ENERGY FROM COCONUT

Foreword

by Rizalinda L. de Leon
Department of Chemical Engineering
University of the Philippines Diliman

The paper was written by Prof. Teodorico F. Festin, one of the few faculty members from the College of Engineering to be conferred the title of Professor Emeritus of the University of the Philippines. He served the University from 1951 until his retirement in 1989 in various positions, including the chairmanship of the Department of Chemical Engineering for 16 years. He was awarded the Dean Alfredo Juinio Lifetime Distinguished Achievement Award for 2007 in recognition of his various and valuable contribution to the field of Chemical Engineering.

Prof. Festin obtained his Bachelor of Science degrees in Chemistry from the University of the Philippines and Chemical Engineering from the National University. He earned a Master of Science degree in Chemical Engineering from the University of California I Berkeley. He was also a Research Scientist at the prestigious Lawrence Radiation Laboratory in Berkeley.

At the time this paper was written, Prof. Festin had been actively engaged in research projects involving agricultural residues. Among the studies he had done were: Pyrolysis of Rice Hull (BED-UNIDO, 1978), Coco Gas from Coir Dust (NSDB-NIST, 1974), Liquid Fuel Synthesis from Waste Products (NSDB-NIST, 1975), Hydrogenation of Solid Fuels (NSDB-NIST, 1975). Among his other publications were "Energy from Coconut" in the Philippine Journal of Coconut Studies, in 1977 and "Pyrolysis of wastes", Philippine Engineering Journal, v 3, no. 1, 1982.

ENERGY FROM COCONUT[1]

Teodorico F. Festin*

INTRODUCTION

This decade of the 1970's produced a crisis unprecedented in history. While the energy problem had been foretold by some scientists for some time, it was only during the Arab oil embargo that the whole world realized the seriousness of the matter.

Governments were driven to near panic as they sought to cushion the effects on their economy of the oil shortage and the increase in price. All possible alternatives and solutions were explored ranging from the search for more oil to conservation to a shift to other sources like solar energy, geothermal and nuclear.

The Philippines is one of the countries hardest hit by the oil crisis. The government has succeeded in minimizing its ill effects for the time being and it is hoped that it will soon find a long-lasting solution to this long-lasting problem.

Of the three approaches to our oil problem – the search for more oil, conservation, and the utilization of substitute sources – the Philippines has tried all. The subject of this paper is the last – the utilization of an untapped source of fuel and energy.

The Philippines is one of the world's top coconut producers. Luckily for it, the coconut is one kind of tree which offers a wide variety of materials for assorted uses among which are shells and husks being used directly as for fuel in copra making and cooking.

Coconut shell charcoal, in several instances in the past, has been used to run motor vehicles. Copra oil is also used for lighting in the barrios. This simply means that the coconut has long been used as an energy source.

It acquires greater importance now when we consider it as a possible substitute to run our motor vehicles and machines. It is significant that the urgency of our oil problem can be matched by the great potential of the coconut as a source of energy.

At the outset, coconut is a renewable source. There are thousands upon thousands of hectares of agricultural land all over the country that are planted to coconut trees, which trees, as long as they exist – surely they will exist for a long, long time – the supply of raw materials will pose no problem at all. Unlike other sources which are depletable and are finally gone in the course of time, the coconut trees replenish its produce.

Scientific experimentations show that it can be a source of solid, liquid and gaseous fuels. Flexibility in fuel types gives additional attractive characteristics to energy from coconut. Its fuel form can be adjusted according to the needs of specific circumstances. Two other encouraging qualities of this concept are: it entails an increase in surface area for foliage, tending to counteract the adverse effects caused by denuded areas; it can solve the waste disposal problem, utilizing as it does materials that are presently considered as waste matter and which come out in vast quantities.

It should be noted that fuels from coconut are not suggested as a complete solution to our energy crisis. While it offers some advantages, it cannot completely replace, at this time and at current levels of technology, traditional sources of fuel. But the shortage of oil should be met in many ways, and using coconut as a substitute fuel can be a major contribution towards finding a solution to the problem. The following is an exposition of experiments made in the past which directly met the problem of deriving energy from coconut materials. It is important to note that while this is only a summary of the experiments without going into details, it provides us with a picture of the striking potential of coconut as a source of energy.

Energy from the Solid Parts of the Coconut

Rough estimates showed that one ton of dry organic materials can be converted into almost two barrels of oil or into approximately 10,000 cu ft of gas (Pirie, 1973).

The solid parts of the coconut (shells, husks, leaves and trunks) can be simply burned as fuel. However, these materials do not burn efficiently, have low heating values, and are considered to be pollutants. There are methods that can be used to convert these materials to more convenient forms of fuel and which are compatible with the environment. These are:

1. **Pyrolysis** – The material is heated in the absence of air to produce solid, liquid and gaseous fuels. By controlling the operating conditions, the amounts of these products can be varied. This process can be carried out in vertical or horizontal retorts and in

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*Professor of Chemical Engineering and Director, Industrial Research Center, University of the Philippines, Diliman, Quezon City.

fixed or fluidized beds.

2. **Gasification** – In this process, a hot bed of solid fuel is made to react with a gasifying medium which normally is air or air and steam. The gas produced has a low calorific value due to the presence of large amounts of nitrogen. Gasification with hydrogen, or hydrogasification, at high temperature and pressure increases the heating value of the gas. The hydrogen is generated from the residual char obtained from the hydrogasification.

3. **Hydrogenation** – The material is reacted with either hydrogen or carbon monoxide and water in a high temperature and high pressure reactor. An oil generally results from such a hydrogenation process.

4. **Fermentation** – This is a biodigestive process where mixed cultures of microorganisms are made to develop in the organic material decomposing it and yielding a combustible gas. Production of methane gas from hog manure typifies this process.

5. **Acid Hydrolysis** – The material is heated in the presence of an acid converting the cellulose into sugars for fermentation to ethyl alcohol.

It could turn out that combinations of these methods will be the optimum process in converting the solid parts of the coconut to energy.

Coir Dust Carbonization

Of the solid parts of the coconut, the coir dust from the husk has the least number of uses and most often is viewed as disposable waste materials. Approximately one-third of the coconut fruit is husk and about one-half of this is coir dust and short fibers. These are concentrated at coir fiber processing plants and the quantity generated is enormous. Special interest is therefore being laid on the possible uses of coir dust and short fibers.

The utilization of coir dust as a source of fuel and energy has for many years been the subject of several studies, the most comprehensive of which is its carbonization (Festin, 1956, 1964, 1964a, 1969; Casillan, 1968; Festin, *et al.*, 1973; Guevarra, 1975). A horizontal screw-conveyor type retort, enclosed in a gas leak-proof tube, was used in one of these studies (Festin, 1964a). A reducer drive allowed the screw to rotate at various speeds to produce char at different rates. Indirect heat was supplied for pyrolysis at temperatures above 500°C and carbonization could be attained in 3 to 5 minutes. The process is self-sustaining as the heat could be supplied either by the gas or by the char which can be recycled into the furnace while still hot, thus conserving the heat. Utilizing the char increases the overall efficiency of the process. A flow diagram of the pilot plant used in the studies together with the utilization possibilities of the products is shown in Figure 1.

A summary of the yields of the different carbonization products at varying temperatures using a smaller retort is shown in Table 1 (Guevarra, 1975) while the pilot plant retort carbonization products (Festin, *et al.*, 1973) are shown in Table 2.

Char, Tar and Light Oil

The char produced has a calorific value of 10,260 BTU/lb as compared to 6,340 BTU/lb of dry coir dust. The char can be converted into either charcoal briquettes or activated carbon. The char produced at 800°C exhibited adsorptive capacity and this activity increased sharply as the temperature was raised. Carbon formed at 1,000°C exhibited activity which was 24% higher than a commercially available active carbon. The tar and light oil can be used for fuel or for wood preservation.

Coco Gas Utilization

The gas, dubbed as coco gas, has many uses. It is rich in hydrogen and carbon monoxide and virtually free of sulfur. The volume of the gas and the amounts of the combustible components in it increase as the temperature is raised. As a net effect, the heat available is increased.

Another study (Festin, 1969) revealed that certain substances could increase the volume and calorific value of the gas. Gas recovery could be improved by as much as 50% with the use of sodium-based catalysts. The heating value could also be increased by pyrolyzing under pressure. Removal of the carbon dioxide by bubbling the gas in lime water right at the floating tank reservoir could further raise its heating value per cubic foot.

The gas has been demonstrated to produce a good bright light. A 50-liter cylinder at a pressure of 60 psig could supply light equivalent to 15-25 watts for one hour. An old stationary jeep engine has also been successfully run using the raw coco gas (Garcia, *et al.*, 1974). The consumption is 159 liters/min (5.6 cu ft per min). Further studies using a smaller engine will be undertaken to be able to get more useful technical information. The use of gaseous fuels for moving vehicles poses a storage problem. A study being undertaken is to convert coco gas into liquid fuels with special emphasis on production of methanol, a good substitute for internal combustion engines (Festin and Albano, 1974). Most commercial methanol plants use either coke, natural gas or naphtha for their synthesis gas. This requires pre-treatment to remove undesirable components, especially sulfur which could poison the catalyst in the methanol converter. Coco gas, on the other hand, is virtually free of sulfur. It can be used directly without much treatment. The right proportion of hydrogen to carbon monoxide can be obtained by controlling the carbonization temperature. Alcohols, although still on a small scale, have been synthesized from coco gas using a CuO-ZnO catalyst (Festin and Albano, 1974).

Critical Problems

There are still problems to be solved and schemes to be developed in order to utilize coir dust as source of gaseous, liquid and solid fuels. Among others, these are:

1. Improvement of the heating value of the gas by methanation.
2. Improvement in the separation of condensible, non-condensible gases and fine particles from one another.
3. Recovery of the sensible heats in both condensible and non-condensible gases.
4. Improvement of burning schemes for the light char in the furnace.
5. Development of pressurized solid feeding schemes and removal of char.
6. Development of liquefaction schemes incorporating lower pressures and temperatures.
7. More effective and economical activation of the char.
8. Development of material feeding and withdrawing schemes in high pressure reactors.

Fermentation

Studies on fermentation showed that the rate of gas production per unit weight of dry coir dust is not comparable to the rate of gas production from hog manure, although the rate is better than from sawdust (Economic Development Foundation, 1974). The methane gas appeared only after one month of digestion of the coir dust, indicating a slow microbial disintegration of the material. A search for agents that will hasten the degradation of coir dust into low molecular weight organic components would be interesting subjects of research (Cruz and Festin, 1975).

Gasification

Gasification studies showed that coir dust did not produce a good producer gas when it was gasified in an updraft gas producer with 10 sq ft of grate areas (Vanichayakool, 1975). At a gasification rate of 80 lbs of coconut shell per hour per sq ft of grate area, the gas producer was able to supply gas to generate 35 kw of electric power for some five hours of operation (Cruz and Garcia, 1974; Cruz, 1974).

Energy from the Coconut Oil

Coconut oil would not do as motor fuel because it is viscous, has low volatility, tends to solidify at low temperature, and forms gums.

Chemical mechanisms which may possibly convert coconut oil into liquid hydrocarbons have been proposed (Banzon, 1970). In view of the increasing cost of motor fuel and the uncertainty of the coconut oil in the foreign market, it would be worth considering the various schemes mentioned in the cited publication.

Another report described a method of converting coconut oil into motor fuel (Banzon, 1970a). This is prepared by reacting the oil with either methyl or ethyl alcohol to produce the esters. What makes the process attractive is its simplicity. No special equipments are needed to carry out the reaction, which proceeds almost to completion even at normal temperature and pressure, and the subsequent separation of the two layers that form. The yield is high at 1.14 kg of esters from 1.0 kg of coconut oil. However, the volatility is just about that of kerosene and when used as a motor fuel tends to "knock".

At the National Institute of Science and Technology (NIST) the methyl ester, particularly the residue left after fractionation, has been successfully used to run a car operating on diesel. The performance was comparable, if not better, to the petroleum-based diesel. In one of the latest test runs at 80 kph, the car ran 14 kilometers to a liter of the fuel. Using ordinary diesel at the same speed, the car consumed one liter for 12 kilometers.

The residues of different viscosities depending on the extent of distillation are being further investigated.

Since the ester blends readily with alcohol, the tendency to "knock" may be eliminated if alcohol, which has a high octane number, is added to it.

CONCLUSION

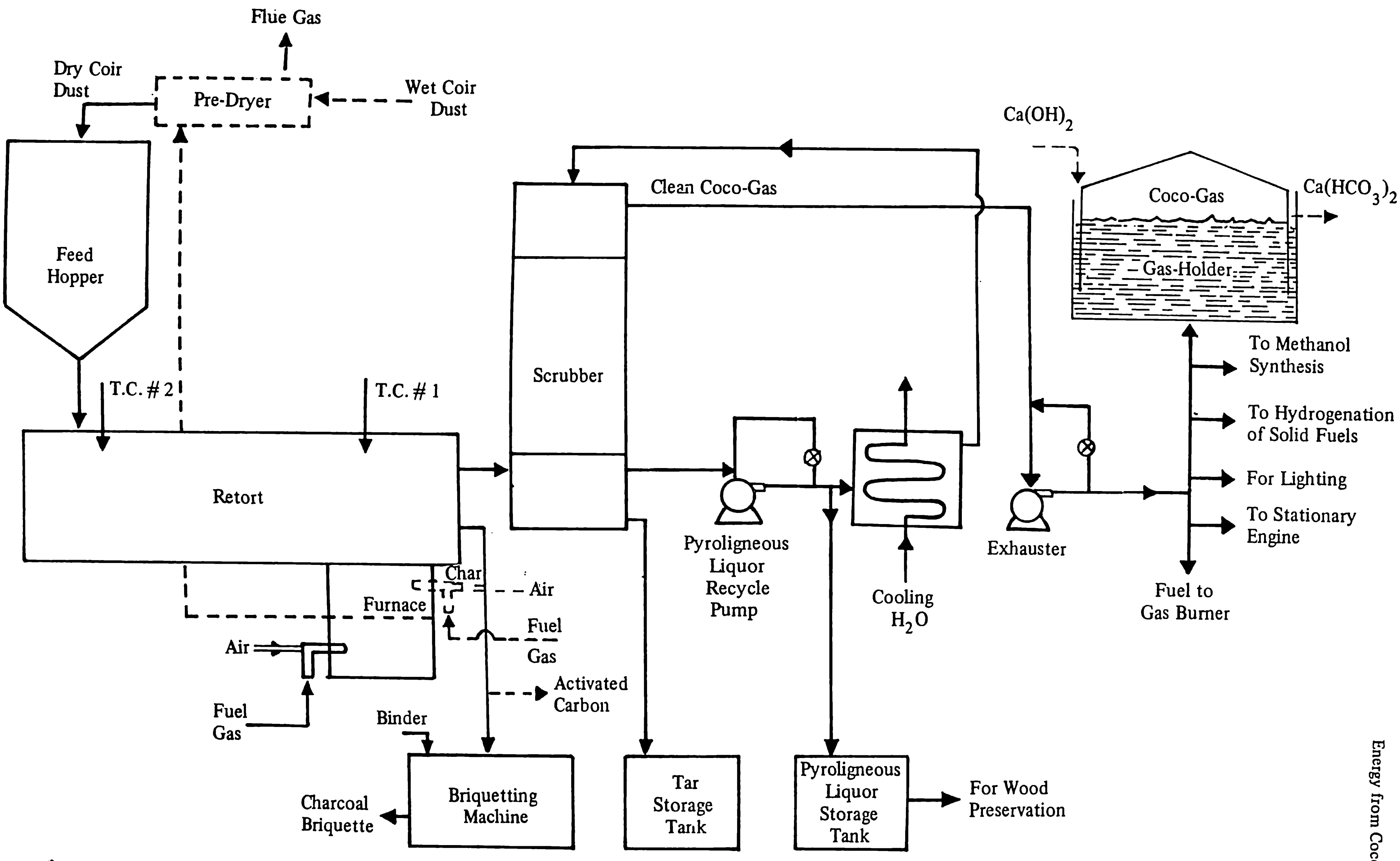
What has just been discussed is the result of one technology insofar as exploring the potential of the coconut is concerned. There may be other approaches in extracting fuel from coconut, and in the final analysis there must be some criteria for selecting alternative technologies. It is a common practice that when new technologies or processes are being evaluated, only the technical feasibility is at first considered in judging them. This is only logical, since the first problem is to discover or confirm whether a particular objective is materially achievable. Other considerations, like the economic feasibility for example, comes later. The economic aspect could be better considered in the presence not just of one but of other alternative technologies. At this stage, when selection has already been finalized, alternative technologies are still important although they may turn out to be a secondary consideration.

This concept of energy from coconut, and any pioneering concept for that matter, will require a series of tests ranging from a modest pilot plant to a much larger demonstration plant. The inadequacy of an initial testing plant is obvious, since it is only in large scale schemes later that it is best to test a concept of this nature under the actual conditions in which it will be applied. An overall assessment can only be made when such a large demonstration plant is operated. In addition to this, it must be borne in mind that more work, more researches and more tests are made in the course of the operation of the plant in order to obtain optimum conditions.

Finally, there has to be extensive systems analysis and organization of a set of procedures to give best results. This entails the setting up of models to generate alternatives, optimizing performance and final selection of strategy. This completes the whole demonstration with proper scientific thoroughness and objectivity.

This concept acquires a final touch of attractiveness because it can integrate the acquisition of oil, food, building materials, and energy from the coconut. While already an amazing tree in itself because almost every part of it, from its trunks to its fruit and leaves, are already being used by civilized man in one way or another, the extraction of energy and fuel for modern machines from its materials provides it with its crowning glory as the "Tree of Life".

Fig. 1 Carbonization pilot plant lay-out at the U.P. Chemical Engineering Laboratory.



Note : Dashed lines represent further studies that can be undertaken.

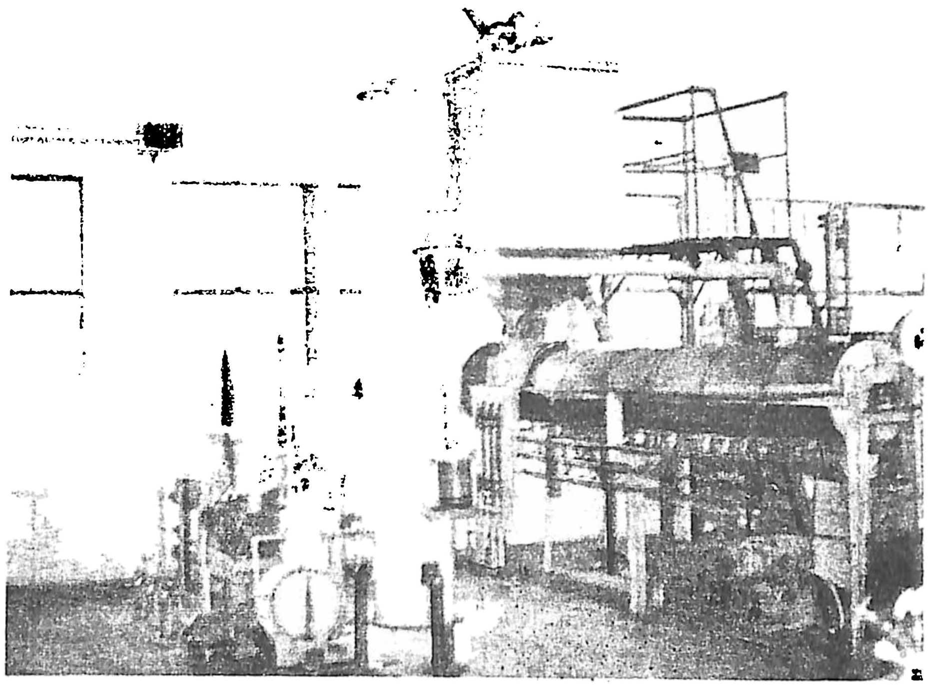


Illustration 1: Pyrolyzer, right, and separation accessories, left.

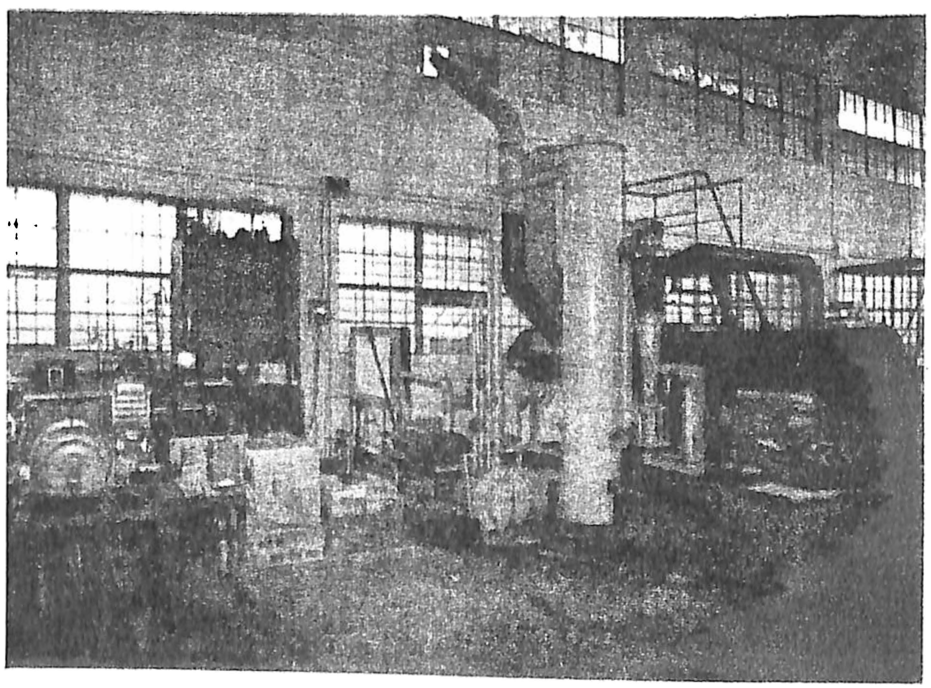


Illustration 2: Carbonization pilot plant, right, and set-ups for by-product utilization, left. A coco gas-lighted lamp is also shown.

Table 1. **Carbonization products as percent of coir dust.**

Products	Temperature 500°C	600°C	700°C	800°C	900°C	1,000°C
Charcoal	42.0	37.0	32.4	27.5	22.6	18.0
Light Oil	1.0	0.1	0.1	0.2	0.1	0.1
Tar & Liquor	13.0	11.0	9.0	7.0	5.0	3.0
Non-condensibles	44.0	51.9	58.5	65.4	72.3	78.9
Gas Composition, %						
CO_2	27.0	15.0	11.0	7.0	4.0	0.0
CO	31.0	26.0	29.0	39.0	48.0	50.0
H_2	31.0	50.0	51.0	47.0	46.0	47.0
CH_4	9.0	9.0	8.0	7.0	2.0	2.0

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CO	31.0	26.0	29.0	39.0	48.0	50.0
H_2	31.0	50.0	51.0	47.0	46.0	47.0
CH_4	9.0	9.0	8.0	7.0	2.0	2.0

Table 2. Carbonization products as percent of coir dust at 550°C from pilot plant.

Products	
Charcoal	35.0
Light oil, Tar and Liquor	33.0
Non-condensibles	32.0
Gas Composition, %	
CO_2	21.0
CO	27.0
H_2	42.0
CH_4	10.0

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