Chapter I

Introduction
Coir is a natural lignocellulosic hard fibre extracted from the outer covering of the coconut “Cocos nucifera” of the family Palmae. It is ecofriendly and therefore is advantageous for environmental operations over synthetics. Its inherent properties (Table 1.1, 1.2) robustness, resistance to biodegradation, low raw material price are suitable for sustainable development (Boben et al., 1999).

India is the largest producer of coconut in the world with a production of 13,968 million nuts against the global production of 53,598 million (Kumar, 1999). Coconut cultivation and production of nuts is prevalent in the different states and union territories of India (Table 1.3). The coconut has to be dehusked to remove the outer covering, which consists of the exocarp and the mesocarp. This outer covering, the husk, is the source of the “coir fibre” which is the raw material for the coir industry.
### Table 1.1 - Physical Properties of the coir fibre.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Ultimates</strong></td>
<td></td>
</tr>
<tr>
<td>Length in mm</td>
<td>0.6</td>
</tr>
<tr>
<td>Diameter / Width (microns)</td>
<td>16</td>
</tr>
<tr>
<td><strong>2. Single Fibre</strong></td>
<td></td>
</tr>
<tr>
<td>Length in inches</td>
<td>6-8</td>
</tr>
<tr>
<td>Density (gm/cc)</td>
<td>1.40</td>
</tr>
<tr>
<td>Tenacity (gm/tex)</td>
<td>10.0</td>
</tr>
<tr>
<td>Breaking Elongation %</td>
<td>30</td>
</tr>
<tr>
<td>Moisture Regain at [65% R.H. (%)]</td>
<td>10.5</td>
</tr>
<tr>
<td>Swelling in water (dia)</td>
<td>5%</td>
</tr>
</tbody>
</table>

*Joseph & Sarma, 1997*
Table 1.2 - Chemical composition of coir fibre

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Solubles</td>
<td>5.25 %</td>
</tr>
<tr>
<td>Pectin and related compounds</td>
<td>3.00 %</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>0.25 %</td>
</tr>
<tr>
<td>Lignin</td>
<td>45.84 %</td>
</tr>
<tr>
<td>Cellulose</td>
<td>43.44 %</td>
</tr>
<tr>
<td>Ash</td>
<td>2.22 %</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.00 %</strong></td>
</tr>
</tbody>
</table>
Table 1.3- INDIA: Coconut cultivation and production of nuts.  
(1996-97)

<table>
<thead>
<tr>
<th>State/Union Territory</th>
<th>Area (thousand hectares)</th>
<th>Production (million nuts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>90</td>
<td>685.9</td>
</tr>
<tr>
<td>Assam</td>
<td>19.6</td>
<td>118.4</td>
</tr>
<tr>
<td>Goa</td>
<td>24.7</td>
<td>119.0</td>
</tr>
<tr>
<td>Karnataka</td>
<td>290</td>
<td>1493.0</td>
</tr>
<tr>
<td>Kerala</td>
<td>980</td>
<td>5759.0</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>15.1</td>
<td>264.5</td>
</tr>
<tr>
<td>Orissa</td>
<td>53</td>
<td>271.5</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>328</td>
<td>3811.6</td>
</tr>
<tr>
<td>Tripura</td>
<td>8.8</td>
<td>5.9</td>
</tr>
<tr>
<td>West Bengal</td>
<td>23.7</td>
<td>313.1</td>
</tr>
<tr>
<td>Andaman &amp; Nicobar</td>
<td>24.7</td>
<td>86.6</td>
</tr>
<tr>
<td>Lakshadweep</td>
<td>2.8</td>
<td>27.5</td>
</tr>
<tr>
<td>Pondicherry</td>
<td>2.1</td>
<td>31.5</td>
</tr>
<tr>
<td><strong>All India</strong></td>
<td><strong>1892.5</strong></td>
<td><strong>12987.5</strong></td>
</tr>
</tbody>
</table>

COIR BOARD
1.1. Importance of coir

The coir industry is an export and employment oriented one and the annual global requirement of coir fibre is about 78900 tonnes (Kumar, 1999). This export oriented small-scale coir industry fetches a foreign exchange earning of over 200 crores of rupees per annum for India (Table 1.4). It forms a major segment of village & small industries sector in terms of production and employment. It is very important in the national context on account of the employment that it provides in rural areas to the economically weaker sections of the population. The coir sector provides employment to over five lakh households in Kerala alone, the majority being women engaged in the spinning of fibre to yarn.

The fibre is consumed both in the domestic and international market as fibre, yarn, coir products, rope, curled coir and rubberized coir (Table 1.5). Other diversified applications include use of coir netting and matting as geotextile material to prevent soil erosion and
Table 1.4 - Export of coir products from India

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Quantity in tonnes</th>
<th>Value in lakhs Rupees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coir Fibre</td>
<td>928</td>
<td>129.73</td>
</tr>
<tr>
<td>Coir Yarn</td>
<td>14547</td>
<td>4201.70</td>
</tr>
<tr>
<td>Coir Mats</td>
<td>19834</td>
<td>13231.37</td>
</tr>
<tr>
<td>Coir Matting</td>
<td>5694</td>
<td>4050.28</td>
</tr>
<tr>
<td>Coir Rugs &amp; Carpets</td>
<td>2566</td>
<td>2002.20</td>
</tr>
<tr>
<td>Coir Rope</td>
<td>189</td>
<td>50.55</td>
</tr>
<tr>
<td>Rubberised Coir</td>
<td>395</td>
<td>305.75</td>
</tr>
<tr>
<td>Curled Coir</td>
<td>252</td>
<td>43.91</td>
</tr>
<tr>
<td>Coir Geotextiles</td>
<td>927</td>
<td>410.63</td>
</tr>
<tr>
<td>Coir Other Sorts</td>
<td>2030</td>
<td>952.04</td>
</tr>
<tr>
<td>Coir Pith</td>
<td>2152</td>
<td>264.90</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>49514</strong></td>
<td><strong>25643.06</strong></td>
</tr>
</tbody>
</table>

COIR BOARD
### Table 1.5- Products from Coir

<table>
<thead>
<tr>
<th>ITEM</th>
<th>USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mats, Matting, Mourzouks,Carpets Rugs.</td>
<td>Floor Covering.</td>
</tr>
<tr>
<td>Geotextiles</td>
<td>Protection of road, rail &amp; canal Embankments.</td>
</tr>
<tr>
<td>Drainage filter material for application as pipe envelopes.</td>
<td>To prevent flooding in grazing meadows, orchards, sport fields &amp; gardens.</td>
</tr>
<tr>
<td>Ship Requisites</td>
<td>Fender Rope</td>
</tr>
<tr>
<td>Tent Components &amp; Army Requisites</td>
<td>Salitah, Wall bag, Pole &amp; Pin bag Camouflage net, dumping net.</td>
</tr>
<tr>
<td>Household Articles</td>
<td>House maids Kneeler, scrubber Shopping bags.</td>
</tr>
<tr>
<td>Speciality Articles</td>
<td>Cricket pitch matting, billiard surrounds, golf tee mat, wrestling mat, tablemat, tealeaf bags.</td>
</tr>
</tbody>
</table>

COIR BOARD
in roof surface cooling, as drainage filter material (Sarma, 1999). Needled coir felt also has been observed to possess properties for reinforcement function in cohesionless soils and as filter fabric in cohesive soils (Iyer and Girish, 1999).

Coir, having a greater aspect ratio (length: diameter), can be used successfully in filling or reinforcing thermoplastics with an improvement in flexural properties and toughness and reduction in the cost as compared to the pure thermoplastic. For aesthetic qualities, polypropylene composites with coir and sisal have been stated as the best.

1.2 Production of coir fibre

Coir fibre is classified into “white fibre” (Plate A) and “brown fibre” based on the extraction process. White fibre is obtained by the retting of coconut husks while the brown fibre is extracted by mechanical means.
1.2.1 Retting of husks

Retting is one of the conventional methods of coir extraction, which leads to the production of "white fibre". To obtain the white fibre traditionally by the "retting" process, 11 month mature green coconut husks are arranged neatly into lots ranging between 5000 to 10000 secured with coir nets in a large circular bundle and released into the saline backwaters. The bundles float freely, get drenched, become heavy and gradually sink. The bundles are left undisturbed for 6 to 10 months for completion of retting following which the husks are drawn out, beaten with wooden mallets to yield the "white fibre". This is the ideal fibre for the spinning of coir yarn and weaving into mats, matting and other floor coverings. In India, the abundant backwater facilities available on the southwest coast provide natural retting conditions. The colour of the fibre is not only influenced by the variety of the nut from which it is derived, its maturity, time lapse between dehusking and retting, but also on the nature of the retting process, environmental conditions and duration of retting. The physical appearance and quality of fibre varies widely with respect to colour, length and percentage of impurities. The best quality fibre is bright in natural colour (Grade II in Xenotest), possesses good staple
length (between 15-20 cms) and is comparatively free from pith and impurities.

1.2.2 Mechanical extraction of unretted brown fibre

“Brown fibre” is obtained by subjecting the husks through a power driven crushing, decorticating and combing system. Brown fibre can be classified as two types viz. the green husk fibre and the dry husk fibre.

Eleven-month mature green husks can be subjected to mechanical extraction to yield bright coloured fibre. The time required for the extraction of this fibre is only a few hours and the problem of pollution of backwaters can be eliminated. However the greatest disadvantage of the mechanically extracted fibre is, its inconsistent colour, harsh texture and poor photostability. Photodegradation is one of the disadvantages for production of good coir yarn and products from mechanically extracted fibre. Dry husk brown fibre is brown in
colour, coarse and mainly used for the manufacture of ropes, rubberized coir and in the upholstery industry.

1.3 Present scenario of the coir industry

“White fibre” production by the retting process is confined to Kerala on the south west coast of India, however, a large percentage of the fibre produced in other coconut growing states of India is “brown fibre”. Retting of husks is disadvantageous on environmental considerations as the pH of the surrounding waters is lowered from neutral to the acidic range and the BOD levels increase with the progress of retting (Aziz & Nair, 1978), it also involves drudgery with laborious methods for steeping and drawing of retted husks. Retting is also not very economical as the investment towards the cost of husks is blocked for 11 months for retting, after which the fibre is available for use.
It is therefore important that, if the requirement of the coir fibre has to be met with, the environmental implications of "retting" have to be understood and alternate non-polluting technologies need to be developed to harness the husk potential available in the country and satisfy the demand of the coir industry.

Coir Board has introduced "Coirret" a formulation of three bacterial cultures that can be applied on coconut husks steeped for retting in the backwaters to reduce the retting period to three months. It can also be treated on mechanically extracted green husk fibre to bestow it with the properties of "retted fibre" in 72 hours. "Coirret" is a patented product of Coir Board produced only at the Boards research Institute at Alappuzha in Kerala. Coirret has to be collected from the Pilot Scale Laboratory, CCRI @ Rs.38.00 per kilogram.
Table 1.6 - Statewise coir fibre production & husk utilization.

<table>
<thead>
<tr>
<th>State</th>
<th>Fibre Production (Tonnes)</th>
<th>Utilization of husk (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kerala</td>
<td>149800</td>
<td>38</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>91300</td>
<td>23</td>
</tr>
<tr>
<td>Karnataka</td>
<td>28900</td>
<td>22</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>15000</td>
<td>16</td>
</tr>
<tr>
<td>Orissa</td>
<td>3000</td>
<td>15</td>
</tr>
<tr>
<td>Others</td>
<td>8000</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>296000</td>
<td>21</td>
</tr>
</tbody>
</table>
Conventional monitoring methods for coconut husk retting are subjective, often more of an art than a technology. The lack of experience with coir retting can be a barrier for potential Indian coir producers and processors. Lack of a good retting measurement method even limits laboratory research aimed at optimizing the retting process. The Flexural Rigidity Tester is an indigenous method developed for comparing the extent of softness imparted to a fibre by a treatment (Mukherjee, 1996).

Global requirement of fibrous materials.

The husk potential utilized in India at present is only 21% and the fibre production is 2,96,000 tonnes (Table 1.6). Most analysts forecast long-term increase in world demand for all types of fibrous materials, at the same time limitations in production capacity is also predicted. New fibre crops, new industrial uses of non-wood fibers, and agricultural diversification in conventional and novel markets, in general,
are therefore subjects of widespread interest for plant fibre. For annually harvested fibre production to be an attractive proposition, the three essential requirements are that the material be produced at a large scale, at a low enough price, with fibre characteristics being adequate for the end use in question. Equally important is that there should be a proven technology available for the processing of the new raw material (Bolton, 1995). The mechanically extracted coir fibre *per se* is not of the same quality as naturally retted fibre but can be made comparable by biological treatments.

1.4 **Aim and scope**

The problems associated with the natural retting process, elaborated under 1.3, has been a concern of the environmentalists. Besides, the low availability of the fibre as compared to the demand has been a point of focus of the coir industrialists. An attempt is therefore made in this work to reduce the period of retting of husks for coir extraction, increase the utilization of the husk potential in coconut growing
regions and tackle the environmental problems arising during retting.

An established fact known to cause the delay in the retting of coconut husks is the presence of the high percentage of polyphenols. (Varrier & Moudgil, 1947, Menon & Pandalai 1958, Jayasankar & Bhat 1966). Polyphenols from the coconut husks get constantly leached out into the surrounding steep liquors and such high percentage of polyphenols in the steep liquors appear to significantly influence the retting process, thereby resulting in a delay in extraction of the fibre (Jayasankar & Bhat, 1966). Retting is also a cause of environmental pollution (Aziz and Nair, 1978) as the pH of the environmental waters in a retting zone is lowered from neutral to the acidic range indicating the release of acidic substances and the BOD levels increase considerably leading to the deterioration in the quality of the backwaters which is detrimental to the aquatic life. Recommendations have been
made for adapting fibre pretreatments by improved retting and biobleaching (van Dam, 1999).

It is therefore imperative to develop ecofriendly methods for coir extraction from coconut husks. Alternative measures, like the development of Coirret, have limitations such as insufficient production capacity to meet the requirement of all coconut growing regions and its high cost. Therefore a process which could overcome these shortcomings would be useful for economic utilization of the husk potential in any coconut-growing region.

Bacteria are the most versatile organisms dissimilating an array of aromatic compounds with catechol as the key intermediate involved in the oxidative cleavage of the aromatic ring (Evans, 1974; Sleeper & Stanier, 1950; Simpson and Evans, 1953). Some important degradative bacteria that occur in water and soil environments belong to the following genera
viz. *Pseudomonas*, *Xanthomonas*, *Azotobacter*, *Rhizobium*, *Agrobacterium*, *Methylomonas*, *Methylococcus*, *Moraxella*, *Acinetobacter*, *Alcaligenes*, *Flavobacterium*, *Escherichia*, *Enterobacter*, *Serratia*, *Proteus*, *Aeromonas*, and *Bacillus* (Cork and Kroeger, 1991). Growth of specific types of microorganisms and their physiological activities are a response to the physicochemical environment. The steeping of coconut husks for retting leads to the establishment of such a unique ecosystem for proliferation of specific microorganisms degrading polyphenols.

The present studies have hence been carried out with a view to explore the possibility of developing a consortium that can survive and proliferate on the leachates from coconut husk which are rich in phenolic compounds. An advantage of such a consortium would be that it can be developed at any site where coconut husk retting needs to be carried out and then develop a method for better utilization of the husk potential in coconut
growing regions. It would lead to increasing the supply of raw material from India and establish coir industry, without high investments in states where natural facilities for retting do not exist. This would generate employment opportunities and increase the economy of the region.

1.5 Objectives of the project

The project undertaken entitled “Studies on coconut husk retting and bioinoculant treatment for process improvement in a natural system“ was aimed to study the following objectives:

1. To study the process of retting in a natural system by monitoring the environmental parameters of the retting ecosystem and study the biochemical changes in the husk during the retting process.

2. To develop a consortium growing on husk leachates, isolate and characterize bacteria growing on phenolic compounds from the consortium.
3. To study the effect of seeding of consortium, a mixture of bacterial cultures growing on husk leachate on the retting process.

4. To develop a sustainable system for the coir extraction process using the consortium as bioinoculant.