UTILIZATION OF WASTE COCONUT COIR DUST AS A SOURCE OF FUEL

Foreword

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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", Phlippine Engineering Journal, v 3, no. 1, 1982.

Dr. Wilfredo Jose is a professor of Chemical Engineering at the UP College of Engineering. He was given the Outstanding Chemical Engineer Award for 2007 by the Professional Regulation Commission for his "exemplary achievements in the field of chemical engineering, having demonstrated exceptional professional competence through his various studies and researches in the field of biotechnology and biochemical engineering, with his works having been applied by the industry in various waste management programs." He was also recipient of the Outstanding Young Scientist Award given by NAST-DOST in 1987.

Dr. Jose graduated cum laude with a Bachelor of Science degree in Mapua Institute of Technology, obtained his Master of Science in Chemical Engineering at the University of the Philippines and his M.S. and Ph.D. In Chemical and Biochemical Engineering at Rutgers University in New Jersey, USA.

At the time the paper was written, he was an assistant professor at the UP Chemical Engineering Department. Among his studies related to the paper were: Charcoal-fired Drier with a Novel Furnace Design, Coconut Shell Charcoal as Packing Material for Distillation Columns, Absorbers and Demisters, and Development of a Model for the Waste Utilization Value. He continues to actively engage in research in many areas of chemical engineering, including applications on health and wellness, process intensification and engineering education.

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UTILIZATION OF WASTE COCONUT COIR DUST AS A SOURCE OF FUEL ‡

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INTRODUCTION

The Philippines is considered one of the world's largest producers of coconuts with its yield of around 8.6×10^9 nuts annually. Oil from the meat is the major product desired but many other by-products can be obtained. The husk, which is about 35% of the weight of the matured fruit, can be utilized for many purposes. It can be used as a fuel for drying copra, as a raw material for handicrafts and other minor applications, or for the production of coir fibres. In the extraction of the fibre however, large amounts of waste coir dust, to the extent of about 60% of the weight of husk, are produced. The disposal of this waste coir dust poses some problems for the coir fibre extraction plants. It readily accumulates and occupies much space which are ideal breeding places for pests. The present method of disposal, landfill, is expensive and time consuming.

Utilization, therefore, rather than mere disposal would be of great benefit to the coconut industry. The Philippines' present output of coir fibre is only 1% of the world market because of the dust disposal problem. The recycling of the waste as a source of fuel or as a source of industrial chemicals will improve the profitability of the coir fibre processing industry. The research on the production of a gaseous fuel (coco gas) from coir dust was primarily aimed at solving the problem of waste coir dust disposal.

PYROLYSIS OF COIR DUST

Pyrolysis or carbonization, which is the breaking down of substances into simpler compounds and elements by heating in the absence of oxygen, is one of the processes that could be applied for the utilization of coir dust. The usual products are solid (char), liquids (tar and pyroligneous liquor), and gases. Pyrolysis is also the process involved in the destructive distillation of wood to produce chemicals. Although wood pyrolysis is a familiar process, the use of coir dust instead of wood introduces variations in the products because of the difference in raw material composition. The average composition of wood[1] and coir dust[2] are given in Table 1.

Table 1. Average composition of wood and coir dust

Component	Coir dust	Hardwood	Softwood
Cellulose	24	56	58
Pentosan	16	18	7
Lignin	54	23	26
Ash	6	1	1
Resin		2	8

‡Paper presented at the Second Recycling World Congress, Manila, Philippines, 20 – 22 March, 1979.
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The lignin and ash contents of the coir dust are higher than that of wood. The coir dust contains lower cellulose and no resin.

Table 2 shows a comparison of the yields of products from the pyrolysis of coir dust[3] and wood[4] at about the same range of temperatures. The charcoal and the liquor yields are almost the same. The coir dust gives a higher yield of gas and a lower yield of tar.

Table 2. Comparison of yields of products from carbonization of coir dust and wood

Product		% coir dust		% wood
Charcoal		40.9		41.3
Pyroligneous liquor		28.0		31.7
Water	27.10		23.8	
Acetic acid	0.82		5.9	
Methanol	0.04		2.0	
Phenol	0.04		0	
Noncondensable gas		27.6		17.0
Tar		3.5		10.0

Table 3 gives the average composition and fuel value of coco gas as compared to that of wood gas. The coir dust yields a gas very high in hydrogen but low in methane and carbon monoxide contents. Wood gas on the other hand has high methane and carbon monoxide but very little hydrogen. Per unit volume, wood gas has a higher fuel value than coco gas, but based on equal amounts of wood and coir dust processed, the total heat available in coco gas is higher because of more non-condensable gases (notably H_2) produced.

Table 3. Comparison of the average composition of carbonization gas of coir dust and wood

Component	Volume percentage coir dust	Volume percentage wood
CO_2	32	54
CO	16	28
H_2	45	1
CH_4	3	15
Other hydrocarbons	4	2
Fuel value, MJ/m^3	9.91	10.80

The pyrolysis of coir dust, as shown by studies conducted by Festin[5, 6], Guevara[7], and Casillan[9], is just as complicated as that of wood. The yields and composition of the products are influenced by several factors such as the speed and temperature of carbonization, the chemical composition of the raw materials, and the physical dimensions of the retort. The production of fuel gas from coir dust can be varied and adjusted according to the intended use of the product. Any increase or decrease in the production of coco gas will affect the yield of other products, particularly the char. For instance, gas production increases as the temperature of carbonization is increased, but with a corresponding decrease in the yield of the char[7]. By introducing a catalyst into the reaction system[8], the fuel value of the gas is increased by as much as 50%.

The pyrolysis of the coir dust is exothermic. Initially, the rise of the temperature of the material being processed is gradual. However, as carbonization progresses, the temperature increases rapidly[9]. If the retort is properly insulated, little external heat will be needed to maintain the desired temperature.

CONTINUOUS PYROLYSIS OF COIR DUST

Based on the chemical composition, and the physical and carbonization characteristics of coir dust, small retorts employing continuous operation can be used to effect capital cost saving. Retorts used in pyrolysis can either be horizontal, vertical or fluidized bed.

In the studies conducted by Festin, two horizontal retorts of different sizes were fabricated[5, 10]. For experimental studies, the small electrically heated retort was used; while for pilot plant studies, the larger gas-fired one was employed. The retort was a leak-proof steel tube with a screw to move the process materials inside. A feeder was provided at one end and a fixed discharge spout at the other end. Provided with a reducer drive, the screw could rotate at different speeds. The small retort was wrapped with nichrome wire to provide indirect heat while the large retort was provided with a set of burners or furnace. A shell of refractory bricks enclosed the retort concentrically.

The exothermic reaction of coir dust carbonization was confirmed in experimental studies using the small retort[9]. The heat of carbonization was found to be 506 603 J/kg (121 cal/g) of bone-dry coir dust at 30°C.

CARBONIZATION PILOT PLANT

If part of the heat available from the gas and char produced from the reaction can be used to preheat the coir dust to the operating temperature, supply the sensible heat of the products and supplant the heat losses to the surroundings, then the process can be said to be self-sustaining. To study whether continuous carbonization could be self-sustaining or not, a pilot plant was set up[10].

The layout of the carbonization pilot plant at the Chemical Engineering laboratory of the University of the Philippines is shown in the accompanying diagram[11]. Coir dust with about

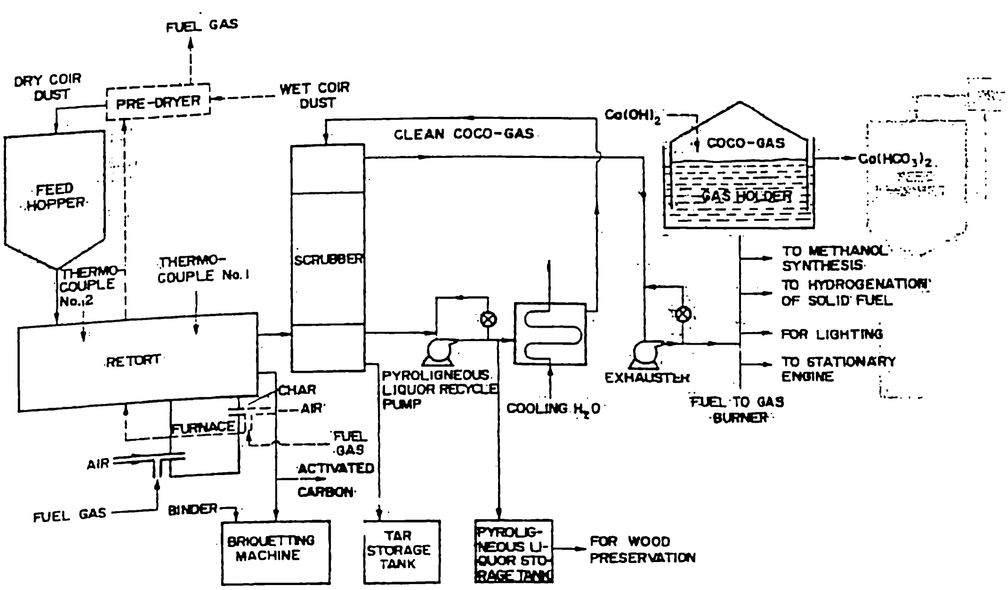

Fig. 1. Carbonization pilot plant lay-out at the U.P. Chemical Engineering Laboratory.

20% moisture is charged by a hopper provided with a vertical feeder and agitator. By means of the action of the screw, the coir dust is moved along the heated horizontal tube. Decomposition takes place and charcoal is discharged at the end of the retort into a closed collector.

The carbonization gases pass through a cyclone separator, where entrained fines are removed. Then the gases enter a scrubber where the condensables are absorbed upon contact with the scrubbing liquid. This liquid is cooled and recycled to the top of the scrubber. The non-condensable gases are then sent to a gas holder with lime water as the holding liquid. The lime water absorbs the CO_2 from the gases. The disappearance of milkiness of the solution when the lime water becomes saturated with CO_2 gives an indication as to when the lime water has to be replaced.

The tar and the pyroligneous liquor are drained out at the base of the scrubber.

The char and the gas product of carbonization can have many applications. When mixed with a suitable binder, the charcoal can be made to form briquettes. The char can also be processed into activated carbon. It can also be used directly as the fuel for pyrolysis.

A comparison of yields of carbonization products from the experimental and pilot plant units is shown in Table 4. The carbonization temperature of the pilot plant at 530°C is higher than that for the experimental retort at 500°C. Despite this however, the volume of the gas obtained, 31.9%, is lower than that for the experimental unit, 44%. This is due to the fact that incomplete carbonization of the coir dust and ashing of the char at certain instances are encountered, indicating that the performance is far from satisfactory. However, this heat output of the gas and char produced by the pilot plant unit is still large enough to sustain the process and to provide mechanical power.

Table 4. A comparison of typical yields of carbonization products from experimental (7) and pilot plant (10).

	Quantity, as % of coir dust	
	Experimental retort	Pilot plant unit
Carbonization temperature, °C	500	530
Charcoal	42	34.8
Tar & pyroligneous liquor	14	33.3*
Coco gas	44	31.9
CO_2, %	27	21.2
CO, %	31	26.6
H_2, %	31	41.8
CH_4, %	9	10.0
Fuel value of gas MJ/m^3	10.88	12.03
Density of gas, kg/m^3	0.961	0.801
Per kg of dry coir dust		
Heat from coco gas, MJ	4.97	4.79
Heat from char, MJ	10.02	8.30
Total heat available	15.00	13.03
Thermal efficiency, % †	88.8	77.6

*Determined by difference.
Based on fuel value of char of 23.86 MJ/kg.
Thermal efficiency defined as the ratio of heat in the gas and char to heat in dry coir dust.
†Based on fuel value of coir dust of 16.89 MJ/kg.

The experimental retort has a thermal efficiency of 88.8% while the pilot plant has 77.6%. This indicates that the performance of the pilot plant can still be improved.

COCO GAS AS A BASIC ENERGY RESOURCE

The following products are obtained in a typical run of the pilot plant at 530°C (per hour):

Coir dust (20% moisture) kg	30.75	24.58(dry)
Charcoal, kg	8.53	
Coco gas, kg	7.85	
Heat input, J	9.117×10^7 (86 400 Btu)	

The heat input to the retort is 91.15 MJ while the heat from the gas and the charcoal are 117.91 MJ (111 758 B.t.u.) and 203.51 MJ (192 888 B.t.u.) per hour, respectively. It can be seen that the char (even at 50% utilization) is more than enough to supply the heat to the retort. While the gas can also be used to supply the heat to the retort, it can better be utilized for mechanical power generation or as a source of synthesis gas for the production of methanol and other alcohols. At 20% utilization, the gas can provide 6.5 kW.

Coco gas has been utilized in many ways in the laboratory. The gas has successfully run a stationary jeep engine[11]. It has been used to produce a light equivalent to 20 watts. On a small scale, alcohols have been synthesized from coco gas[12]. When coir dust was heated with coco gas under pressure, a portion of the solid was converted to a brownish oily liquid, soluble in acetone[13]. This liquid is a possible source of liquid fuels and chemicals.

For the coconut industry, the most promising use of the pyrolyzer is by integrating it with a coir fibre extraction unit, the coco gas and the by-product coir providing the mechanical power for the decorticator*. Table 5 shows a comparison of consumption of coco gas and bio-gas

Table 5. Comparison of consumption of coco gas* and biogas (60% CH_4) for different uses

Use		Coco gas m³	CO_2-free coco gas m³	Rate
Lighting	0.119	0.221	0.176	per mantle per h
Cooking	0.368 – 0.765	0.680 – 1.444	0.536 – 1.333	per h per 5 – 10 cm burner
Incubator	0.8 – 1.2	1.5 – 2.2	1.2 – 1.7	per h per m³ incubator
Gas refrigerator	2.0	3.8	3.0	per h per m³ refrigerator
Gasoline engine	0.536	0.991	0.736	per brake horse-power per h
Gasoline equivalent	1.98 – 2.75	3.71 – 5.15	2.78 – 3.88	per litre
Diesel oil equivalent 25% efficiency	2.18 – 3.06	4.13 – 5.75	3.09 – 4.30	per litre

*See reference[11].
Source: energy primer, 1975.

(60% CH_4) for different uses. The fuel value of coco gas which is almost one-half that of bio-gas could be raised to two-thirds were the CO_2 to be scrubbed off the coco gas.

FUTURE DIRECTION OF RESEARCH

Since pyrolysis offers a good solution to the waste disposal problem of coir dust, extensive research and development are currently being pursued to resolve the technical and optimization problems associated with the process. Aside from being a good source of fuel, coco gas, which is rich in hydrogen and carbon monoxide, could be used as a raw material for different processes such as the manufacture of methanol, hydrogenation of vegetable oil, metal extraction from ores, and in making other industrial chemicals.

*Equipment used for extracting fibres from coconut husks.

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