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COCONUT SHELLS AS AN INDUSTRIAL RAW MATERIAL

IV. COCONUT SHELL CHARCOAL: (A) COMMERCIAL

THE second article of this series³¹ dealt with miscellaneous uses of coconut shells as such and with their value as fuel. The uses there considered were only of local importance. The present article is concerned with a commodity—Coconut Shell Charcoal—which, during the War of 1914-18, and again in the years immediately preceding the present war, acquired general commercial importance.

Charcoal is essentially a more or less impure form of carbon obtained from various animal or vegetable matter by ignition out of contact with air. Charcoal burning is a very ancient art; and the use of wood charcoal for smelting must date back to the earliest use of metals, which has been put back as far as 4000 B.C. The description of charcoal burning in Theophrastus' (370-285 B.C.) *Enquiry into Plants*⁴² is supplemented by practical information which sometimes has a curiously modern ring: "Different kinds of charcoal are used for different purposes—thus in iron mines they use that which is made of sweet chestnut when the iron has already been smelted, and in silver mines they use charcoal of pine-wood—Smiths require charcoal of fir rather than oak; it is indeed not so strong, but it blows up better into a flame, as it is less apt to smoulder." "Worst of the woods mentioned is oak, since it contains most mineral matter."

Charcoal prepared from coconut shells does not appear to have come early into use in coconut-growing countries. Thus, although Robert Knox in the seventeenth century describes iron smelting as for long practised in Ceylon, he makes no specific mention of

coconut shell charcoal. It appears likely moreover that wood charcoal rather than shell charcoal entered into the manufacture of gunpowder, described in 1818⁴³ as "of very ancient practice in the country" (Ceylon); the latter is indeed not very suitable for the purpose.

Bennett (1843)¹⁹ and later authors (e.g., Seeman, 1856),⁴⁴ mention the conversion of coconut shells into "lampblack, and charcoal; which latter, when pulverized, forms an excellent dentifrice". Lampblack, so referred to, is probably a preparation made by condensing the soot from burning shell, though Grisard and Vanden-Berghe (1889)²¹ seem to suggest the use of ground shell charcoal in paints, and as late as 1919 a writer in the *Mysore Engineers' Association Bulletin*⁴⁵ used the charcoal from dry distillation of shells with linseed oil as a blackboard paint and said that the finely powdered "shell-coke" (as he called it) "may probably prove to be a good substitute for lampblack". What is nowadays described as lampblack is essentially the soot from an unobstructed hydrocarbon flame and has properties which could hardly be reproduced by powdered charcoal.

Regnaud (1856),²² who evidently wrote more at first-hand than most of the nineteenth century authors quoted, notes the use of shell charcoal in the Maldives and elsewhere in metal working: "La coque du coco ... Transformée en charbon, elle devient précieuse pour le travail des forges, et ne le cède en rien à la houille entre les mains des Maldiviens et des habitants des îlots de la mer de l'Inde, qui sont sous la dépendance de Maurice." A cor-

respondent of the *Madras Mail* in 1886⁴⁶ stated that "charcoal of the coconut shell is specially used by native goldsmiths in melting gold and silver". In Ceylon, shell charcoal is still considerably used for such small-scale metal work, including precious metals and brass.

The desiccated coconut and machine-made coir industries developed in Ceylon from the end of last century; in mills devoted to these manufactures the large accumulations of shells were and are used as fuel (cf. ref. 47) and frequently converted into charcoal used for producer gas engines. There are also references to the use of shell charcoal in copra drying, and the manufacturers of the "Chula" copra drier were stated in 1914⁴⁸ to recommend this fuel; such use has not, within the writer's knowledge, ever been general.

The War of 1914-18 brought into use the product known as "activated carbon" as a means of defence against poisonous gases in warfare. Coconut (and other nut) shells give products particularly active for this purpose, and were developed considerably in the U.S.A. Brown and Merrill (1919)⁴⁹ state: "In 1918 the United States military authorities had an extensive organization for securing large quantities of this charcoal in the Philippines." Much of the work on research and manufacture at that time was secret and precise statistics of production do not seem to be available.

From 1933 fairly extensive exports of coconut shell charcoal were made from Ceylon; Tabel I shows the quantities exported in the years 1933-41 inclusive.

TABLE I
Exports of Coconut Shell Charcoal from Ceylon

Year	Amount tons	Value Rs.	Value per ton Rs.
1933	2,019	90,541	44.85
1934	6,234	350,996	56.30
1935	7,667	365,608	47.68
1936	6,751	377,137	55.86
1937	13,455	977,708	72.66
1938	10,997	823,781	74.91
1939	18,568	1,361,880	73.35
1940	14,967	758,739	50.69
1941	1,697	68,807	40.55

Table II shows the distribution of the Ceylon exports from 1936-39 inclusive.

TABLE II
Distribution of Coconut Shell Charcoal Exports from Ceylon (in Tons)

	1936	1937	1938	1939	Total 1936-39
U.K. ..	3,223	7,448	4,077	4,085	18,833
France ..	3,353	5,603	6,570	14,272	29,798
Holland	175	100	100	200	575
Italy ..	..	300	..	..	300
Roumania	..	..	250	..	250
Others ..	..	4	..	11	15
	6,751	13,455	10,997	18,568	49,771

In the same period there were some sporadic shipments from the Philippines, where, however, there were no official trade figures prior to 1939. In 1936-37 there seem to have been shipments of at least 1,000 tons to Italy and Germany and for the first six months of 1939 the Bureau of Customs issued the following figures.⁵⁰

TABLE III
Exports of Coconut Shell Charcoal from the Philippines (First 6 months, 1939)

	Tons	Value (Pesos)
Great Britain	139	10,242
France	225	5,827
Japan	15	194
	379	16,263

There was little development in Malaya, shipments being only recorded of 80 tons exported in 1940;⁵¹ and whilst there was some apprehension in Ceylon of competition from the Netherlands East Indies in 1938, output from this source was apparently not large. Only comparatively small quantities were supplied from there to Japan, Germany, Denmark and France.⁵²

In South India, shell charcoal has been made for service purposes, but particulars have not been released.

All of these exports were of crude charcoal; there has been so far no development of the manufacture of "activated carbon" in coconut-producing countries, although one large shipping firm in Ceylon installed plant for granulating crude charcoal, which in granular form (ready for processing) was supplied for French requirements up to 1939. The possibility of the local manufacture of active carbon has been considered in the Philippines, in India and in Ceylon, and reference will be made in the next article of this series to the preliminary investigations carried out in these countries.

PREPARATION OF SHELL CHARCOAL

Shell charcoal is usually burned in pits, which may be anything from a simple hole in the ground to large brick-lined pits with steel lids. Accounts of the procedure adopted in Ceylon are given by Cooke (1932)⁵³ and by Child (1940).⁵⁴ Similar accounts have been published in attempts to encourage production in other countries; these include, for Malaya, an article by Cooke (1935),⁵⁵ and for Fiji, a note by Jack (1940).⁵⁶ In New Guinea, Hutchinson has described a method of burning shells in 40-gallon oil drums (1941).⁵⁷

Up to the present patent steel and brick-work kilns such as the Hornsby Patent seem nowhere to have come into use. In the writer's opinion, a portable type of kiln such as has been used in England during the War (1944)⁵⁸ would be very suitable for a raw material like coconut shells, production of which is scattered.

The production of retort charcoal by carbonization with recovery of by-products is now

carried out in the Ceylon Government Acetic Acid Factory. Further reference will be made to this in a later article on Distillation of Shells.

It may be remarked here that shell charcoal burning in pits is not a pleasant occupation either for those who conduct it or for dwellers in the neighbourhood. The smoke is peculiarly acrid and deleterious to metal work and fabrics. Charcoal burning has, in fact, been held by a Ceylon court to be a "nuisance" trade.

YIELD OF CHARCOAL

The yield of charcoal from pit burning of shells averages between 29 and 30 per cent. by weight of the original shells, when the operations are efficiently conducted on clean dry shells. Adopting a figure of 29 per cent. Table II (b) of Article III of this series⁴¹ can be extended to show the relation between out-turn of copra per 1,000 nuts, and the number of shells required to make a ton of charcoal. A usual working average is that 20,000 whole dry shells go to a ton of charcoal (this corresponds to 4,400 nuts per long ton of copra).

It may thus be estimated that in Ceylon in 1939, some 360 million whole shells (= about 60,000 tons) were converted to charcoal or about one-fifth of the Island's total production (cf. above Table I and also Table I of Article III, ref. 41, p. 150). Charcoal production could not have expanded much beyond the 1939 output, since some 60 per cent. of the shells produced annually are used for copra drying. Nevertheless, the Ceylon authorities were subjected to ill-informed criticism early in 1940 for failing to secure a possible contract for a further 2,000 tons a month.⁵⁹

QUALITY OF PIT CHARCOAL: IMPORTERS' SPECIFICATIONS

Good quality coconut shell charcoal should be uniformly black in colour and free from carbonised fibre (from adhering husk on the original shell). Broken edges should show a shining black surface and the characteristic sharp conchoidal* fracture. Dropped on a stone floor well-burned pieces give a clear ring; under-burned pieces a dull sound. Over-burned pieces are very thin and brittle, and are not favoured for inclusion in samples for export as they easily go to dust.

Besides over- or under-burning, common faults of pit charcoal are (a) excessive moisture, due to too much water being used to damp down when opening the pit, (b) high salt content, due to brackish water being used to damp down, (c) contamination with sand or earth. Importers' specifications aim at limiting these faults.

Such specifications nearly always impose limits for moisture, ash and volatile matter, and some include limits for chlorides, water-soluble matter and alkalinity. They usually also have limits for sizes of pieces as determined by screening through sieves of various mesh. Table IV gives a summary of importers' specifications.

* *i.e.*, "a fracture presenting smooth shell-like convexities and concavities" (*Oxford English Dictionary*)..

METHODS OF EXAMINATION

(a) Sampling in the case of bulk products such as minerals, coal, soil, copra and charcoal, presents considerable difficulties. Analytical determinations on charcoal are performed on powdered quantities of a few grams and it is apparent that great care must be exercised in order that such small samples shall be truly representative of the original bulk.

In drawing from bulk the primary sample to be sent for examination, it is necessary to open and sample more bags than is usually recognized. A useful rule, which has been found adequate for copra⁶¹ and for feeding stuffs,⁶² is to take a number of bags equal to the square-root of the total number. In the case of charcoal, this number of bags should be opened and turned out, each lot mixed up, and three pounds drawn from each lot. The quantities so drawn are bulked.

Further sampling by the analyst is (according to Specification E) done as follows. The sample received is reduced to 5 lbs. by direct quartering; this amount is broken through quarter-inch mesh and again sampled by quartering down to 1 lb. This is broken through an eight-mesh sieve and quartered down to 100 gms. From this final sample is drawn 30 gms. which is finely ground through a sixty-mesh, and used for determination of moisture, ash and volatile matter.

(b) *Moisture*.—According to Specification E, 20 gms. powdered charcoal (sixty-mesh) are dried at 110° C. for two hours, cooled in a desiccator and weighed. D uses 1 gm. powdered charcoal and dries at 120° C.

(c) *Ash*.—According to E, 2 gms. of the dry charcoal from the moisture determination are ashed in a muffle furnace; being first burned off at a low temperature and finally at 950° C. for 1½ hours. In the writer's experience (see below) it has been found preferable to determine the sulphated ash, since it is somewhat difficult to get consistent results by the above method owing to the volatility of potassium salts in the ash.

(d) *Volatile Matter*.—The "volatile matter" is an arbitrary comparative figure depending on the method of determination adopted.

E proceeds as follows: Into a weighed porcelain crucible (without lid) of diameter 1¼", 1 gm. powdered charcoal from the moisture test is weighed. The crucible is placed in a Davies Crucible Furnace, and heated by means of a Téclu burner at 950° C. for exactly 7 minutes; cooled in a desiccator and re-weighed.

According to Specification B: volatile matter is determined by heating over a Bunsen burner in a closed platinum crucible for 10 minutes.

The French Specification D heats the charcoal in a closed crucible contained in a larger crucible packed with dry charcoal so that the smaller crucible does not come into contact with the flame (1 hour at 700-800° C.).

The writer was not able to obtain very concordant results by the last method. The first method was preferred and gave results satisfactory for comparative purposes.

(e) *Water-Soluble Matter*.—For this and the following two determinations, Specification E

TABLE IV
Specifications for Commercial Shell Charcoal

	A	B	C	D	E
	London firm (Cooke, 1935, Ref. 55)	London firm 1936 ⁶⁰	Manchester firm 1936 ⁶⁰	French firm 1936 ⁶⁰	Manchester firm 1937 ⁶⁰
Moisture. Not more than ..	10%	5%	10%	5-6%	10%
Ash. Not more than ..	..	3-4%	..	1-2%	2%
Volatile matter. Not more than	15%	15%	15%	12-16%	30%
				(sample rejected if over 20%)	
Chlorides. Not more than ..	..	..	(see below)	..	1.0 mg./gm. (but should be below 0.5 mg./gm.)
Water-soluble matter. Not more than	..	..	..	..	0.5% (but should be below 0.25%)
Alkalinity. Not more than ..	..	..	..	..	0.5% (but should be below 0.2%)
Size	Not < 10% on 1" mesh Not > 5% passing ¼"	..	Not < 10% on 1" mesh Not > 10% pas- sing ¼"	..	On 1" not < 10% Thro' 1" on ¼" 10-20% " ½" on ¼" 30-40% " ¾" on ¼" 15-25% " 1" on ¼" 10-20% " 1½" not > 5%
Other remarks .. ..	..	..	Free from conta- mination with salt water. Free from foreign matter. Shells to be of good thick qua- lity.	..	..

uses the remainder of the coarse (eight-mesh) 100 gm. sample. Ten grams are added to 100 c.c. of boiling distilled water, boiled for 10 minutes, filtered and washed with 50 c.c. of cold distilled water. The filtrate is evaporated and the residue dried at 110° C. and weighed.

(f) *Alkalinity (or Acidity) and Chlorides.*—Ten grams coarse sample are treated as in (e) and the filtrate titrated to methyl orange with N/10 sulphuric acid (or caustic soda if filtrate is acid). Results are expressed as c.c. N/10 acid (or alkali) per gm. of dry charcoal.

Chlorides are determined on the so neutralised filtrate by titration with standard silver nitrate solution, using chromate indicator; expressed as mg. C/1' per gm. of dry charcoal.

The writer has determined chlorides (see below) on the soluble ash. The results are reasonably concordant with those obtained by the foregoing method.

All determinations except (b) are expressed as per cent. of dry charcoal.

(g) *Screen Test.*—Specification E recommends that at least a 1 kilo. sample should be used. The writer prefers a larger sample if available. Each screen is well tapped until no more sample passes through.

RESULTS OF EXAMINATION OF COMMERCIAL SAMPLES

Thirteen samples locally produced* have been examined by the writer.

* i.e., in Ceylon.

(a) *Moisture.*—Only five samples had moisture per cent. below 5; all but one, however, were below 7 per cent. and that was 8.1 per cent., the mean being 5.5 per cent. A specification limit of 5.0 per cent. seems rather stringent and 7.5 per cent. is suggested.

(b) *Ash.*—The range of figures for ash on eleven samples was 0.8 to 2.2 per cent., only one however being over 1.6 per cent., with a mean of 1.3 per cent. Sulphated ashes (13 samples), ranged from 1.2 to 3.2 per cent., only two samples (2.1 and 3.2 per cent.) being over 1.9 per cent.; mean 1.7 per cent.

A specification limit of 2.0 per cent. seems quite satisfactory. The two samples which failed to pass this specification were known on other grounds to be bad. That high ash figures indicate contamination with sand or soil is shown by the results of ash determinations on material which passes a quarter-inch or sixth-inch mesh:—

SAMPLE I		
Passing ¼" mesh .. ..	..	2.6%
		(Specification limit 5.0%)
Ash on material remaining on ¼"	..	1.50%
Ash on material passing ¼"	..	16.2%
Ash on sample as received .. ..	..	1.92%
SAMPLE II		
Passing ⅙"	..	5.4%
Ash on material remaining on ⅙"	..	1.1%
Ash on material passing ⅙"	..	11.2%
Ash on sample as received .. ..	..	1.64%

It may be observed that an average ash content of 1.7 per cent. of the charcoal corresponds to 0.58 per cent. ash on the original shells, which is in accordance with the figures of Phillips and Goss (1940),⁴ Georgi (1941)⁵ and the writer (1938)² quoted in the first article of this series (1943, p. 292).¹⁷

(c) *Chlorides*.—Twelve samples examined by the writer averaged 0.41 mg. Cl/gm. dry charcoal. Four samples exceeded 0.5 mg. Cl/gm., three of these only slightly; the other sample (1.34 gr. Cl/gm.) was one of those referred to above as known to be unsatisfactory. Specification E is thus a reasonable one.

A figure of 0.41 mg. Cl/gr. dry charcoal corresponds to 0.14 per cent. Cl on the original shells or 2.1 per cent. Cl on the ash (cf. ref. 17).

(d) *Volatile Matter*.—Using the French method the writer obtained high and variable results and the first method was preferred. Of twelve samples, six gave figures below 15 per cent., three between 15 and 20 per cent., two slightly over 20 per cent. (21.2 and 21.9) and one 29.5 per cent. The last sample was obviously under-burned; omitting this, the average was 16.0 per cent. A limit of 15 per cent. is perhaps a little stringent; 30 per cent. is unnecessarily tolerant.

(e) *Screen Test*.—Importers do not insist on accurate compliance with such a detailed specification as E, but expect other limits of not less than 10 per cent. to remain on a one-inch mesh, and not more than 5 per cent. to pass a quarter-inch to be observed. There is some breaking up in transport, but less than might be expected.

OTHER PROPERTIES OF COMMERCIAL COCONUT SHELL CHARCOAL

Elementary analyses for carbon, hydrogen and oxygen do not appear to have been recorded for coconut shell charcoal. What is referred to as "Fixed Carbon" is the figure obtained by deducting the sum of percentages of moisture, ash and volatiles from 100. Thus a sample of shell charcoal from Ceylon examined by the Imperial Institute in 1916³³ was reported as moisture 4.7, volatile (at low red heat) 18.2, Ash 1.0, fixed carbon 76.1. Total 100.0 per cent.

CALORIFIC VALUE

The same sample was reported as having a calorific value of 7,529 cal. per gm. Cooke (1935)⁵³ found a gross calorific value of 7,640 cal. per gm. dry weight. Expressed in B. Th. U. per lb., the calorific value of coconut shell charcoal should not be less than 13,000.

SULPHUR

The Imperial Institute (*loc. cit.*) found 0.05 per cent. sulphur in the sample examined by them. This was probably present in the form of potassium sulphate and is in any case negligible.

COST OF MAKING PIT CHARCOAL

It is perhaps not very useful at the present time to discuss the cost of producing pit charcoal from coconut shells since what details are available relate to pre-1940 conditions. The figures given for Malaya by Cooke⁵³ and

for Ceylon by Child⁴⁰ may, however, have some comparative value.

According to Cooke, in Malaya in 1935, charcoal was being manufactured and bagged on contract at 28 Straits cents per picul. Cost of bags, handling and road transport brought the total to about 60 cents per picul f.o.b. Singapore (or about Rs. 16 per ton).

Child, writing in early 1940, stated that in Ceylon a usual contract charge for burning shells, sorting and bagging was Rs. 4.00 a ton. Bags cost Rs. 3.00 and transport about 20 cents per ton mile. The cost f.o.b. Colombo was, therefore, from localities about 30 miles from Colombo about Rs. 13.00 per ton plus value of shells. Taking the latter at Rs. 1.50 per 1,000, this gives a cost at Colombo of Rs. 43.00 per ton, assuming 20,000 shells to a ton of charcoal. In practice, the cost of shells became in Ceylon dependent on the demand and price paid for charcoal (see Article II, ref. 31, p. 5). The industry did not develop in Malaya despite its lower costs, presumably because of the longer distance and higher freight to Europe.

PACKING, STORAGE AND SHIPMENT

Since accidents have occurred both by sea and land through cargoes or stocks of charcoal becoming re-ignited (spontaneous combustion is doubtful), it is made a condition of shipment that charcoal shall be spread out and freely exposed to the air for at least fourteen days before packing. It is usually packed in strong gunny bags (coir bags have been used) containing 90 to 130 lbs. (generally 1 cwt.). Twelve 1 cwt. bags go to the shipping ton (50 cubic feet).

The shipment of granulated charcoal already referred to had distinct advantages on account of more economical stowage, besides the preference of buyers for charcoal in a partially prepared state for activation.⁵⁴

Long storage (for over six months) is found to result in deterioration of the bags by chemical action, and bulk storage is preferable when immediate shipment is not possible. Obviously such storage must be in dry godowns. Bulk storage and consequent rehandling has the disadvantage of breakage leading to an increase of smalls and dust; rescreening may become necessary.

USES OF COCONUT SHELL CHARCOAL

Shell charcoal was developed from a minor local product used as fuel and in gas producers to a general commercial product owing to its value as a raw material for the production of Active Carbon. This forms the subject of the second section of this article.

Before concluding this section, however, brief reference must be made to the possibilities of coconut shell charcoal as a fuel for gas producers for motor vehicles.

GAS PRODUCERS FOR MOTOR VEHICLES

It is not necessary here to discuss at any length the general subject of gas producers for motor vehicles, especially as a detailed review has recently been published by the Imperial Forestry Bureau (1942).⁶⁵ Reference may also be made to a leaflet of the Forest Research Institute, Dehra Dun (1942),⁶⁶ on

the subject of the quality of charcoal required for producer gas plants.

Little study seems to have been devoted to the possible use of coconut shell charcoal for this purpose. The writer made certain enquiries in Ceylon and S. India in 1942-43 from users of automobile gas producers, some of whom stated that commercial shell charcoal tried by them contained too high a percentage of tar products with the result that the gas filters became clogged very quickly and tar fouling of the pistons and valves occurred. The distillative products of shells differ somewhat from those of wood (see Article V of this series) and it is possible that their more phenolic nature tending to resinous tar formation may be a drawback to the use of shell charcoal in this field. On the other hand, it is possible that a higher grade of retort charcoal would be suitable and it certainly seems desirable that further investigations should be carried out. The utilization of shell charcoal in this way would be of economic interest to coconut-growing countries. The writer would be glad to hear of any information obtained from trials on this subject carried out by investigators in India.

REGINALD CHILD.

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JOURNAL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

It is a matter of great satisfaction that during the short span of two years and a half, the *Journal* has established itself not only as the official organ of the Council of Scientific and Industrial Research but also as the *Journal* to whom the world will look to as the medium reflecting the progress of industrial research in this country. The *Journal*, published as a quarterly at its inception, has now been made into a monthly to meet the growing demand for the prompt publication of the results of industrial research pursued in the various labo-

ratories. Further, the *Journal* has been largely responsible for establishing the long-felt *liaison* between the industrialists and the scientific workers.

The get-up and format of the *Journal* have been greatly improved and considering the difficult times during which this journalistic enterprise has been launched, the *Journal* has to its credit a record of substantial progress. The Editorial Board and the distinguished Editor deserve to be heartily congratulated.