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The Uniquity of Coir Retting

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COIR, a versatile hard fibre obtained from the fibrous husks of coconuts, is known to the world from ancient times. The oldest recorded evidence that the practice of extraction of this fibre began centuries ago in the coastal areas of the south-western peninsular India may be found in the travelogue of the fourteenth-century Persian traveller Ibn Batuta[1]. The annual production of coir throughout the world is estimated at 2,90,000 tonnes. India accounts for more than 50% of this, her annual production being of the order of 1,60,000 tonnes. Indian coir enters the world markets in the form of raw fibre, spun yarn and woven mats, mattings, rugs and carpets, coir rope, curled coir and a variety of other articles manufactured out of it. To date India enjoys a monopoly position in the production of retted fibre, curled coir, yarn, door mats, mattings, carpets and rugs, cordages and ropes, rubberized coir, etc., though some other countries like Ceylon and Philippines pose a threat to this industry which fetches 140 million rupees per year as foreign exchange[2].

According to the method of extraction and use, the product is classified into three main classes. The fine yarn fibre or the so-called mat fibre is the finest and longest variety obtained from the retted husks and is extensively used for spinning coir yarns and for weaving mats and mattings. The thicker and coarser variety extracted from dry coconut husks is known as the bristle fibre and is suitable for the manufacture of brushes and brooms. Likewise, mattress fibre, extracted from ripe and dry husks, is mainly used for filling mattresses and in upholstry industry. Whatever be the manner in which it is extracted, because of its high resistance to microbial decay and impervious nature, coir is preferred to other plant fibres for multiple types of operations in sea water. Among the other uses to which coir is put is the manufacture of fabricated cement articles[3], roofing boards[4], hardboards[5], heat-insulating materials[6], thermosetting plastics[7] and rubberized coir. Thus, the coir industry has a vital role in the nation's economy for the manufacture of a large variety of products of day-to-day use. Besides, the industry provides employment for nearly half a million people in Kerala State alone (Coir Board, Cochin, personal communication). The industry has now been extended to Bengal and Mysore States. In fact, more than 99% of the total quantity of coir yarn entering the world market is supplied by India and as much as 80% is exported the world over in the form of finished goods like mats, mattings, rugs, carpets, etc.

The Retting Process

The raw material for the coir industry is the coconut husk which represents the entire fibrous material enveloping the fruit constituting both the exocarp and the mesocarp. Retting in water of this material causes separation of the leathery exocarp from the fibrous mesocarp, which is nothing but an assemblage of individual fibres with the cork-like parenchymatous cells containing the cementing materials dispersed throughout the mass. The elastic cellular cork-like material forming the non-fibrous tissue of the husk is generally referred to as the coconut pith and accounts for as much as 50-70% of the total weight of the husk; the remainder constitutes pectic substances, polyphenols, etc. Thus, 1000 husks, on an average, yield only 82 kg of coir. It is important to consider in this context the economics of coir extraction. Whereas 1000 husks would cost about Rs 40 only the same number of retted husks would fetch Rs 75, but the coir of average quality derived from the same number of husks would fetch as much as Rs 110.

The age of the mesocarp, i.e. the husks, is an important factor in the yield of good quality fibre. According to Fowler and Marsden[8], the mesocarp of the ripe coconut should be preferred for the extraction of coir, whereas Copeland is of the view that husks from almost near ripe nuts produce the best fibres[9]. In the investigations carried out in our laboratory, husks of 11 months' old fruits were used with uniform success.

The separation of the tightly bound fibres can be achieved by mechanical, biological or chemical means. The traditional method of natural retting practised in India consists in soaking the husks in saline backwaters. For this reason and because of the intense cultivation of the trees, this industry is concentrated along the coastal belt of Kerala. The practice in Anjengo area is to arrange the husks in coir nets into bundles and float them freely in the backwaters until they get soaked, become heavy and gradually sink to the bottom. Often, the bundles are weighted down by piling on their tops mud and slime collected from the bottom of the retting yards. The method followed in the areas adjacent to Ashtamudy differs in that the husks are weighted down inside bamboo stake enclosures within the shallow backwaters. Yet another common method practised is to steep the husks into pits dug within the reach of tidal action of the backwaters. Whatever the practice, the principle involved is to steep the husks for retting in sea water or brackish water or brackish mud. Interestingly, unlike other plant fibres which get released within a few days of retting, coir fibre takes a long time to get separated from the binding material, the retting time varying from 4 to 12 months, depending on the area and the variety of yarns required to be produced. In fact, the quality of the product is judged by the area from which it is derived. According to a survey report[10], majority of the retters (67%) ret their husks for a period ranging from 7 to 9 months, 25% ret their husks for more than 9 months and the remainder (8%) do so for 2-6 months.

Extraction of the Fibre

For extraction of the fibre, properly retted husks are removed from the rets, washed free of adhering slime, mud and/or sand and the exocarp is then easily peeled off with hand. The husks are beaten thereafter on granite stones with wooden mallets in order to separate the fibre from the cork and pith. A further cleaning by hand, rewashing in water and lightly beating again are also often resorted to with a view to getting rid of the pith adhering to the fibres. The fibres thus obtained are then spread out in the sun to dry.

The extraction of bristle fibre is facilitated by an initial crushing of the husks before they are soaked in shallow pits or in concrete tanks for 3-6 weeks. The separation of the fibres from the soaked husks is then brought about by feeding them on to breaker drums fitted with spikes. The drums are driven at a high speed in opposite directions to effect the separation of the long and short fibres. The bristle fibres passing between the drums are collected and passed through another pair of drums having closer nails for cleaning, washing and drying. This method is practised in Ceylon[11,12].

Though not found useful because of the cost involved, various chemical methods, as an alternative to the traditional method of retting, are available in literature. In all the chemical methods, the husks are first split or crushed as much as possible by the use of machine or rollers[13,14]. In one of the methods, called the Nanji process[15], the partially crushed green and dry husks are treated under pressure with sodium sulphate or sodium carbonate containing traces of aluminium sulphate for 2 hr, whereby the fibre is loosened from pith and separated by washing. In Elod and Thomas method[13,15-17], the fibre separation is achieved by mechanical means after the crushed husks have been twice immersed in hot water, slaked lime or similar material during second immersion, by which means discoloration, if any, is avoided, whereas in the Rowell process[14], the husks are subjected to high pressure steam in specially constructed chambers, whereby the fibres get loose and separated.

In the Van der Jagt process, the mechanically opened husks are boiled with 5% caustic soda solution followed by squeezing[13,18]. The compressed fibres are then reopened, softened and cleaned. By this method it is claimed that the fibres can be obtained in marketable form in less than 2 hr.

In the Hayes-Gratze process[14], split husks are immersed in water, pressed and boiled in a solution of HG ionized oil in water. Coconut oil can be used for the preparation of ionized oil[13], but the process becomes extremely costly. According to a report by Jayasankar and Menon[19] on the effect of 20 chemicals on the retting of coconut husk, the main advantages of the chemical processes are: (1) saving in time, (2) higher yield, and (3) products of uniform quality. The main disadvantage is the high cost involved. Mechanical means, either alone or in conjunction with chemicals, have also received wide attention[20-23].

Processing of the Fibre

Coir fibre is processed on similar lines as other more common natural fibres, the steps essentially consisting of dry processing, viz. spinning and weaving followed by wet processing, which includes dyeing and printing. A detailed account of the procedures has been given by Menon and Pandalai[13]. Briefly stated, in 'hand spinning', two strands obtained by clockwise twist of the hand are made into two-ply yarn by giving a counter-twist and the process is continued. 'Wheel spinning' introduced in 1859 is an improvement over this method[24]. The device consists of two wheels, one stationary and the other mobile. Slivers of the coir fibre are made into a loop and fixed to a notch of one of the spindles attached to the stationary wheel. Rotation of the wheel and continuous feeding of fibre of uniform thickness result in the formation of strands, which are tied together to the notch of the movable wheel which is then rotated to give a counter-twist with slight movement towards the stationary wheel.

For the manufacture of mattings, the operation is similar to pit-loom weaving without fly-shuttle arrangements. Close weaving is effected by the insertion of slick through every shed, before the weft is passed. While the designs in the matting are made by weft yarn, the warp is used in the design of carpets. Rugs are made by cutting the matting to the required size with the edges either stitched or covered with hessian webbing. Pit mats are made on wooden frames to the required sizes and the edges braided. Further finishing includes shearing and trimming by scissors and stoving by heating a mixture of sulphur and alum in closed chambers.

Dyeing of the coir fibre can be carried out in their loose fibrous state on yarns or on the woven materials. A wide variety of colouring matters, including acid, acid-mordant, basic, substantive, sulphur and vat dyes, as also a few of the neutral colouring matters, are available for the dyeing operation[25-29]. Basic dyes are generally used for achieving brightness of shade, whereas for better fastness with reasonably bright shade, selected acid dyes are preferred. The optimum conditions of dyeing vary with different classes of dyes. Pretreatment of an oxidative or reductive nature is known to lighten the natural colour of the fibre and is often resorted to, as it imparts improved tone and brightness to the dyed products[30-33].

Physical and Chemical Properties of the Fibre

Coir fibre is multicellular in nature and measures 12-14 μ in diameter[34]. The length to thickness ratio is found to be 35 and cells on the fibre surface are occasionally covered with silicized stegmata about 15 μ in diameter. According to Thomas and Hevitt[35], the cellulose chains in the secondary walls of the cells form the helical spirals of crystallites, making an angle of 45° with the fibre axis. Alternatively, the pattern could be interpreted as two distinct spirals at right angles to each other, each running at 45° in opposite directions. X-ray diffraction studies[36] revealed that the fibre obtained from green husks does not differ essentially from that derived from dry husks. Delignification of the fibre also does not seem to have any effect on the diffraction pattern.

Chemically, coir is composed of cellulose, cellulosan, lignin and hemicellulose[37]. The percentages of these constituents, however, vary largely, depending upon the age of the nut from which the coir is derived[38]. In this respect, the coir fibre differs from jute in that the latter has a uniform chemical composition at all stages of the plant growth, from the earliest stage to maturity[39]. Based on the analysis of tender coconut, Menon[37] concluded that the aromatic compounds of phenolic nature present in the husks serve as lignin precursors. The nature of the lignin complex has been studied by Menon[37] and the various constituents of the fibre are suggested to be in some form of association or in combination[31].

Based on the principle of O'Neil tester for cotton fibre[40], Mathai *et al.*[41] fabricated an apparatus for testing the breaking load of single coir fibres. Exhaustive study of the various physical properties of the coir fibre, viz. tenacity, extension at breaking load, torsional rigidity and abrasion resistance, was carried out by Prabhu[42-44]. Based on colour differences, Van Vreaswijk[45] made an attempt to grade the fineness and strength of fibre and yarn.

Biology of Coir Retting

Ever since the first isolation of a bacterium associated with the retting of flax by Winogradsky and Friebes[46] in 1895, it has been generally accepted that microorganisms are the chief agents involved in all natural retting processes. Retting, it has been well established, brings about loosening of the fibre from the surrounding non-fibrous tissues through the degradation of the binding materials, collectively referred to as pectic substances. In a broad sense, the process could be achieved in two ways, viz. dew retting or land retting and water retting. Dew retting is believed to be brought about mainly by fungi, where the system is exposed to air. Water retting, on the other hand, is facilitated by bacteria. The conventional retting process may be divided into three phases: (i) the physical phase, (ii) the biological phase, and (iii) the mechanical phase[47], though it is hard to draw a line of demarcation between the physical and biological phases.

Kluyver and Reksohadiprodjo[48] were, probably, the first to propose the involvement of microorganisms in the retting of coir, but they provided no information on the subject. Pioneering work on the microbiology of coir retting was done by Fowler and Marsden[8]. It is pertinent to mention in this context that Dr Gilbert Fowler was the first Professor of Biochemistry at this Institute and his studies on the isolation of microorganisms from retted husks resulted in the isolation of a bacterium closely resembling *Sphaerotilis* species, besides another short bacterium and a yeast. Though the present authors have not come across any *Sphaerotilis* type of organism in the rets, the observation by Fowler and Marsden of short bacteria and yeast is of considerable significance in that these organisms appear to be the most dominant and important organisms from the point of view of coir retting. Fowler and Marsden were also the first investigators to attribute the difference observed in the quality of fibre harvested from different retting centres to the differences in the activities of the distinct flora associated with these processes. However, their view, on the basis of the general theory of Fowler and Christie[49], that the distinct flora associated with retting under different conditions are contributed by the husks themselves is not tenable in the light of the experimental data accumulated since then.

Heyn was another early investigator in this field. He isolated from retting liquors six strains of bacteria, viz. *Diplococcus* sp., *Vibrio* sp., three strains of clostridia and two unidentified yeasts[50]. Restricting their studies to fungi, Jayasankar and Menon[51,52] identified species of *Aspergillus*, *Penicillium*, *Fusarium*, *Trichoderma* and *Mucor* as those associated with the retting of coconut husks at different retting yards of Kerala.

With this much of previous fragmentary information, a systematic study of the nature and characteristics of the organisms bringing about retting of coir and the biochemical transformations involved in the process was initiated in our laboratory over a decade ago. Prior to this, Betrabet and Bhat[53,54] had established that *Pseudomonas* were the most dominant and vital species of bacteria concerned in the retting of *Malachara capitata* and *Hibiscus cannabinus* plant straws. Work on similar lines with sisal (Agave) also brought to light the predominance in the ret liquors of *Bacillus*, *Erwinia*, *Flavobacterium*, *Corynebacterium*, *Xanthomonas*, *Aeromonas* and *Micrococcus* species[55].

Initial investigations on coir retting were confined to systematic enumeration and isolation of aerobic ret microflora. Rets for these were set with single husks, keeping the husk-liquor ratio at 1: 10. The gross physical appearance of a typical sample of ret liquor obtained from the natural retting yards, the predominant flora observable on stained smears directly under the microscope, *p*H and the average count per ml of the sample are given in Table 1. It was found that the coir retting system consistently harboured, in addition to the bacterial flora, sizeable yeast population which merited attention. The mixed population of yeasts and bacteria was also observed in the ret liquors and retted husks drawn from Kerala retting yards. The series of rets worked out in the laboratory comprised (i) husks steeped in distilled water, (ii) husks steeped in 1% brine, and (iii) husks steeped in brackish water prepared in such a way and with such minerals as to approximate in chemical composition the sea water, in which the commercial steepings are carried out.

Microbiological examination revealed the dominant aerobic bacteria of coir rets to be made up of the genera *Escherichia*, *Pseudomonas*, *Micrococcus*, *Bacillus*, *Paracolobactrum* and *Alcaligenes*, the subsidiary flora associated therewith being of the genera *Achromobacter*, *Aerobacter* and *Corynebacterium* (Table 2). The predominant yeast species of coir rets were found to be *Saccharomyces fructuum*,

TABLE 1 — CHARACTERISTICS OF DIFFERENT SAMPLES OF NATURAL RETS

Source of sample	Appearance and dominant flora	*p*H	Counts per ml	
			Bacteria	Yeasts
Thiruvallam	Somewhat turbid, dull brown colour, predominantly *Bacillus* sp. gram negative rods and gram positive cocci	6·8	$5\cdot8\times10^{5}$	$1\cdot97\times10^{3}$
Kanniyapuram	Turbid, dark brown, predominantly *Bacillus* sp. and gram negative rods	6·5	$2\cdot1\times10^{6}$	$9\cdot7\times10^{3}$
Nedumganda	Clear, yellowish brown, predominantly gram positive cocci and gram negative rods	6·5	$5\cdot6\times10^{6}$	$1\cdot63\times10^{2}$
Mangad	do	6·7	$10\cdot8\times10^{7}$	$4\cdot7\times10^{2}$
Alapat	Somewhat turbid, dark brown, predominantly *Bacillus* sp. gram negative rods and gram positive cocci	6·4	$1\cdot92\times10^{5}$	$5\cdot1\times10^{3}$
Ashtamudi	Clear liquid, dark brown, predominantly *Bacillus* sp. and gram positive cocci	6·1	$2\cdot93\times10^{6}$	$1\cdot38\times10^{3}$
Vayalar	Slightly turbid, yellowish brown, predominantly *Bacillus* sp. and gram negative rods with yeasts	5·8	$6\cdot5\times10^{6}$	$1\cdot8\times10^{4}$

TABLE 2 — BACTERIAL FLORA OF COIR RETS

Genera	No. of isolates	% of isolates
Escherichia	129	26
Pseudomonas	92	19
Micrococcus	87	18
Bacillus	68	14
Paracolobactrum	50	10
Alcaligenes	48	10
Achromobacter	7	1
Aerobacter	4	1
Corynebacterium	3	1

TABLE 3 — YEAST FLORA OF COIR RETS

Species	No. of strains	% of isolates
Saccharomyces fructuum	38	24
Debaryomyces hansenii	26	16
D. kloeckeri	25	16
Cryptococcus diffluens	23	14
Rhodotorula flava	23	14
R. glutinis	15	9
Debaryomyces nicotianae	7	4
Hansenula schneggii	3	2

Debaryomyces hansenii, D. kloeckeri, Cryptococcus diffluence; Rhodotorula glutinis and *R. flavus* and the less dominant was *Debaryomyces nicotianae* (Table 3). Later investigations, making use of several husks in each container but keeping the husk-liquor ratio constant, revealed the presence in them of yeasts belonging to the species *Candida, Cryptococcus* and *Rhodotorula* and bacteria belonging to the genera *Achromobacter*, though this may be purely incidental.

Mitscherlich[56] was perhaps the first to correlate the change brought about by retting of plant tissues to the pectinolytic activity of microorganisms, in spite of the considerable uncertainty which existed in the past regarding the minimum molecular weight and chemical nature itself of pectin. The term pectic substances was indeed used in defining them because of the heterogeneity of the material. Recently, however, it has been accepted that the basic structure of these carbohydrate derivatives comprises polygalacturonic acid, though the exact nature is still obscure. While some workers[57-59] hold the view that they are composed of other carbohydrate moieties or certain groups attached to the chains of anhydrogalacturonic acid units, others believe that the nonuronides represent only impurities and not pectic substances[60-64]. Several reviews are available on pectic substances[65-72] and their biological degradation[73-84].

Biochemical Aspects

The principal change brought about in the plant tissue during retting is the breakdown of pectic substances which form the chief constituent of the middle lamellae between the fibre cells and the cementing material. Varrier and Moudgill[85] pointed out that during progression of retting, there is a fall in pectin, pentosan, fat and tannin contents and that practically no loss occurs in the cellulose and lignin contents. Their findings led them to the conclusion that the pectins or the pectocellulose, which probably form the binding materials, undergo a microbiological degradation during the process. Added support for this kind of transformation was provided by the work of Heyn[50]. Baruah and Baruah[86,87] also held the view that coir retting is essentially brought about by the degradation of pectin. However, Menon[38] was of the opinion that biological retting of coconut husks differs from that of other fibrous materials in that it is not confined to pectin decomposition alone but extends also to the disintegration of the phenolic cement binding the fibres together.

One of the important observations made in the retting of husks was that polyphenols from the husks get constantly leached out into the surrounding steep liquors during the course of retting[24]. The relatively high percentage of such polyphenols in coconut husks[50,85] has been pointed out by Menon and Pandalai[13] as the very reason for the delay (4-12 months) in the completion of the retting process. A proximate analysis of the husks (derived from 10-12 months' old nuts) best suited for retting and production of good fibre showed polyphenols and pectins to be the more important constituents, as they represented respectively as much as 75-76 and 16-17 g/kg of husk materials[24,88]. For determining the end point of retting, it was considered essential to estimate residual polyphenols and pectins in the retting husks. For this purpose, several series of laboratory rets were set up, and at monthly intervals for four months the husks were analysed for the fall in the levels of these compounds. The results indicated positive correlation between the progress or the extent of retting and the rate of disappearance of these compounds (Fig. 1).

Examination of the aerobic microflora of coir rets for their pectinolytic activity revealed the general ability of several bacterial genera such as *Aerobacter*, *Bacillus*, *Escherichia*, *Micrococcus* and *Paracolobactrum* to be particularly conspicuous in this respect. Though the ability to degrade pectin is not as widespread among the yeasts as in bacteria[84], Bilimoria and Bhat had demonstrated pectinolytic activity in *Cryptococcus laurentii*, a marine yeast[89]. Hydrolysis of pectin by certain other salt-tolerant yeasts has also been reported[90,91]. Of the yeasts encountered in coir rets, this property was restricted to be the genera *Rhodotorula* and *Cryptococcus*[24].

Enrichment of the retting medium with pectin as the sole source of carbon and incubation with ret liquors resulted in the isolation of 330 bacterial cultures from which 110 were taken up for further examination, leading to their specific identification[24,88]. Those found to be pectinolytic were *Aerobacter cloacae*, *Arthrobacter pascens* var. *pectinolyticus*, *Bacillus subtilis*, *Escherichia coli*, *E. freundii* and *Paracolobactrum aerogenoides*. Among them, *Arthrobacter pascens* var. *pectinolyticus* and *Bacillus* sp. could attack pectin by virtue of their possessing polygalacturonase (PG) and pectin *trans*-eliminase (PTE). The enzymatic make-up of the *Micrococcus* isolates from coir rets differed distinctly from that of *M. pectinolyticus*[55] (isolated from sisal rets) inasmuch as the latter elaborated the enzymes depolymerase and pectinmethyl esterase (PME)[92], whereas the former showed the presence of PME, PG and PTE[93]. Interestingly, under the conditions of test, none of the isolates belonging to the coliaerogenes group were found to elaborate the enzyme PTE.

After establishing the presence of pectinolytic enzymes among the positive isolates, a detailed study of polygalacturonic acid *trans*-eliminase (PATE) of *Arthrobacter pascens* var. *pectinolyticus* was taken up[24] inasmuch as *Arthrobacter* species were not known to be pectinolytic. The *p*H optima of the intracellular and extracellular enzyme were observed to vary between 7·0 and 9·0 and the enzymes were found to depend on Ca^{2+} for maximal activity. The PATE of *A. pascens* var. *pectinolyticus* resembled other bacterial pectinolytic enzymes[94-101] in its general properties, but differed from the fungal enzymes in many respects[102,103].

Most of the yeast isolates contained PG and PE, but not PTE or PATE, with the exception of *Rhodotorula glutinis*, which did not exhibit PE activity. These results are in agreement with that of Vaughn[104]. The constitutive PG from yeast culture filtrates showed maximal activity in the *p*H range 4·5-5·0, while the PE activity increased with increase in *p*H towards the alkaline side.

The gradual fall in the high polyphenol content of the husks during the progress of retting led to ascertaining the nature of the polyphenols present in the husk and the type of microflora associated with the process. That simple phenols may be found dispersed amidst the built-in units of polyphenols of plant origin has been indicated earlier[105]. Based on the colour reactions with alum, ferrous sulphate, bromine water and *p*-dimethylaminobenzaldehyde, the polyphenols of the husks were identified as catechin-like tannins[24]. Also, the fact that the product gave intense red colour on treatment with molybdate in the presence of $NaNO_2$ and trichloroacetic acid[106] proved the presence of a benzene nucleus having two vicinal hydroxyl groups[24] in the molecule. The occurrence of phloroglucinol in the polyphenol fraction obtained from the husk was also established by specific colour tests[107]. Enrichment with phenols as the only source of carbon, using coir ret liquor as inoculum, resulted in the isolation of *Pseudomonas desmolytica*, *P. fragi*, *P. dacunhae* and *Micrococcus varians*[108].

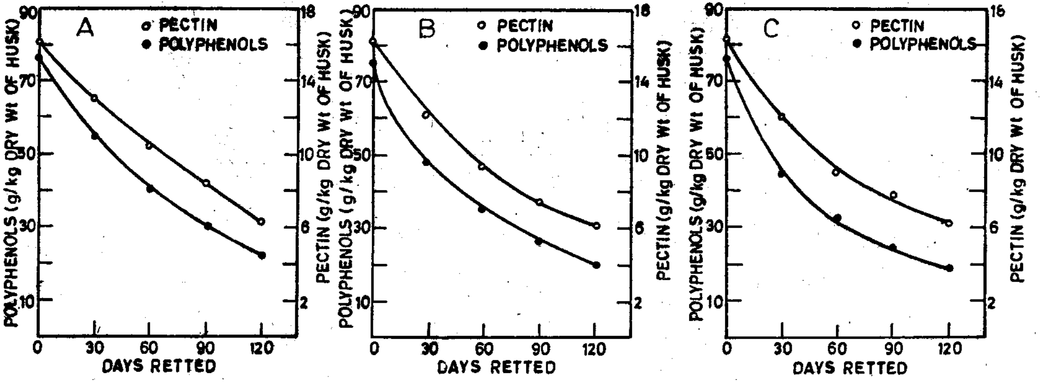

Fig. 1 — Rate of degradation of pectin and polyphenols in laboratory rets (according to Jayasankar[24]) [(A) Husks steeped in distilled water; (B) husks steeped in distilled water containing 1% NaCl; and (C) husks steeped in artificial brackish water approximating in its chemical composition to that of natural retting environments]

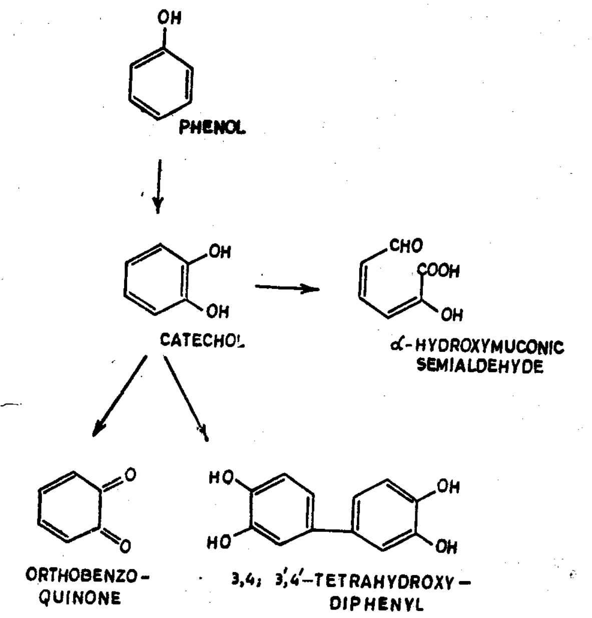

Chart 1 — Overall mode of attack on phenol (*M. varians*)

Inasmuch as the oxidation of phenol by pseudomonads has been studied by many, including workers in this laboratory, further work was confined only to *Micrococcus varians*. This bacterium gave good growth in a medium containing 1·2 mg/ml phenol. A crude enzyme preparation was, therefore, made from this species and it was found to contain a phenol hydroxylating system. The crude preparations also catalysed a metapyrocatechase type of ring fission of catechol (Chart 1). The organism, besides, produced a diffusible melanin-like pigment, identified as 3,4,3',4'-tetrahydroxydiphenyl, in the growth medium containing phenol as well as many other aromatic compounds. The formation of this compound was proved to be due to the presence of a copper-dependent polyphenol oxidase system in the organism, as the copper-chelating agents like salicylaldoxime and diethyldithiocarbomate inhibited the production of this pigment[108]. This black compound, in fact, may be one of the causes for the discoloration of coir.

It is significant that whereas the phenol enrichments seeded with samples of ret liquor promoted the development of only bacterial isolates[108], the catechol enrichments resulted in the exclusive isolation of one yeast, viz. *Debaryomyces hansenii*[109]. This organism displayed remarkable ability to grow on phenol and catechol as well as some related aromatic compounds as the sole sources of carbon. Significantly, it exhibited a very high degree of tolerance for both catechol and phenol (Table 4).

Table 4 — Optimum Concentration and Tolerance Limit of Phenol and Catechol for *D. hansenii* Isolates

Substrate added	Concentration, mg/ml	
	Maximum growth	Tolerance limit*
Catechol	2·4	4·0
Phenol	1·5	2·6

*Beyond which no visible growth occurred.

The finding that *Micrococcus* species are involved in the oxidation of phenol[108] as well as pectin[93] confers a uniqueness on coir fermentation all its own. Added to this the association of unusual bacteria[108] and yeasts[109] in the decomposition of pectin and phenolics respectively bestows on the microflora of the coir rets a distinctive character hitherto unknown in other rets so far studied.

Factors Effecting Retting

Water — Coir retting is an art practised by retters for generations in brine. According to Fowler and Christie[49], salinity of water is of little or no consequence in determining the course of retting or the quality of the product. Choudhary[110] also could not find any relationship between the salt content of the water used for soaking and the quality of the resultant fibre. On the contrary, Pandalai *et al.*[111] made the observation that retting takes place quickly and efficiently only in brackish waters, i.e. in the presence of NaCl, thus sharing the belief prevalent among the people engaged in the trade that salt is indispensable in the retting process.

The results obtained in this laboratory, however, provided no evidence for the beneficial effect of NaCl (ref. 24). In artificial rets, virtually no difference was observed in the rets or retting time taken in the presence or absence of NaCl. The extent of decomposition of pectin and polyphenols (taken as a criterion of the extent of retting) in the fresh water was more or less comparable to that of brackish rets. The view that NaCl is not essential for retting was further strengthened by the finding that the fibres obtained from different rets were alike in quality. Recent experiments conducted on a larger scale (underway since two years) have also confirmed these findings. All the results suggest that setting up of retting yards in hinterland, where no saltish or brackish water is available, is feasible and renders further exploitation of coconut husks possible which has hitherto been considered as out of question.

Periodic flushing of the ret liquor — Though an attempt was made by Heyn[50] in Java to study the influence of renewal of the ret liquor from the retting tanks, he provided no details about the frequency of this renewal or the material-liquor ratio maintained. A series of experiments were conducted in this laboratory to ascertain whether or not a periodic flushing of ret liquor is conducive to the production of good quality fibre[24]. In all the experiments tap water was used (as previous studies indicated that salt was not essential) and the liquor in the different rets was renewed at intervals of 3, 6, 10 and 15 days by siphoning out the ret effluents, followed by replacement of the liquid to the original volume with fresh water. Stagnant rets, wherefrom the liquors were not flushed out, served as controls. The progress of retting in the series was followed by estimating the residual pectin and polyphenols for four months at monthly intervals (Figs. 2 and 3). Judged by the overall performance, it appeared that renewal of ret liquor at 10-day

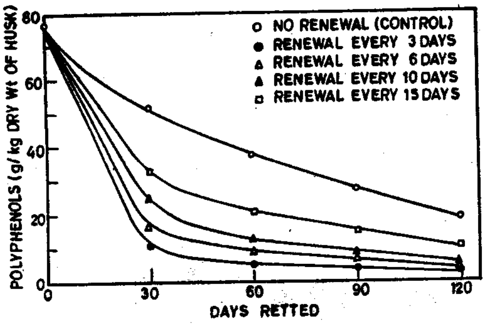

Fig. 2 — Influence of periodic flushing of ret liquor on the polyphenol content of husk

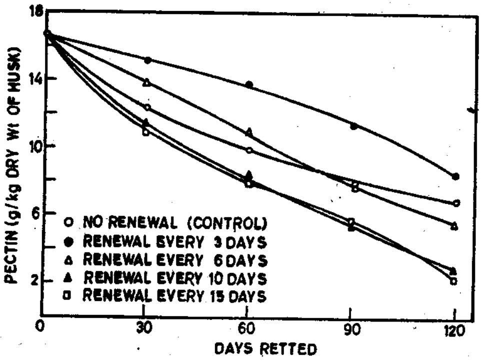

Fig. 3 — Influence of periodic flushing of ret liquor on the pectin content of husk

intervals is optimal for efficient retting under laboratory conditions. The effect of flushing of the ret liquor on the colour of the resultant fibre further confirmed the desirability of periodic flushing. Based on colour, the fibre obtained from periodically flushed vats was superior even to 'No. 1' commercial grade (boxed colour standards), whereas the fibres from stagnant rets were inferior even to grade III material.

These results could be correlated to the conditions prevailing in coastal Kerala, where the tidal waves help in leaching out the polyphenols. This, perhaps, also explains the difference in the quality of coir obtained from different retting yards.

Aeration — In the case of other natural fibres, aerating the retting environment has been attempted to accelerate the process. Aeration of the retting water was found to have no effect on the time taken for retting or the quality of the fibre from *Hibiscus cannabinus*[112]. On the other hand, partial aerobic conditions were found to be beneficial for the retting of jute[113]. In pilot experiments and field trials, it has been found that the retting water can be reused for as many as 40 batches of flax straw by aerating the ret systems[114].

Since the microflora associated with coir retting were found to be mostly aerobic in nature[24], studies to ascertain the effect of aerating the retting environment were undertaken in this laboratory. The results indicated that aeration promotes both bacterial and yeast growth (Figs. 4 and 5). Judged by colour, it was found that the aerated rets yielded superior quality fibre. It appears that aeration leads to faster degradation of the products of fermentation, which, under normal conditions, tend to accumulate and thereby adversely affect the quality of the fibre.

Crushing the husks prior to steeping — Studies on the effect of crushing the husks prior to steeping revealed that the retting time is reduced by half when the husks are crushed (unpublished data). At Alumpeedika, near Ochira in Kerala, an intermediate crushing is in fact practised from January to May. The husks are soaked as usual for about two months, during which time most of the water-extractable tannins are removed, followed by crushing of the husks with wooden mallets and a subsequent soaking for another two months[115]. This results in the completion of the retting in 4-5 months instead of 7-8 months normally required.

The results of studies conducted by the authors showed that the degradation of polyphenols and pectin was much faster when the husks were crushed than when they were uncrushed. However, there was little or no difference in the retting patterns when the material-liquor ratio was varied. Also, it was found that precrushing of husks and aeration resulted in an increase in the microflora

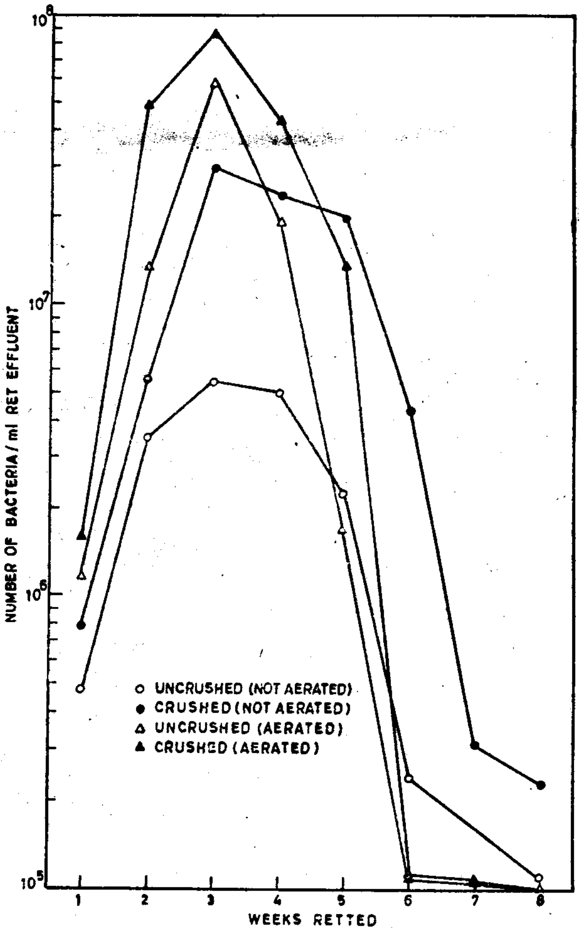

Fig. 4 — Incidence of bacteria during the progress of retting [The numbers of bacteria are plotted on a log scale]

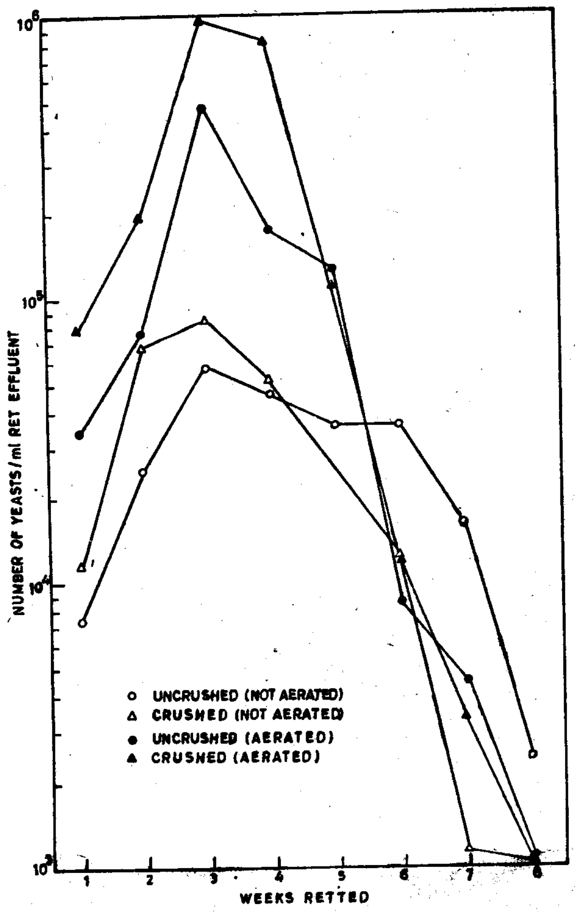

Fig. 5 — Incidence of yeast during the progress of retting [The numbers of yeasts are plotted on a log scale]

(both yeasts and bacteria) during the progress of retting (Figs. 4 and 5). To conclude, the results of the past ten years of investigation have led much to the understanding of the coir retting as a microbiological process and to finding ways and means by which the retting period could be reduced without affecting the quality of the product.

Summary

The various methods followed for the retting of coconut husk, the biology and biochemistry of retting, the factors influencing the production of good fibre and the types of articles manufactured therefrom are reviewed. Different types of microorganisms involved in coir retting and their role in the degradation of pectin and polyphenols are discussed. The long time taken for retting of husks has been shown to be due to their polyphenol contents. That sea water or brackish water is not essential and that fresh water is equally suitable for this retting has been clearly brought out.

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