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FINAL REPORT
OF PROJECT RG/AID/05

ON PROMOTING JATROPHA CURCAS OIL
AS A SUBSTITUTE FOR DIESEL
IN SRI LANKA

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ABSTRACT

Attempts to use alternative to fossil fuels in internal combustion engines have been many and varied. The substitution of diesel in a diesel engine by a vegetable oil has been attempted in Sri Lanka too. The oil chosen for the present experiment is extracted from the seed of Jatropha Curcas plant. This plant is of the Euphorbacea family and is planted as a fence post. It is considerd to be draught resistant and easily cultivable. Being a non-edible oil it does not complete in the food market.

The attempts to extract the oil mechanically and by chemical methods are reported here. The two successful methods are described. The subsequent usage of oil in a single cylinder diesel engine is reported. Most of the problems associated with the use of Jatropha curcas oil have been overcome and the engine was able to generate power to drive an electric generator. However the economic benefit of the oil is not very attractive for its widespred usage as these seeds are not found in abundance.

1.0 INTRODUCTION

1.1 Background

The use of vegetable oil as an alternative fuel in the compression ignition engine invented by Dr. Rudolph Diesel date as far back as 1900. During the Paris Exposition of 1900, one of the engines on display was fueled with peanut oil (Grinaker, 1989). From then on up to the early 1950's numerous studies were made to evaluate plant oils as fuels, substituting either completely or partially for diesel (Wiebe and Nowakowska, 1949). Parameters evaluated most frequently then were power output and thermal efficiencies relative to diesel. In most investigations, problems with carbon deposits, corrosion and wear were reported. However, no general trends regarding the suitability of vegetable oils as alternative diesel fuels emerged from those studies.

In Sri Lanka too, early studies on the use of coconut oil in a Tangye diesel engines have been reported from University of Peradeniya. Subsequent attempts of using rubber seed oil have been reported by the Lever Brothers (Ceylon) Ltd. (1968-1973)

With the oil embargo in the 1970's, interest in plant oils as alternative diesel fuels re-emerged. Since many problems associated with the use of plant oils were already known, recent studies have been aimed at methods to overcome problems of processing vegetable oils to suit diesel engines or vice-versa, ie; alteration of engine operating conditions to accommodate plant oils. Many recent studies have also been made to determine performance characteristics of vegetable fuels in modern types of diesel engines (Peterson et.al., 1983; Bruwer et.al., 1980; Engler et.al., 1983; Strayer et.al., 1983).

Major problems in using unmodified plant oils as alternatives to diesel fuels have been summarized as follows: (Lipinsky et.al., 1982)

1) Clogging of fuel lines and filters with gums and waxes;
2) Oil ring sticking;
3) Poor ignition and combustion characteristics caused by improper atomization;
4) Carbon Deposits;
5) Polymerization of fuel into the crankcase which causes thickening and/or increased solids contamination of the lubricating oil.

These problems in general are caused by the higher viscosity of plant oils, the presence of unsaturated fatty acids in such oils, and the low volatility. These problems can be minimized by heating the oil, esterification, forming a micro-emulsion or by blending with diesel fuel.

Plant oils considered for substitute diesel fuels, particularly in the U.S., are from plants such as Sunflower, Castor, Soybean, Peanut etc. which also competes as sources of food or other beneficial uses to mankind. The oil from Jatropha curcas, which is the subject of this feasibility study is not so, as it is not a source of food.

Sunflower, Soybean and other vegetable oils have ignition qualities suitable for compression ignition in diesel engines. However, the viscosity of vegetable oils is too high for adequate spray atomization in a direct-injection diesel engine.

Blending of vegetable oil with diesel fuel to obtain a hybrid fuel with suitable viscosity is a feasible alternative. Use of a 25/75 blend of Sunflower oil in diesel fuel in a 200 hour screening procedure indicated that long-term use of such a mixture would not be feasible in a direct-injection engine (Ziejewski and Kaufmann). However, with a different type of direct-injection engine, the same test procedure indicated that a 33/67 but not a 50/50 blend of soybean oil in diesel might be tolerated for emergency use (Adams et.al.).

Although vegetable oils such as Sunflower, Soybean etc. can be tolerated in direct-engines only as dilute blends in diesel oil, there exists evidence that simple esters of such oils perform better. They display improved viscosity and volatility properties in comparison to the blends. In short term tests with a single-cylinder, direct-injection engine (Klopfenstein and Walker). Most of the ester fuels tested had higher efficiencies than did No.2 diesel fuel.

Micro-emulsions of vegetable oils is yet another alternative where extensive research has been carried out, with the objective of lowering the viscosity to attain improved engine performance. In a Soybean oil-methanol micro-emulsion and in comparison with No.2 diesel fuel, the micro-emulsion produced only slightly heavier carbon deposits on the exhaust values (C.E. Goering, 1984). However, it was reported that above micro-emulsion produced varnish deposits in the needles inside three of the four injectors and that the deposits were causing sluggish needle movement at the end of a 200 hour test.

A more economical and indigenous method of converting raw vegetable oils for use in engines is by purification. Simple purification by washing with alkali solutions to nullify acidity and by processes to reduce tar-content, vegetable oils may be adapted for use as alternate fuels.

Plant oils generally considered for substitute diesel fuels are composed primarily of triglycerides which are branched molecules having approximately three times the weight of typical diesel fuel components (Engler, Lepori et.al., 1983). Oils produced in the U.S. belong to the following two groups:

1. Oleic - linoleic acid oils (Cotton seed, sunflower & peanut)
2. Linolenic - acid oils (Soybean)

Plant oils not currently produced extensively in the U.S. (eg: Coconut, Palm, Castor, Rubber and Jatropha) could be important alternative diesel fuels in tropical countries.

In the selection of Jatropha for a feasibility study as an alternative fuel for diesel, many positive factors were taken into consideration. Factors such as its high calorific value (equivalent to that of diesel), easy adaptability of the plant to arid conditions, abundant availability were some such that favoured the promotion of Jatropha oil.

Jatropha Curcas is more commonly known as 'Rata Endaru' in Sri-Lanka; 'Sabu Dam' in Thailand; 'Jarak Budeg' in Indonesia; 'Thinbankyeksu' in Burma; 'Tuba' in the Philippines and as 'Nepalam' in India. Takeda (1982).

It is a shrub or a small tree which can grow up to 7 m high and has thick branches. However, an arid environment it does not exceed 2 m in height. It grows wild in many tropical regions and does not need any external agricultural inputs whatsoever. It can be grown on arid, stony land and is very adaptable as regards soils. In suburban Sri-Lankan villages, it is commonly used for fencing since it provides a very economical, trouble free alternative to other forms of fencing.

In early Sri-Lanka the oil from Jatropha seed was used for candle-fabrication, lamp-lighting, soap making and the like in view of its cheap availability. The latex from its damaged branches was also used in small quantities as a purgative. However at present, most of these practices are less evident and the major use of the tree now is for fencing.

Most of the species are adapted to sandy loam soil. They grow readily from seeds and cuttings from hard young branches can be rooted in sand with little assistance. Propagation by cuttings of between 50-100 cm. is more rapid than by seeds and such cuttings can grow up to over 2 meters and bear nuts within one year. It is evident that propagation of Jatropha is therefore very simple and economically easily within reach of all farmers in Sri Lanka.

Jatropha Curcas bushes begin to yield oil when they are about 04-05 months old. They have a lifetime of upto 40 years and the seeds, even when dry remain on the bush for a long time. Each fruit contains 02 or 03 ellipsoidal seeds covering a softer

kernel. The seed is generally 20 mm. long, 10 mm. wide and 09 mm. thick. The average yield for a five year old tree is 3-4 kg.

Oil extracted from Jatropha has a calorific value of 9,400 kCal/kg, as compared to 10,100 kCal/kg for diesel and 10,600 kCal/kg for petrol. The oil has a substance called Curcasine which is very purgative in small doses and toxic in large doses. The meal remaining after extraction of oil is therefore too toxic to be used as animal-feed, but has uses as fertilizer.

1.2 Objectives of the Study

The objective of this project is to determine the feasibility of using Jatropha oil as a substitute for diesel fuel. In determining the feasibility for such an analyses, the prime questions that have to be researched are :

1. Are seeds easily available and if not what is the feasibility of mass cultivation ?
2. What methods can be easily adapted in Sri-Lanka to extract oil from such seeds ?
3. Can Jatropha oil be used, either as crude or in some other form, to power diesel machinery ?
4. If so, is it economically viable ?
5. Has Jatropha oil got any intrinsically adverse properties which would restrict its use as an alternate fuel ?
6. Finally, possibly all important, can the potential of Jatropha oil be exploited indigenously in Sri-Lanka ?

2. STUDY OF RESOURCES OF JATROPHA SEED

2.1 Local Availability of Jatropha Seed

This research initially focused on the case of collection of a sufficient quantum of seeds, enough to generate quantities of oil to justify its use as an alternate fuel. Failing which, it was planned to carry out an agronomic study to evaluate its potential for mass cultivation.

It was estimated that around 01 tonne of seed would be required for preliminary experimentation. With that quantum as a goal, extensive investigations were carried out in arid and semi-arid zones of Sri-Lanka. It was established that the most efficient mode of collection was the establishment of selected agents. Accordingly agents were appointed in Nikeweratiya, Maho and Kekirawa of the North Central Province of Sri-Lanka in order to establish a network for collection of Jatropha seeds.

The first trips for collection of seeds was made to the Polonnaruwa and Kurunegala districts during April 1985, and just beginning to flower then. By late June, it was reported that the seeds were just beginning to mature, turning a ripe yellow in colour. At a subsequent visit made in early July 1985, a quantum of 1.24 tonnes of Jatropha seed were purchased from cultivators and agents, at the rate of Rs.3/50 per kg. Eventually a quantum of seeds weighingover 2.5 tonnes were collected using such methods.

Having established that collection of seeds from Jatropha plants grown for fencing was feasible,it was decided to explore the feasibility of mass-cultivation of Jatropha. Since an extensive Agronomy Study was being conducted by Dr. Y. Takeda at Agricultural Development Research Centre, Khon-Kaen in Thailand on Jatropha Curcas and also since research on its use as an alternate fuel was being conducted, a study tour was undertaken to Thailand.

2.2 Agronomy study of Jatopha Curcus

Though no systematic classification of varieties have been done on Jatropha, different provincial ecotypes have been collected, grown and evaluated for their performances. Studies in general have not shown any significant differences between varieties. Optional plant density for Jatropha has also been carried out with plants spaced at 50cm x 50cm, 50cm x 75cm, 100cm x 100cm and 50cm x 100cm. The closest spacing of 50cm x 50cm had yielded the most promising results. Propagation is done through seeds and stem cuttings. However studies in Tahiland have indicated that seed propagated plants were healthier. Even so, propagation by cuttings is more usually practiced since it enables more rapid propagation than by seeds. Cuttings of 45cm-100cm are usually used for planting.

There is also some work being carried out in Thailand on the evaluation of different methods of pruning & fertilizing. An experiment evaluating three types of pruning of the main stem at 1'', 1.5' and 2' had been conducted at the Thapra field crop experimental station. Based on such research, it was suggested

that heading back at one foot was idea. However, experiments with pruned plants and a control plant had also indicated that control plants performed better than the pruned plants.

In fertilizer trails, applications of NPK mixture of 15:15:15 four months after planting has been shown to be most effective. However, there is a wide concensus of opinion in that this crop responds poorly to application of fertilizers. This had been attributed to two reasons viz:

i) The poor canopy architecture which increases mutual shading of branches with increased fertilizer application, thus making the leaves less productive and;

ii) Inherently high levels of soil fertility.

Studies on pest and disease incidences have indicated that Aphid attack is the most severe pest problem under commercial cultivation. Insecticide spraying could be practiced as a general method of control.

Inspite of all above useful studies and results on commercial cultivation of Jatropha, strong evidence was found to suggest that seed yield obtainable in such forms were much lower than that obtained from natural fence stands. It was also strongly indicated that such fence stands were much less prone to pest and disease incidences.

2.3 Adaptation for mass-cultivation in Sri-Lanka

Based on the agronomical study conducted in Thailand, it is the researchers' suggestion that the following be practiced, if

mass-cultivation of Jatropha is to be planned.

i) Site for growing should be chosen in an arid zone

ii) Propagation of plants should be tried out both through seed and stem cuttings and growth and yield should then be compared.

iii) When using stem cuttings, a range from 30-125cm should be used with more emphasis on the 45-100cm range.

iv) Plant spacing should ideally be 50cm x 50cm. However, experiments with different spacing may still prove to be useful.

v) Prunning & trimming should be carried out on a major part of the cultivation with experiments on a smaller scale allowing the plants to grow freely.

vi) Some experimentation with fertilizer inputs may prove to be useful.

3. EXTRACTION OF OIL

3.1 Feasibility study of Extraction Methods

Over the centuries, four basic methods of extracting vegetable oil from various seeds have evolved. The first was the process in which oil bearing material was boiled in water, the oil was then skimmed off the top of the vessel. The second was the press, in which pressure was applied on a stationary mass of seed by using screw jacks or hydraulic cylinders, and the vegetable oil was collected in collecting rings below. The third was the mechanical worm screw press in which the worm conveyed the material through chamber and at the same time, pressure was exerted on the conveyed material. Oil extracted from the compressed seeds were run through in-built filters and collected.

The fourth and last method was solvent extraction. Whole seeds were ground and then extracted by organic solvents. Oil is separated by evaporating the solvent and the solvent is collected by condensation later.

All four of the above methods were experimented with in order to extract Jatropha oil and to establish a procedure most suitable for adaptation in Sri-Lanka. These methods researched and their findings are as reported below.

3.2 Extraction by separation through boiling

De-hulled Jatropha seed were washed, sun-dried, weighed and crushed using a grinder. The resulting pulp was then weighed, mixed with an equal part of water and boiled. When traces of water were non-evident, the liquid was skimmed and weighed. However, repeated experiments indicated that the percentage of extracted oil was not sufficient to warrant the use of heat energy required. Experiments were also conducted by boiling with raw papaya, a fruit freely available in Sri-Lanka. Raw papaya is indegenously used as a natural catalyst to soften food that needs to be boiled. This too proved to be ineffective. The maximum return of oil by weight was 14%, inspite of the large energy input necessary.

3.3 Chemical Extraction

Chemical extraction was attempted in the laboratory using a soxlate apparatus. Petroleum Ether was used as the solvent. The trails were done with

(a) whole kernals

(b) kernals in crushed form

(c) meal obtained after mechanical extraction (described later).

Again, the results of the yield recorded were not very encouraging, maximum yield obtainable was from the kernal in crushed form. The value of the maximum oil extracted was nearly 20% of the weight of the kernal after 14-18 hours. Hence this method to was not considered to be effective to warrant further experimentation.

3.4 Mechanical Extraction

The extraction of oil from the Jatropha seed was tried using a mechanical press. The press used in here basically consisted of a cylinder made of a perforated plate as shown in figure 3.1. The 150 mm diameter perforated cylinder was filled with the seed and which was pressed using a piston. In the apparatus used, the piston was kept fixed whilst the cylinder was pushed upwards using a hydraulic jack kept at a lower elevation. The frame consisted of two bars which had a screw facility at the top end. This enabled re-positioning of the piston as the extraction progressed. The oil which drained into the tray was collected below.

A batch of 2 Kg. of kernal could be accommodated in the cylinder at one go. Earlier attempts used the whole seed i.e. the kernal and the hard coat. Later it was realized that the presence of the hard coat would mean an additional force on the press. Thus, seed was de-hulled and the kernal alone was used in the press.

Typically about 5 hours were required to achieve a reasonable extraction rate. The yield figures recorded were about 550 cc in 4 hours. A slight improvement is achieved in the next hour. This amount corresponds to about a 25% recovery rate on weight basis (in 4 hours) and this represents more than 80% of the available oil. Although time consuming, this technique represented a very useful extraction procedure for the laboratory experimentation. The load on the press had to be maintained by using the jack. However, on the whole, the de-hulling operation was labour intensive as it was done manually.

3.5 Traditional Milling

The traditional mill used to extract coconut oil is still found to be available in certain areas of Sri Lanka (see figure 3.2). This "chekku" device is usually powered by animals. It consists of a approximately 100 cm high stone mortar which is firmly held in the ground by a sunken rod. Inside the mortar is a pestle made from hard wood about 150 cm long and 25 cm diameter. The pestle is held obliquely in position by a cone-like construction which enables the pestle to revolve by means of a lever. One extremity of the 5 m long lever is driven by a pair of oxen. The other extreme of the lever carries a counter weight. The motion of the pestle causes it to experience an up-and-down movement in the process of which, the material contained in the mortar gets crushed expelling the oil.

The traditional method described above was employed to extract oil from the Jatropha curcas seed. The seed containing the kernal and the hard coat was used in the process, as the

presence of the hard coat did not pose any difficulty to the pestle.

The yield figures obtained were quite favourable. A 15 kg of seed was able to produce more than 2 litres. On the average,15kg produced 2.75 litres of oil. This represented a 14% oil recovery rate (by weight). This actually works out to more than a 16% recovery rate, if only the weight of the kernal was taken into account. Although a more complete extraction rate could be achieved if more crushing was done, it was determined to be not time-economic. The quality of the oil obtained was much better than in the case of the mechanical press and was free of particles. The oil was infact ready for use in an engine even without the filteration or cleaning.

4. TESTING OF JATROPHA OIL IN ENGINES

4.1 Introduction

The basic aim of the project was to study the feasibility of using Jatropha oil as a substitute for diesel in engines. It has to be borne in mind that diesel engines available in the market are designed to utilize the available diesel derived from crude oil. Thus the design is basically meant to convert the energy contained in the diesel to a mechanical form through combustion. If we are to use a different fuel, the properties of it should match those of diesel as much as possible. On the other hand the engine can be modified to accommodate the new fuel. This may be done by changing some of the parameters like compression ratio, timing of the fuel injection, speed and pressure of the jet, location of the jet, shape of the head etc. However these

proposals involve either a major or a minor change in the design. In most of the cases, this involves an additional cost component and will not be popular in the long run. The changes of the design also prohibits the possibility of changing back to diesel. Thus it is always advisable to think of using the substitute which would not require engine modifications which cannot be reversed easily.

In the present project the concentration was on the use of an existing engine and the feasibility of using a substitute for diesel.

4.2 Experimental facility

The engine performance in terms of the power output had to monitored. This could have been done by using a brake dynamometer or a similar device. Instead, it was decided to utilize an electric generator as the load, output of which could be monitored and changed using an electrical load. Hence a diesel engine-generator set was utilized for the purpose.

A Lister generator was chosen to perform the load tests. The engine generator set was mounted on a frame. The diesel tank was removed from the assembly and mounted separately. This was done to facilitate the management of fuel consumption. A suitable measuring device was incorporated.

The electrical load used in the apparatus consisted of a bank of bulbs mounted on a panel. Switches necessary for changing the load were available.The load was measured using a wattmeter. The

speed of operation was noted down during and after attaining stable conditions.

4.3 Specifications of Test Facility

Diesel Engine

Make	Lister Petter AA1 engine
Cylinders	Single cylinder
Injection type	Direct injection
Bore x stroke	69.85mm x 57.15mm
Swept volume	219 cc
Compression ratio	17:1
Shaft Speed	3000 rev/min
Rated continuous power (BS 5514)	2.2kW/3BHP
Torque	- 8 Nm
Brake thermal efficiency	25%
Mechanical efficiency	59%

Electrical Generators

Make	Markon
Power factor	0.8
Rated output	1.6kW/2kVA
Speed	3000 rev/min
Full load excitation	59V 3.8A

Electric load

Bank of electrical bulbs

5. RESULTS AND DISCUSSION

5.1 Properties of Jatropha oil

The oil obtained by mechanical extraction using a hydraulic press was found to contain particles derived from the meal. The size of perforations of the press cylinder had to be determined to obtain effective oil extraction. Larger holes would enable easier extraction initially. However, this would result in larger particles of kernal finding the way to the oil. This resulted in a lower yield of oil too. On the other hand smaller holes would necessitate a higher load at the press. This caused the whole structure to fail at some stage resulting in screw bar failures. The filtration of oil under high pressure using a filter press was attempted. This too was found to be cumbersome and time consuming.

The oil obtained using the traditional mill (Chekku) was found to be cleaner. It was not necessary to filter the oil as there was no visible particles. Earlier attempts of using unfiltered samples of this oil in the engine were successful and hence it was decided to go ahead with the use of unfiltered oil.

The average properties of the Jatropha oil obtained are as follows. These are compared with the values obtained in Thailand and with Diesel specifications.

	Value obtained	As reported in Thailand	Diesel
Specific gravity	0.9153	0.9186	0.82-84
Flash Point °C (Open cup)	233°C	240	≥50
Calorific value kCal/kg	9,200	9,470	10,170
Kinematic viscosity cs	42.9	50.73	≥2.7
Distillation Temperature °C	295	295	≤350
Octane Value	--	51	>50

Chemical Composition

Type of acid	Value obtained	As reported in Thailand
Palmitic acid	16%	14.2%
Stearic acid	6%	6.9%
Oleic acid	45%	43.1%
Linolic acid	33%	34.0%
Other	--	1.4%

Chemical Analysis

Saponification value	189	195
iodine value	90	101.7

5.2 Engine Tests

Tests were carried out with 100% diesel, 100% Jatropha oil and different blends of diesel and Jatropha oil. These were done under different load conditions. Initially tests were carried out with 100% diesel so as to establish the experimental setup. The problmes that arose due to vibrations etc. were overcome after a few trials.

Blends of oil were made by simple mixing as the missibility of Jatropha oil and diesel was quite good. There was no problem of separation in the short term. Initially Jatropha oil was filtered before the blending. Earlier attempts to purify the Jatropha oil by washing were not repeated as the performance was not affected by the use of unwashed oil.

The trials were confined to laboratory tests with the Lister engine. The duration of each test was limited to a maximum of four hours. The engine was allowed to run for about one hour on no load to allow stable conditions to be reached before most of the experimentation was done. This eliminated the chances of the readings getting distorted.

Consumption (l/hr)

Load Watts	100% D	90:10 D oil	80:20 D oil	70:30 D oil	60:40 D oil	100% oil
100	0.50	0.44	0.43	0.50	0.47	0.45
300	0.61	0.48	0.55	0.58	0.60	0.57
500	0.69	0.63	0.60	0.65	0.60	0.72
700	0.71	0.70	0.68	0.63	0.73	0.68
900	0.80	0.82	0.73	0.73	0.76	0.70

Based on the results of the trials, it is possible to support most of the findings and views expressed in the literature. The general conclusions are as follows;

(a) There is no necessity to modify the engine to use a blend of Jatropha oil and diesel as a substitute for diesel in direct injection diesel engines

(b) The use of a blend of Jatropha oil with more than 50% diesel does not pose any problem in starting

(c) The fuel consumption is not significantly different to diesel under similar loading conditions.

(d) Knocking problem would be experienced with blends having higher proportions (75%) of Jatropha oil. The degree of knocking goes down with time (heating).

(e) The exhaust gases were found to be not so visible in the case of mostblends. The traces were reduced with the increased proportion of Jatropha oil.

5.3 Economic Analysis

Presently, the crop is not grown in any organized scale. It is found in a very dispersed manner, spread over a large area as it is only a 'fence post'. This poses a problem in harvesting and collection. The most efficient method of collection available in Sri Lanka seems to be through small-time private traders who run

establishments which collect minor agricultural crops. They in turn publicise the idea in the area. This promotes another group of people who do the actual harvesting and collection. However the price paid for the seeds during the experimentation i.e Rs.3.50 per kilogramme was eventually worked out to be rather high. The cost of one batch of seed fed at the "chekku" was Rs.52.50 without considering the transport cost. Each batch produced 2.75 litres and the cost of extraction was Rs.50.00. Thus the basic cost of litre of oil was Rs.37.25. This compares very unfavourably with the p[rice of diesel which was Rs.8.40 at the time. The economic benefit did not justify its usage even at present. However a large proportion of the cost was for the harvesting due to collection being done over a large land area. This was evident from the initial reluctance shown by the collectors. The price had to be increased substantially to create a reasonable interest. If the density of a availability was high, the price could be reduced, thereby lowering the cost of oil. This could be done only on a commercial scale plantation. Even the mill owners showed a reluctance to allow this oil to be extracted due to possible contamination of coconut oil. Here too they had to be paid more to compensate for the additional trouble undergone. Again an increased scale of operation would have reduced the cost of extraction. The mechanical extraction was not as expensive as the "chekku" method. This was due to the oil draining operation being mostly unmanned. However it was decided to use the cost of the "chekku" method as it was a commercially acceptable extraction process.

Thus the Jatropha curcas oil as at present cannot compete

with petroleum derived diesel. However the oil seems to be technically acceptable. The promotion of this oil which does not compete with the food market would be very worthwhile, if manufacturing cost can be reduced.

SCHEMATIC SKETCH OF MECHANICAL EXTRACTION PRESS

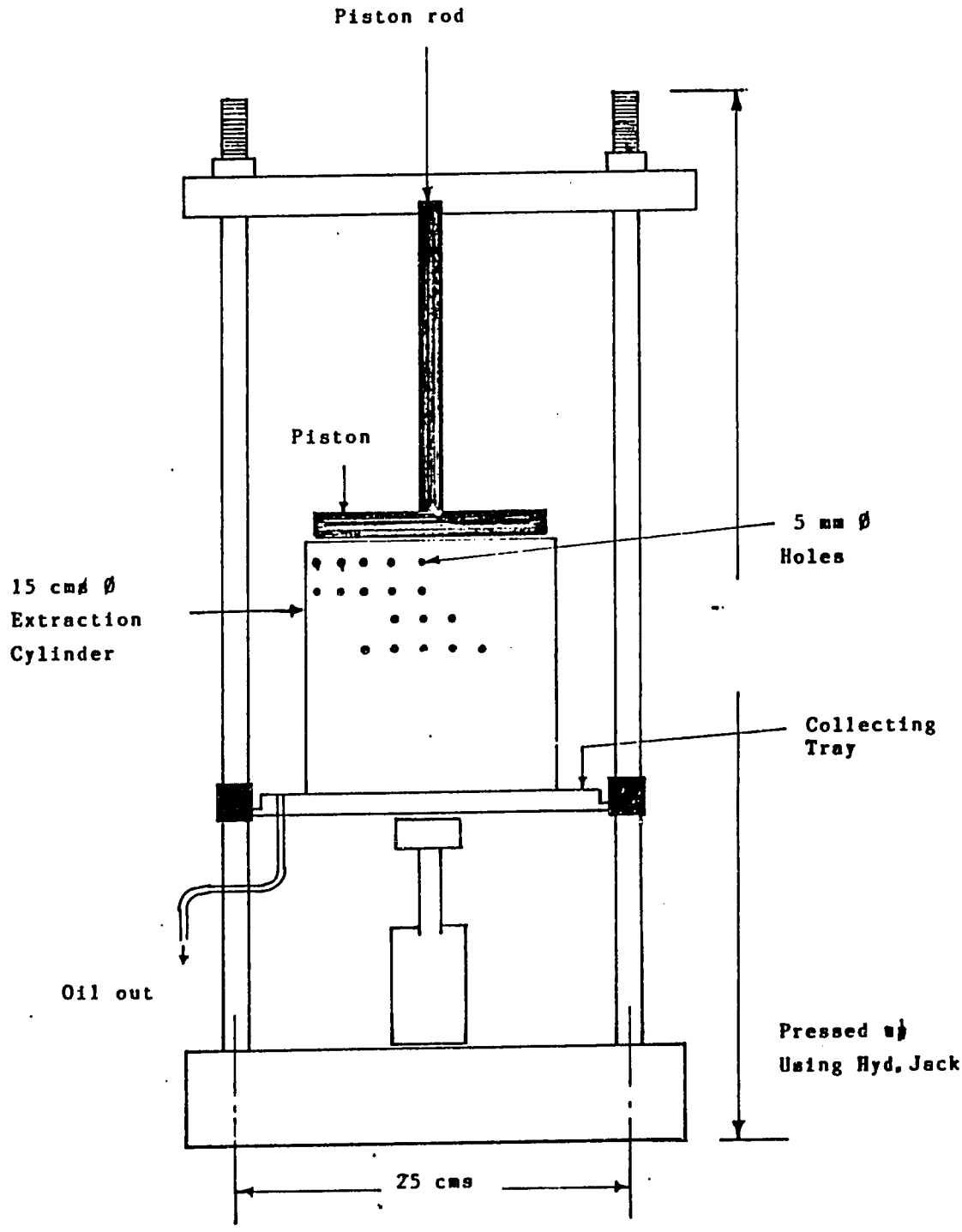

Figure 3.1 MECHANICAL PRESS

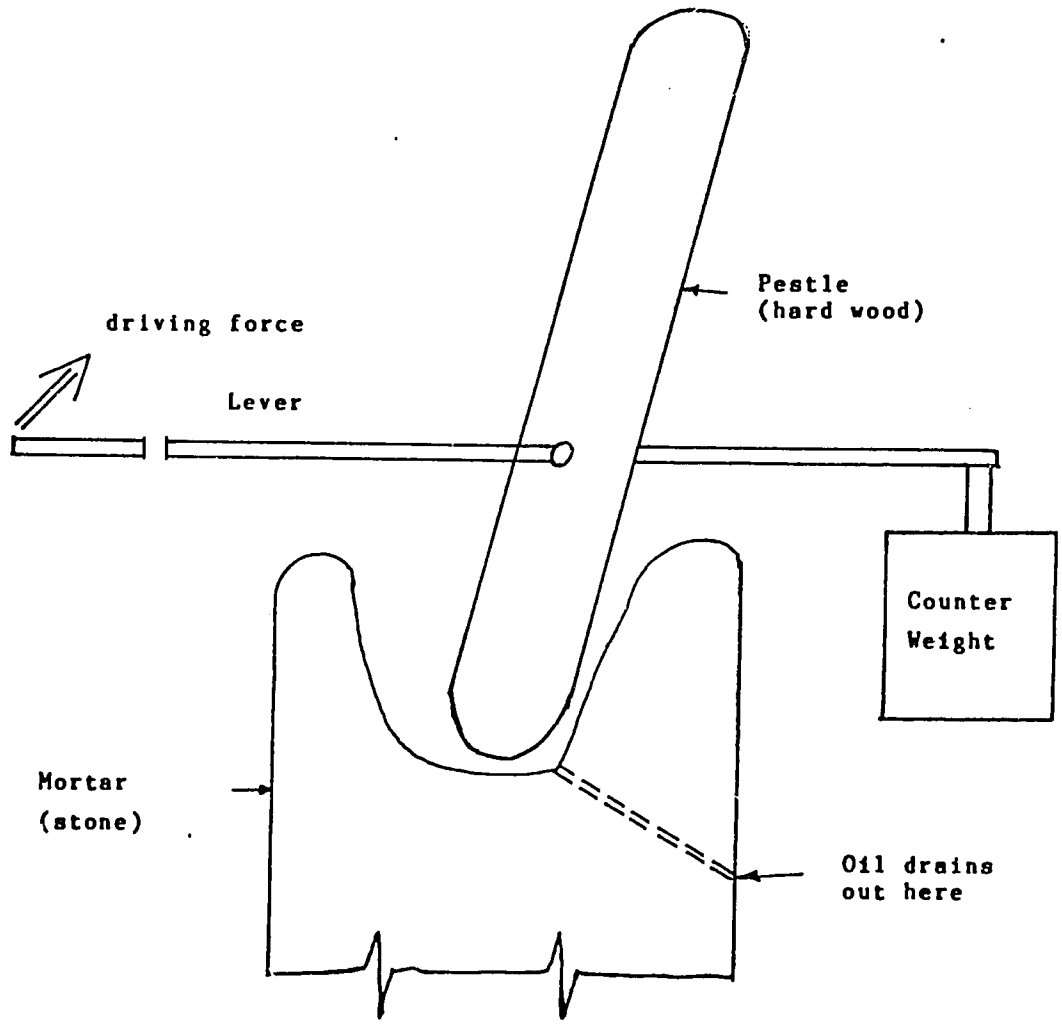

Figure 3.2 TRADITIONAL MILL

("Chekku" found in Sri Lanka & India)

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