3 RESULTS AND DISCUSSION

3.1 Quantity of the Wastes

The falling rate of the wastes is shown in Table 1.

Table 1

Falling Rate of the Wastes

unit in grams

Week	D/M/Y	Area* 1	Area* 2	Area* 3	Weekly total
1	1/3/91	781	929	868	2,578
2	8/3/91	963	574	2,095	3,632
3	15/3/91	936(251)#	1,492(150)	1,591(364)	4,019(765)
4	22/3/91	5,819(604)	5,554(508)	5,378(653)	16,751(1,765)
5@	1/4/91	4,951(98)	6,177(153)	3,656(105)	14,784(356)
Total		13,450(953)	14,726(811)	13,588(1,122)	41,764(2,886)

* *Each sampling area is 98 m^2*
\# *Figures in parentheses are weight of branches*
@ *After week 5 no waste was found on the sampling areas; buds new leaves and only few yellow leaves were seen on the trees*

The average weight of a dry leaf (average of 50 leaves) is 0.196 gram. The length and the width are 8.192 and 4.172 cm, respectively. The total amount of wastes was found to be 14.883 kg/sampling area, which was classified as leaves of 13.921 kg and twigs of 0.962 kg. The average bulk density of the dry leaves is 22.8 kg/m^3 which is, perhaps, the bulkiest waste compared with other Thailand's agricultural residues reported by Bhattcharya (1990). The total per-rai (1 rai = 1600 m^2) wastes is calculated as 243.0 kg (of which 227.3 kg are dry leaves). Considering the leaves and taking the plantation area of the whole country as 10.7×10^6 rais (Sinturahat et al 1986), the amount of 2,439,000 tons of dry rubber leaves a year can be expected. This figure ranks number 4 in term of weight in all major agricultural residues in Thailand (after paddy straw 33,151,359; bagasse 9,168,728; paddy husk 5,037,800 and cassava stalk 4,106,368 (Bhattcharya 1990)).

There is no available data for the amount of seeds since the rubber trees did not produce seed during the fall season. Time scale for this project has been limited to 90 days during the fall season only. However, the amount of seeds can be derived from Arope & Subramaniam (1980) and Lim (1986) reports that about 132.2×10^6 kg of seeds are presently being produced in Thailand. Seeds are scattered all over the fields, thus collection is difficult.

3.2 Effects of Waste Collection on Soil Moisture

At the end of the waste collection programme[@], the sampling areas were left as-it-is and waited for the first rain to wet the soil. The first rain was on April 25. Top soil samples of 1-3 cm depth from the surface were collected on April 29 and 30 to determine the moisture contents. There was a heavy rain again on the 1st of May and nearly every day thereafter which disabled the continuity of the moisture investigation programme. Results

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@ By this time the team was unofficially notified that there was an uncertainty of the financial support for the project due to political situation of the country. The team, therefore, stayed idle and waited for further positive development. It was not until 16 April 1991 that the team was reconfirmed of the support.

of the moisture contents and the effects of waste collection are shown in Table 2.

Table 2

Moisture of Top Soil

D/M/Y	Moisture (%)							
	Site 1		Site 2		Site 3		Average	
	In side	Out side	In side	Out side	In side	Out side	In side	Out side
29/4/91	1.51	6.59	1.35	3.20	1.34	2.67	1.40	4.15
30/4/91*	0.90	4.50	0.72	1.75	0.67	1.34	0.76	2.53

** There was a heavy rain in the afternoon just after the collection of the sample. It rained regularly thereafter. Thus terminated the moisture investigation.*

Moisture in the bare areas decreased drastically because the sun shone directly on the sampling areas while outside the sampling areas was covered by about 2-3 layers of leaves (calculated from the size and arial density of leaves, see section 5). Four to five days after the rain the average moisture in the covered area was nearly three folds of the bare areas. It was envisaged that the less in moisture will deter decomposition of the wastes and should have effects on the soil fertility. The issue of soil fertility and the re-cycling 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 (Eriksson & Prior 1990). There is likely to be very little local knowledge about what impact a sudden change in residue recycling patterns would have on the soil. 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. However, discussion with the Rubber Research Center personnel we believed that this will have minimal effect on the mature rubber trees. Taking into account of the risk of fire, perhaps, the dry-cleared land is preferred.

3.3 Leaf Densification

3.3.1 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 material. Studies on the densification of agricultural wastes had been attempted by many organizations, e.g., TISTR. None of them paid attention to the rubber plantation wastes, although this type of wastes has great potential. Unlike other kinds of leaves, rubber leaves contain dry latex which is a good combustible ingredient. Therefore, high heating value can be expected then.

One hundred grams of as-collected leaves were filled in a 3.5 inch diameter die and compressed by a hydraulic press. The compression pressure was varied from 5,000 to 8,000 psi. Figure 1 illustrates the experiment arrangement. It was found that the

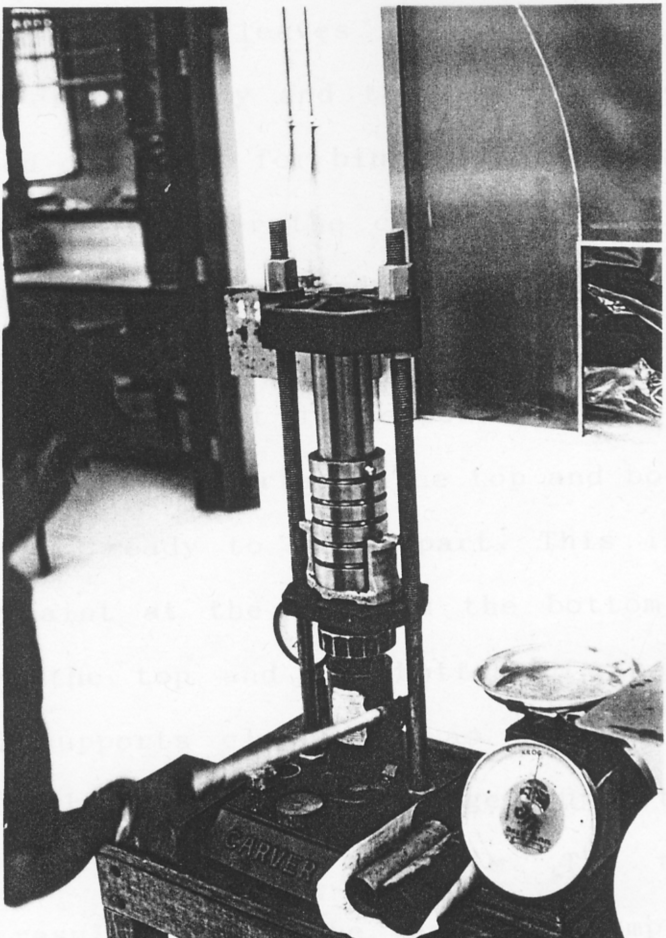
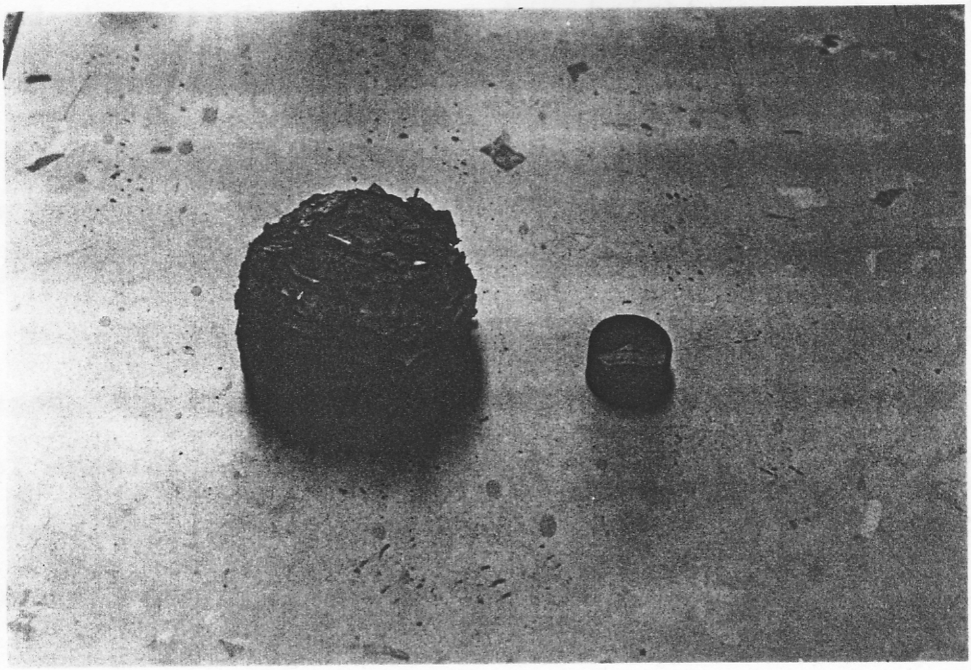


Figure 1. A densification apparatus

leaves can be compressed to have density of 0.317 gram/cm^3, fourteen times higher than the original bulk density of 0.0228 gram/cm^3. However, the leaves did not firmly bind together because they were too dry and the flat surfaces of the leaves were not a good condition for binding. Furthermore, it tended to elongate a few hours after the compaction. It was noticed that the leaves at the outer (cylindrical) surface were crushed and produced a good strong bond. It was the constraint at the die (cylindrical) surface that is responsible for the crushing of the leaves at the outer surface. The top and bottom surfaces are loose leaves and ready to fall apart. This is because of the lack of constraint at the top and the bottom. To create more constraint at the top and the bottom of the cylinder, three types of end supports classified as cylindrical, conical and combined conical-circular knife edge supports, as shown in Figure 2, were tested with the die. The tests yielded no satisfactory result. Due to the 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 inch die was replaced by a 2.25 inch diameter die with an expectation that the top and bottom problem could be solved. Because of the decrease in diameter the compression pressure in this case increased to 12,100-19,360 psi which produced compacted leaves of density 0.415 gram/cm^3. The result showed that the difficulty at the top and bottom, although was lessen because the leaves are longer than the die diameter, still existed. The densified mass was not as strong as was expected.



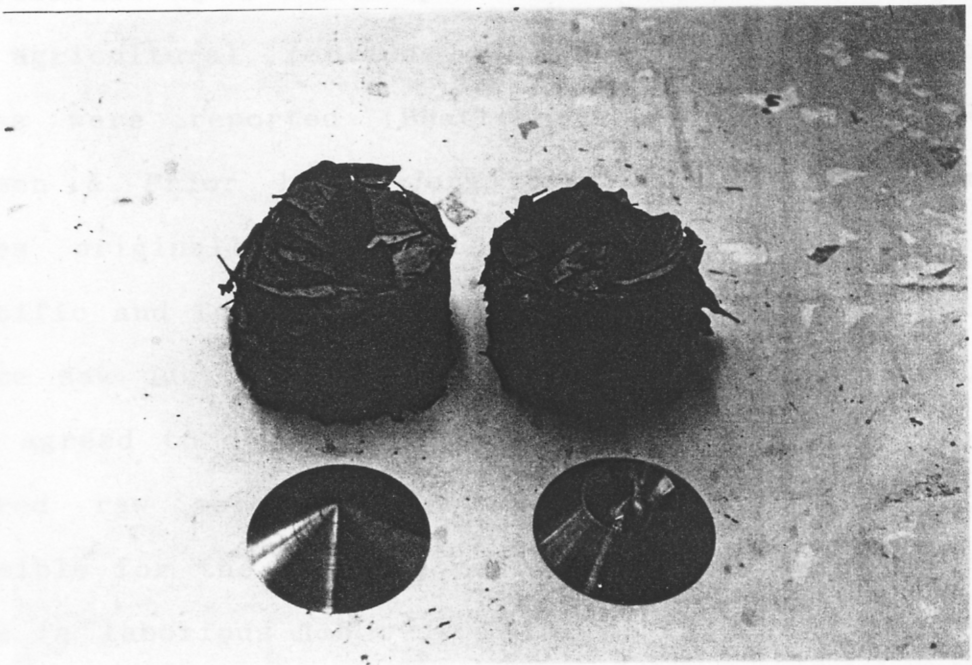


Figure 2. Different types of densification end supports

Repeated drop tests at one meter height on a concrete floor could easily disintegrate the samples.

It was concluded that rubber leaf densification by compression die is difficult and unlikely to success unless binding agent is used. Densification with binder was not tried because it was envisaged that there was other form of fuel obtained from the leaves; densified carbonized leaves. The carbonized leaves could be successfully densified with the aid of binder as described in section 7.

Densification by a screw press is an attractive alternative. Many agricultural residues successfully densified by screw presses were reported (Bhattcharya et al 1987, ERD 1984, Eriksson & Prior 1990, Jongjitirat 1983). There are screw presses originally designed by the Thailand Institute of Scientific and Technological Research used by some factories to produce saw dust and rice husk briquettes. After consultation, TISTR agreed to densify the rubber leaves for the project but required raw material at least 200 kilograms. It seemed impossible for the research team to acquire such amount of the leaves (a laborious job over 1 rai of land) and transport them to Bangkok (200 kgs of as-collected leaves will has volume of 8.8 m^3). It was then decided to design and build a screw press in the Department of Mechanical Engineering, Figure 3. Trial tests on the screw press were not successful. The dry-fibrous nature of the leaves made it was difficult to be pressed through the conical section of the screw press. The friction was so high that the leaves were easily sheared off at the entrance of the

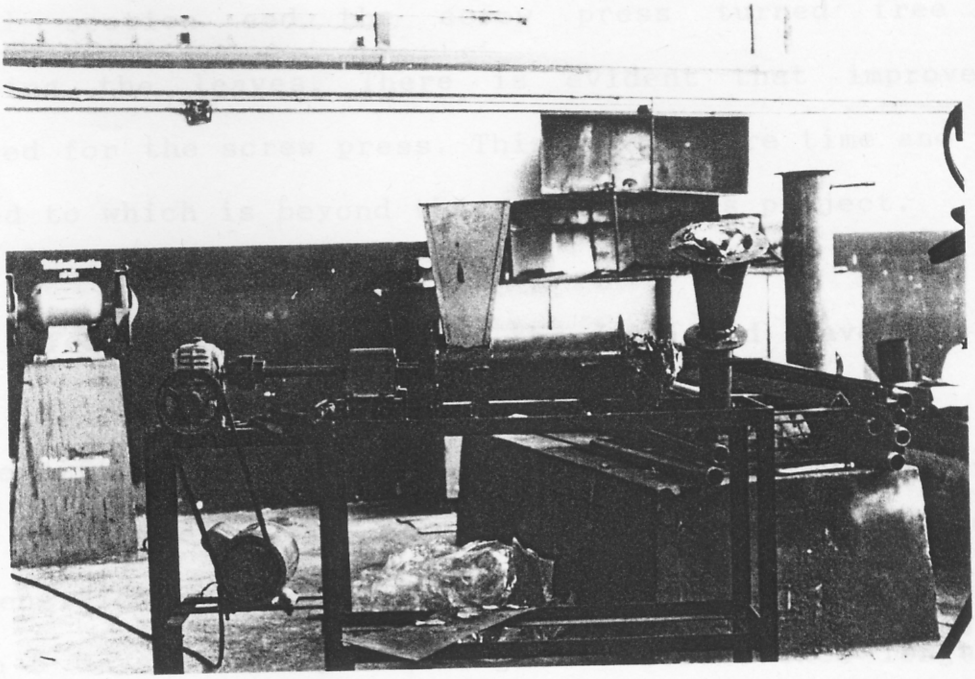


Figure 3. A screw press

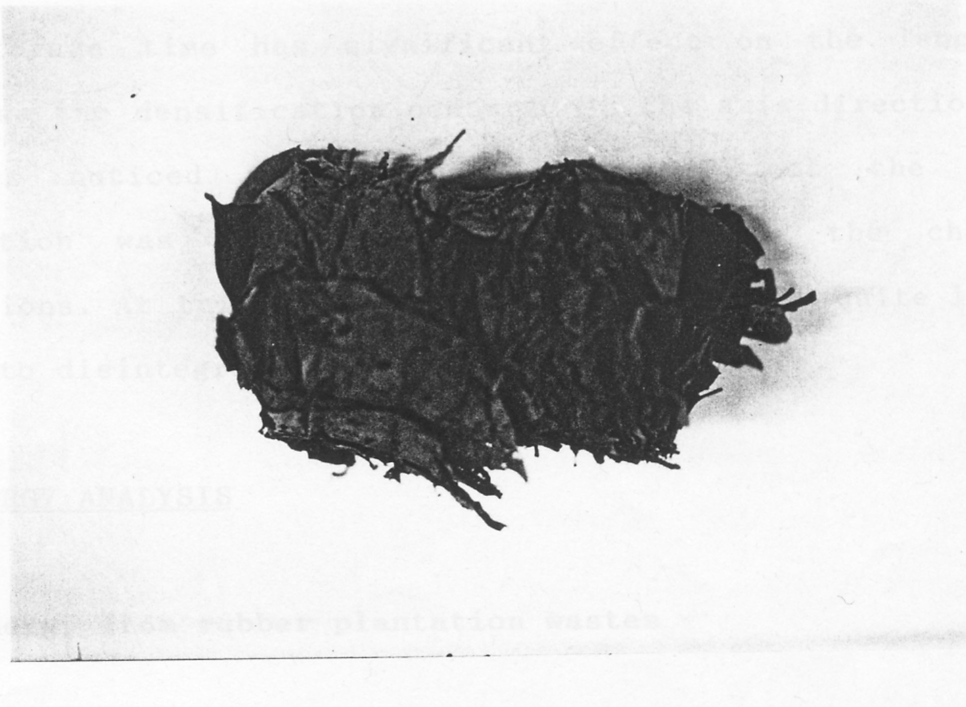


Figure 4. Densified leaves after 3 months

conical section and the screw press turned free without advancing the leaves. There is evident that improvement is required for the screw press. This needed more time and resource devoted to which is beyond the scope of this project.

3.3.2 Effect of storage time on the densified leaves

The densified mass was stored at room condition for 3 months after which the dimensions were remeasured. It was found that the densified mass enlarged as the time passed by, Figure 4. Within 5 days the original length of 2.25 inches lengthened to 2.91 inch while the diameter enlarged from 2.23 to 2.38 inches. After 3 months the total length was 4.25 inches but the diameter remained constant. These figures represented an increase by 88.8% and 6.7% for the length and the diameter, respectively. The storage time has significant effect on the length only (because the densification occurred in the axis direction only). It was noticed that stress relaxation not the moisture absorption was the prime factor to cause the change in dimensions. At this stage the densified mass was quite loose and ready to disintegrate with a small applied force.