nitrogen (%)	1.1	0.58
Sulphur(%)	0.28	0.15
High heating value (kcal/kg)	5,103	4,287

proximate and ultimate analyses of the residues. The ash content is in the same range with other major agricultural residues⁽²⁾ (except for rice straw and rice husk which have significantly higher ash content) but the fixed carbon is lesser. It is interesting to note that the heating value of the rubber leaves is the highest among other agricultural residues ever studied in Thailand. This might be the result of the presence of dry latex in

the leaves. Comparison of the two types of residues revealed that the leaves have higher percentage of carbon, ash and heating value, but lesser in fixed carbon.

As the amount of rubber plantation residues and their energy values were obtained, the total energy from the residues can be estimated as appeared in Table 3.

Table 3
Energy of Ruber Plantation Residues

Total planted area is 1717.56×10^3 ha

Leaves 1420.6 kg/ha, branches 98.1 kg/ha, seeds 77.0 kg/ha

Type of residues	Quantity (x10 ⁶ kg)	Energy Value	
		kcal/kg	Total (x10 ¹⁰ MJ)
Leaves	2432.11	5,103	5.1929
Branches	167.99	4,287	0.3132
Seeds	132.2	5,825 [@]	0.3222
Total			5.8283

@ from ref 5.

The total amount of 5.828×10^{10} MJ is equivalent to $1,364.9 \times 10^3$ toe. In 1990, Thailand's energy consumption has been quoted at $28,934 \times 10^3$ toe⁽⁶⁾. Thus energy of the rubber plantation residues is equivalent to 4.7% of the energy consumption of the country. Availability of energy from this type of residue is, however, questionable. Average weight of fallen leaves

was 0.142 kg/m^2 or, in term of energy, was only $3,030 \text{ kJ/m}^2$. Harvesting of the bulky and scattering leaves needs energy, hence the net energy obtained will be even less. The energy of the rubber plantation residues ranks fifth in comparison to some major agricultural residues in Thailand (Table 4).

Table 4
Comparison of Energy from Some Major Residues in Thailand

Residues	Quantity (x10 ⁶ kg)	Energy Value		
		kcal/kg	(x10 ¹⁰ MJ)	x10 ⁶ Toe
Rice straw	33,151.4 ⁽²⁾	3,824 ⁽²⁾	53.042	12.42
Bagasse	9,168.7 ⁽²⁾	4,322 ⁽²⁾	16.580	3.88
Rice husk	5,037.8 ⁽²⁾	3,692 ⁽²⁾	7.782	1.822
Cassava stalk	4,106.4 ⁽²⁾	4,188 ⁽²⁾	7.195	1.685
Rubber residues	(see Table 3)	(see Table 3)	5.828	1.365
Corn cob	1,176.3 ⁽²⁾	4,232 ⁽²⁾	2.083	0.488

At the end of the residue collection programme, the sampling areas were left for the first rain to wet the soil. Soil samples of 1-3 cm depth from the surface were collected on the fourth and fifth day after the rain to determine the moisture contents. There was a heavy rain again on the sixth day and nearly every day thereafter which disabled the continuity of the moisture investigation programme.

On the fourth day after the rain the average moisture contents of the soil were 1.40% and 4.15%(db) for the bare and the covered areas, respectively. The corresponding figures for the fifth day were 0.76% and 2.53%.

Moisture in the bare area decreased drastically because the sun shone directly on the area while outside the sampling area was covered by about 2-3 layers of leaves (calculated from the size and area density of the leaves). Four to five

days after the rain the average moisture content in the soil in the covered area was nearly three times of that in the bare area. It was envisaged that the less moisture content in the soil will deter decomposition of the residues and should have effects on the soil fertility. The issue of soil fertility and the recycling of residues is not well understood. There is little nutritional value in the direct restoration of undecomposed residues to the soil. However, they may play a part in maintaining the quality of the soil by keeping up its organic content⁽⁸⁾. There is likely to be very little local knowledge about what impact will have on the soil if a sudden change in residue recycling patterns occurs. In principle, monitoring of the yield after the change should indicate whether any adverse effects have resulted. In practice, such monitoring would be complex and expensive whilst changes could easily be hidden in the normal fluctuation of agriculture.

3.3 Carbonization of rubber leaves

The densified leaves is not a desirable end product if one wants to utilize this residue. Carbonized-briquetted leaves is preferable. Charcoal is one of the major household fuels in Thailand especially in the rural. In the light of growing pressure on the reserve of forest wood in the country, briquetted-charcoal produced from agricultural residues could be a substitute to meet the charcoal demand.

The leaves cannot be carbonized in the same fashion as the wood can. Because of the

very high surface to mass ratio the leaves will be burnt down very rapidly. However, after trial tests the leaves could be successfully carbonized by an indirect firing process as described previously. It was found that the carbonization took place within 7 minutes at 307°C. Conversion rate from dry leaves to carbonized leaves was 45.75% by weight, i.e., 100 g of dry leaves weighed 45.75 g when carbonized. The characteristics of carbonized leaves and rubber wood charcoal are tabulated in Table 5.

Table 5
Characteristics of Carbonized Leaves and Rubber Wood Charcoal

Components	Carbonized leaves	Carbonized wood
Proximate analysis		
Moisture(%)	5.1	7.8
Ash (%)	13.3	2.6
Volatile matter (%)	35.9	8.1
Fixed Carbon (%)	45.7	73.7
Ultimate analysis		
Carbon (%)	55.5	75.4
Hydrogen (%)	5.0	3.6
Oxygen (%)	24.2	17.9
Nitrogen(%)	1.6	0.49
Sulphur(%)	0.42	0.04
High heating value (kcal/kg)	5,767	7,263

In general, the carbonized rubber leaves have poorer quality in all aspects compared to the rubber wood charcoal. The carbonized leaves contain lesser carbon and higher in ash and volatile matter. This resulted in lesser heating value (weight basis) for the carbonized leaves.

3.4 Leaf Densification

Biomass densification means the use of some forms of mechanical pressure to reduce the volume of vegetable matter to a solid form which is easier to handle and store than the original bulky form. Studies on the densification of agricultural residues for fuel have been attempted by many researchers, but, perhaps, none has paid attention to the dry rubber leaves.

The leaves were densified by means of hydraulic press and a cylindrical die. It was found that the leaves could be compressed to a 0.317 g/cm^3 density, fourteen times higher than the original bulk density of 0.0228 g/cm^3 . However, the leaves did not firmly hold together because they were too dry and the flat surface of the leaves was not a prone condition for holding. The compacted leaves substantially elongated within a few hours after the compaction. Nevertheless, it was noticed that the leaves at the circumferential layer were crushed and produced a good strong bond. The die surface limited the movement of the leaves and played an important part in the crush-

ing of the leaves. To crush the leaves at the top and the bottom of the cylinder, three types of end supports classified as hollow cylindrical, conical and combined conical-circular knife edge supports were used. However, the test did not give a satisfactory result. Due to a very high compression force, the leaves at the top and the bottom were sheared off by the edge of the end supports.

The 3.5 in cylinder was replaced by a 2.25 in diameter one with an expectation that the problem of lacking constraint at the top and bottom could be solved. Because of the decrease in diameter the compression pressure in this case increased to 835-1,336 bars which produced compacted leaves of 0.415 g/cm^3 density. The difficulty of compaction at the top and bottom, although was lessen, still existed. Repeated drop tests at one meter height on a concrete floor could easily disintegrate the samples. It was concluded that rubber leaves cannot be densified by a compression die unless binding agent is used.

Densification by a screw press is another attractive method. Many agricultural residues successfully densified by screw presses have been reported^(8,9,10,11). An existing screw press was used to densify the rubber leaves. It was found that the dry-fibrous nature of the leaves made it difficult to be pushed through the conical section of the press. The friction was so high that the leaves

were easily sheared off at the entrance of the conical section and the screw turned free without advancing the leaves.

The densified mass (from compression) was stored at room condition for 3 months during which the dimensions were remeasured periodically. It was found that the densified mass enlarged as the time elapsed. Within 5 days the original length of 2.25 in increased to 2.91 in while the diameter enlarged from 2.23 in to 2.38 in. After 3 months the length became 4.25 in but the diameter remained constant. These figures represented the increases by 88.8% and 6.7% for the length and the diameter, respectively. The storage time has a significant effect on the length (axis direction) only because the densification occurred in this direction and hence the direction of residual stress. It was noticed that stress relaxation not the moisture absorption was the prime factor that caused the change in dimension (i.e. no weight change). At this stage the densified mass was quite loose and ready to disintegrate.

Densification of the carbonized leaves was conducted. The brittleness of the carbonized leaves is a beneficial property for densification because they can arrange themselves to effectively fill the cylinder and be pressed in a confined boundary. However, binder is needed to keep them in shape. The usual binder is starch from any source, whichever is the cheapest. Although other binders have been used such as china clay

and molasses they did not produce as satisfactory briquettes as starch⁽¹²⁾. An experiment was performed having cassava flour as a binding agent. Ten percent (by weight) of cassava flour stirred well with water was mixed to the carbonized leaves. The damp mixture was then densified at pressure of 380 bars. After heating, which transformed starch to sticky paste, and drying the compacted mass had final density of 3.78 g/cm³. It was hard and strong enough to withstand repeated 1 meter drop tests.

4. CONCLUSIONS

Residues from rubber plantation possess tremendous amount of energy. When compared with other agricultural residues, the rubber plantation residues ranked fifth in terms of quantity and energy. The inherent energy has been estimated as 5.8283×10^{10} MJ or $1,364.9 \times 10^3$ toe. However, the availability is undoubtedly less than the estimated figure because, unlike other agricultural residues such as bagasse and rice husk which are readily available at the mills, the rubber plantation residues are scattering all over the plantation. Handling of the rubber plantation residues is very difficult. Dry leaves can not be densified by an ordinary press. However, the leaves can be converted to carbonized leaf briquettes. It is a questionable approach, at present condition, if the carbonized leaf briquettes are going to substitute charcoal in domestic use. Cost competitiveness will be a major obstacle because it requires harvesting and briquetting processes.

It must be borne in mind that the energy value of the residue presented in this report is the inherent energy in a primary form(heat). If energy from this residue is to be utilized, the overall energy of the proseses involved must be carefully examined to ensure an appreciable net energy gain. It is likely that the mechanical work must be minimized.

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