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CONTENTS.

THE RETTING OF COCONUT HUSK FOR THE PRODUCTION OF COIR.

By Gilbert J. Fowler and F. Marsden.

This investigation resulted from observations made in the Department of Industries, Madras, when it became responsible to the Munitions Board for the control of the supply of coir-products required by the military services from 1914 onwards. Large quantities of ropes, matting, etc., were purchased, and contact with the industry left the impression that it was capable of development. There is practically no literature on the subject of coir-preparation and the only references which it has been possible to trace are short articles in Watt's *Commercial Products of India* and Goulding's *Cotton and other Vegetable Fibres* (Imperial Institute Handbook).

These give short descriptions of the methods by which the coir fibre is obtained but supply no details of the actual process ; apparently the matter has not been studied, and the production probably follows the lines to-day which it did 500 years ago. There are rumours that some time ago a German living on the West Coast of India was interested in the retting process and published a pamphlet, but we have not been able to obtain any further information regarding this.

In July, 1921, a Conference of officers of the Department of Industries was held in Madras, at which the desirability of investigating the production and methods of utilising the coir-fibre was stressed and the available information discussed. From the fact that clean fibre was separable only when the husks had been soaked in water for some time, it appeared certain that the softening was due to bacterial action, just as in the 'retting' of flax, and that as this method of preparation was only carried on intensively on the West Coast, whereas in Ceylon and other places mechanical means were largely employed for the production of an inferior quality of fibre, the condition of the water on the West Coast exerted some special influence. One of us, as the Industrial Chemist of the Department, was therefore deputed to investigate the conditions under which retting takes place and to obtain samples of water and husk for bacteriological examination. A tour was made embracing the chief centres of coir production and the investigation has been carried out at the Indian Institute of Science, Bangalore as part of the work of the Bio-chemical Department.

The word 'coir' is manifestly the transliteration of *kayiru*=rope, fibre and rope having long been important produce on the West Coast and exported to Europe from the middle of the fifteenth century, but apparently articles manufactured from coir were not known in England until about the middle of the nineteenth century. The source of the fibre is the thick fibrous layer (mesocarp) surrounding the kernel in the fruit of the coconut palm (*Cocos nucifera*), the mesocarp being surrounded by a layer of smooth resistant fibres—the outer skin or epicarp.

There are many varieties of *Cocos nucifera*, not all of which however appear to bear nuts of sufficient size or with a mesocarp suitable for the extraction of fibre. According to the *Commercial Products of India* there are at least eighteen varieties but only three are really suitable for coir-production, the best being *C. nucifera* var. *rutila*; but it is considered that the quality of the fibre may be dependent to some extent upon the locality, palms growing near the sea yielding a better quality than those growing further inland.

Wherever the coconut palm grows some kind of rough rope appears to be made from the husk-fibre for local use, but it is on the West Coast of India and in the Laccadive Islands that the best qualities are produced and exported. Ceylon is the other large producing centre, but the value placed on its products does not appear to be so high as on those exported from India.

Exports of coir (raw and manufactured) from Ceylon.

—	Tons	Value
		£
1913	19,487	222,475
1914	17,712	188,512
1915	15,744	143,082

Exports of raw fibre from India.

—	Tons	Value
		£
1912-13	466	6,532
1913-14	741	11,449
1914-15	247	3,491

Exports of manufactured coir from India (excluding rope).

—	Tons	Value
		£
1912-13	36,216	550,486
1913-14	38,613	592,741
1914-15	25,793	380,299
1919-20	38,297	687,228
1920-21	30,041	653,060
1921-22	27,742	610,475

Goulding (*loc. cit.*) appears to have gathered his information from Ceylon and based his remarks upon the conditions prevailing there for he states ' The fibrous material in its raw state, that is, unbeaten and uncombed, consists of fibres of varying lengths associated with a quantity of corky and other non-fibrous tissue. For the preparation of coir the coconuts should be gathered before they are quite ripe. The fibre becomes coarser as the nuts ripen and then requires to be soaked for a longer period in order to free it from the corky tissue with the result that the coir acquires a dark colour. In the old, native system of treatment, the coconuts are immersed in pits of salt water and left there for several months, but in the preparation of the best commercial coir it is now usual to detach the husks, which is accomplished by striking the nuts on sharp spikes fixed in the ground or by means of a simple machine and to steep these in large tanks of water warmed by steam. The treatment is much shortened in this way.' The softened husks are then beaten by hand or crushed in a machine and passed through an extractor, or breaking-down machine, for complete disintegration and then through a willowing machine to remove dust and non-fibrous matter.

As a comment on this, we may at this stage only remark that we have never heard of ' whole ' nuts being soaked without the kernels being first extracted for copra, and that our experiments indicate that the riper the nut the less dense is the mesocarp and the more easily is it resolved and the fibres separated. Comparative experiments showed that the extraction of the colour-producing principles was more rapid, and discoloration of the fibre correspondingly less, with a ripe husk than with an unripe one ; after a visit to Colombo, Mr. C. W. E. Cotton, C.I.E., I.C.S., noted ' It appears that there is a good deal of retting done in streams and artificial tanks in the south of the Island and a great deal more elsewhere by machinery. The output in

Colombo and the neighbourhood is chiefly of bristle and mattress fibres and the poor colour suggests that it has been machine retted. I saw nothing corresponding to the fine white fibres of Alapat and Anjengo.'

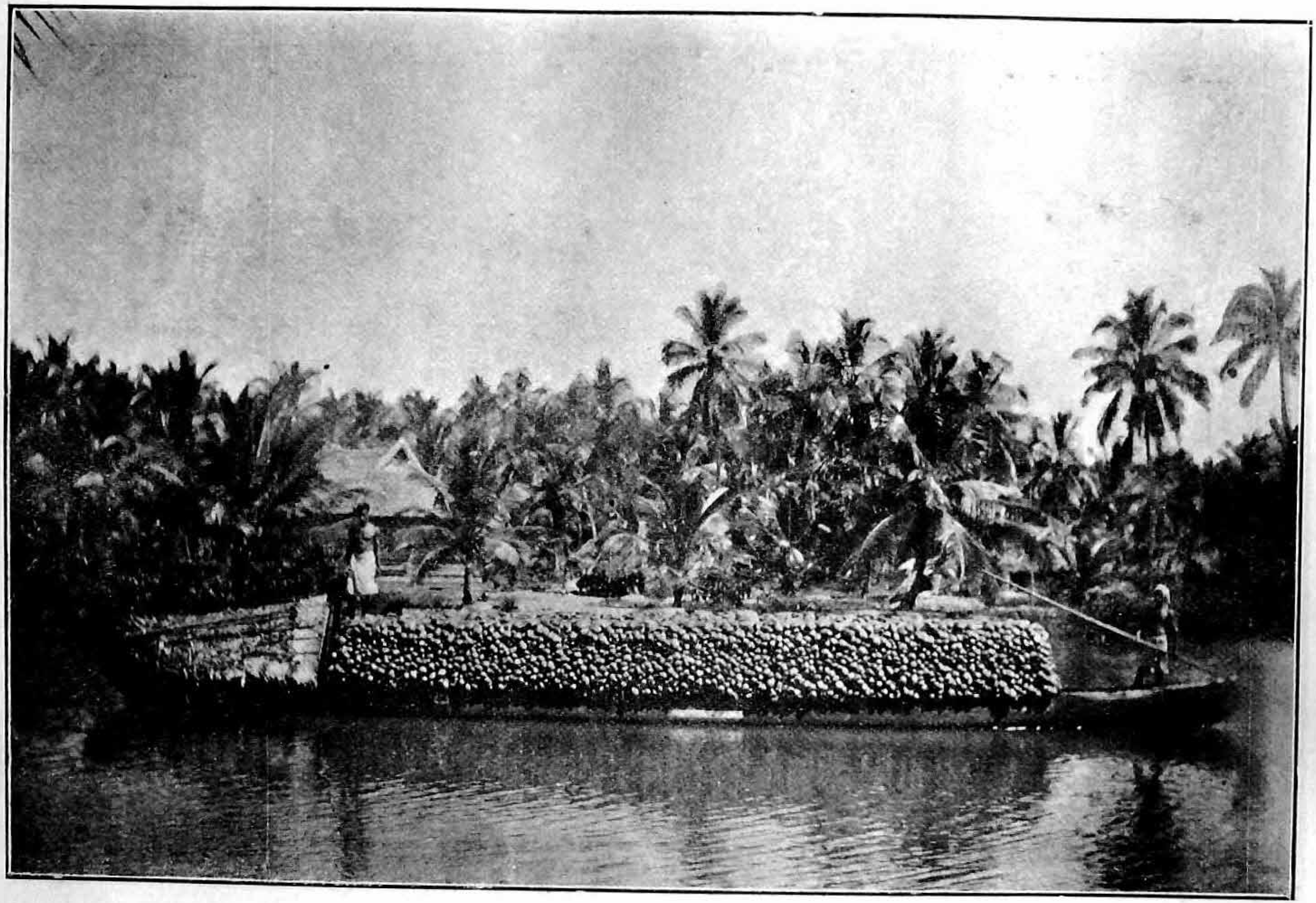
The method of producing coir for manufacture and export is materially different therefore in Ceylon from that employed in Malabar, and during a short tour in the latter area the endeavour was made to obtain as much information as possible from the workers actively engaged in the production and thus have the benefit of their experience. Naturally, from untrained observers of the agricultural class, the opinions expressed varied considerably, but from conversation with European firms and individuals having years of experience in the industry and being able to express definite opinions, a better idea of the conditions was obtained.

From Anjengo in the south to Mangalore in the north the extraction of coir seems to follow the same broad principle—based on a prolonged steep in water, the variations being caused by differences in the conditions of water-supply. It was generally agreed that stagnant water was unsuitable and that a periodical change was necessary; this change of water is caused, in all the areas visited, by the rise and fall of the tide amounting to about 1½ feet in the backwaters and channels extending along the whole Malabar Coast.

Experiments in stagnant water have shown that the action soon ceases, when the husk becomes dark in colour.

In the Laccadive Islands retting is carried out in salt water only, but on the mainland the salinity of the water varies with the locality of soaking, its distance from the sea-entrance to the backwater and the nature of the freshwater-flow from the landward side. The general impression appeared to be that salt or brackish water was essential for good retting and that an increase in the amount of fresh water entering the pits in flood-time was detrimental to the husk, especially if only recently set to soak. It was at first thought that the elucidation of these points would require a thorough study and investigation of the different areas over a long period, but the results of our experiments have indicated that the opinion of one European that 'the question of more or less salt in the water was not of so much importance as the conditions of flow' was correct.

The actual soaking of the husk and separation of the coir appears in general to be carried on as a 'cottage' industry, the products being collected and graded for export by the mercantile firms. The market-value of the coir is dependent upon the colour and fineness of the fibre and the quality of yarn which can be spun from it.



WALLAM LOADED WITH HUSK FOR SOAKING

SPLITTING COCOANUTS

The finest qualities are admittedly produced at Anjengo and Alapat, but no definite information could be obtained as to whether this was an effect of a superior quality of nut, or was due to the water conditions. Husk is sent by boat from remote places to soak at Anjengo, and the coir obtained is not of the same quality as that obtained from local nuts, but this may be due to the exposure undergone during handling and transport, or it may be due to differences in the variety of palm cultivated.

The soaking of the husk may take place in pits some 6 to 7 feet deep, dug in the sandy soil adjacent to a river or backwater so that the water-level is subject to the effect of the rise and fall of the tide by percolation through the sand, or areas are staked out and fenced in among shallow, unfrequented parts of the backwaters, the space thus protected being filled with husk. In the deeper parts, husk may be set to soak by enclosing in large nets of coir-rope, anchored and weighted with stones until the mass is submerged. As flotation-power is lost, the stones are gradually removed until the mass of husk sinks until it rests upon the mud, where it remains until retting is complete. In the neighbourhood of Anjengo the pits take the form of regular 'fields' with raised bunds pierced by openings through which the water runs over the submerged husk at each ebb and flow of the tide in the backwater.

Although husk is placed to soak at all times of the year, it was generally stated that the usual age for collection of the nut was about ten months, or just before it was fully ripe, and that the best time for setting the pit was in the dry season and not in the rainy season (May to August) as the nuts were then somewhat smaller.

The effect of ripeness of the nut was not so generally appreciated, for in some quarters we were informed that unripe husk gave a better fibre and that unless the price of copra was high, unripe nuts were preferred; other people definitely considered that husk from unripe nuts gave a dull-coloured fibre and took longer to ret. Our experiments have indicated that the latter view is correct.

The nuts having been collected (this takes place every forty to forty-five days) the husk is removed from the kernel by smartly 'jabbing' the end on the point of an iron stake fixed firmly at an angle in the ground. With three cuts, giving a slight twist each time, the husk is completely removed and an expert workman can treat about 1,500 to 2,000 nuts per day.

For producing coir of good colour it is everywhere recognized that the husk, after splitting, should not be exposed to the sun and weather, but should be set to steep with as little delay as possible. Exposure reddens the mass and from such exposed husk the production of the fine, light-coloured fibre characteristic of the best districts is an impossibility.

When the husks come into soak, the water for the first few days is tinged distinctly brown, due to the juices extracted from the husk; but the colouring principle is not entirely removed until retting is completed, and danger of discoloration is always present until the retted fibres have been well washed in fresh water. After a few days the water becomes somewhat milky and this increases until, after about thirty days, a scum may form on the surface, a distinct smell of sulphuretted hydrogen becomes noticeable and there is a marked increase of temperature in the mass of husk, bubbles of gas frequently rising from it. The turbidity, gas-formation, smell and rise of temperature increase from the third to the fifth month, but after six months the water becomes clearer, the smell and evolution of gas appearing to diminish.

The husks are now soft and the fibre can be separated, but the effect has not progressed completely throughout the husk, the layers next to the epicarp or skin and especially those nearest to the pointed tip of the husk being the last to be affected, and for the complete disintegration of these it is usual to continue the soaking for a full period of ten months or even longer.

When the retted husks are lifted the fibres are of a bright pale-yellow colour interspersed with loose bits of white corky matter. If now dried, the 'cork' would darken and the fibre itself would be affected, so it is essential to rinse well in fresh water. The discoloration of fibre from well retted husk lifted in the dry weather is due to the insufficient rinsing which arises from shortage of suitable water.

It is true that there are variations in the colour of coir from husks which have been soaked under seemingly almost identical conditions, and it is difficult to say whether this variation is due to differences in the time elapsing between splitting and soaking, or to unnoticed differences in the water conditions whilst the husk is in soak. Thus in Anjengo, husk which has come from a distance is expected to give a deeper coloured coir than that grown locally, but it is noted that when salt water is used for the first soak the colour is better than when, in the early periods, fresh water has been brought down by floods. Under these conditions, the water in the pits often becomes blue-black; the brightness of the fibre is dulled and the soaking period is prolonged, but the same harmful effects are not noticed when the husk has been in soak for a few months before the floods occur.

BEATING RETTED HUSK

Retting being completed, the husk has become so soft that simple squeezing in the hand compresses it and causes the fibres to separate. The bulk of the cork-like matter and mud adhering to the fibres are removed by rinsing, and the fibres are completely separated by beating the husk with a wooden mallet while resting it on a block of wood or smooth stone. Any residual cork is thus completely loosened and the fibres are thoroughly freed from it. The fibres are cleaned and the short and long ones intimately mixed by teasing and willowing—the mass being worked by hand with short sticks. The coarse fibres from the ridges of the husk are more suitable for bristle-fibre than for spinning, and are therefore separated; only the finer portions are worked up and spun by hand or on a primitive machine into the yarn which is sold to the merchants for mat-making, etc., and for export.

Observations made during the tour of the retting centres confirmed the assumption that micro-organisms were concerned in the process; samples of water and husk were therefore taken from places widely separated, for examination at Bangalore.

Examination of the water samples showed that some organisms were common to almost all, but the variation of colonies was so great as to render difficult the separation and characterisation of each species, or determination of the part it plays (if any) in the retting process. This variation of species found in the waters is not surprising when the soaking areas and the conditions of housing and drainage are reviewed. The task appeared much simplified when some samples of husk kept soft in the laboratory were examined, and it was noticed that a gelatinous growth was taking place in the containing vessels. Ordinary tapwater was used so the growth was probably traceable to the husk; cultivation of the growth showed that the forms were identical with some found in the West Coast waters but quite absent from the Bangalore water.

It appeared, therefore, that the effective organisms were derived not so much from the waters of Malabar as from the coconut husk direct—a view consistent with observations (made in the Bio-chemical Department of the Institute) which tend to show that all seeds carry distinctive bacteria. If this is the case and the coconut husk itself carries the bacteria which assist the sproutlet of the seed to force its way through the husk, and these bacteria in the presence of water are able to disintegrate and destroy the matter binding the fibres together, then soaking in water under suitable conditions should permit them to develop their activity, and whether the water is salt or fresh should be immaterial so long as the necessary conditions for maintaining full bacterial activity are assured. The main condition for this would seem to be a controlled temperature and a sufficiently frequent change of water to prevent the killing of the bacteria by any accumulation of toxic life-products.

To test this view, local (Bangalore) coconuts were split and the husks set to soak in a vessel filled with tap water, in which the water could be periodically renewed.

The phenomena observed (excepting rise of temperature) followed closely those described as taking place in practice. The water became at first brownish and in about ten days turbidity was distinctly noticeable, increasing gradually until the vessel was filled with a white jelly-like mass and the smell of sulphuretted hydrogen was pronounced.

The temperature in Bangalore was then about 30° F. lower than is usual in Malabar, so that the rate of development and the rise of temperature taking place in practice there could not be expected.

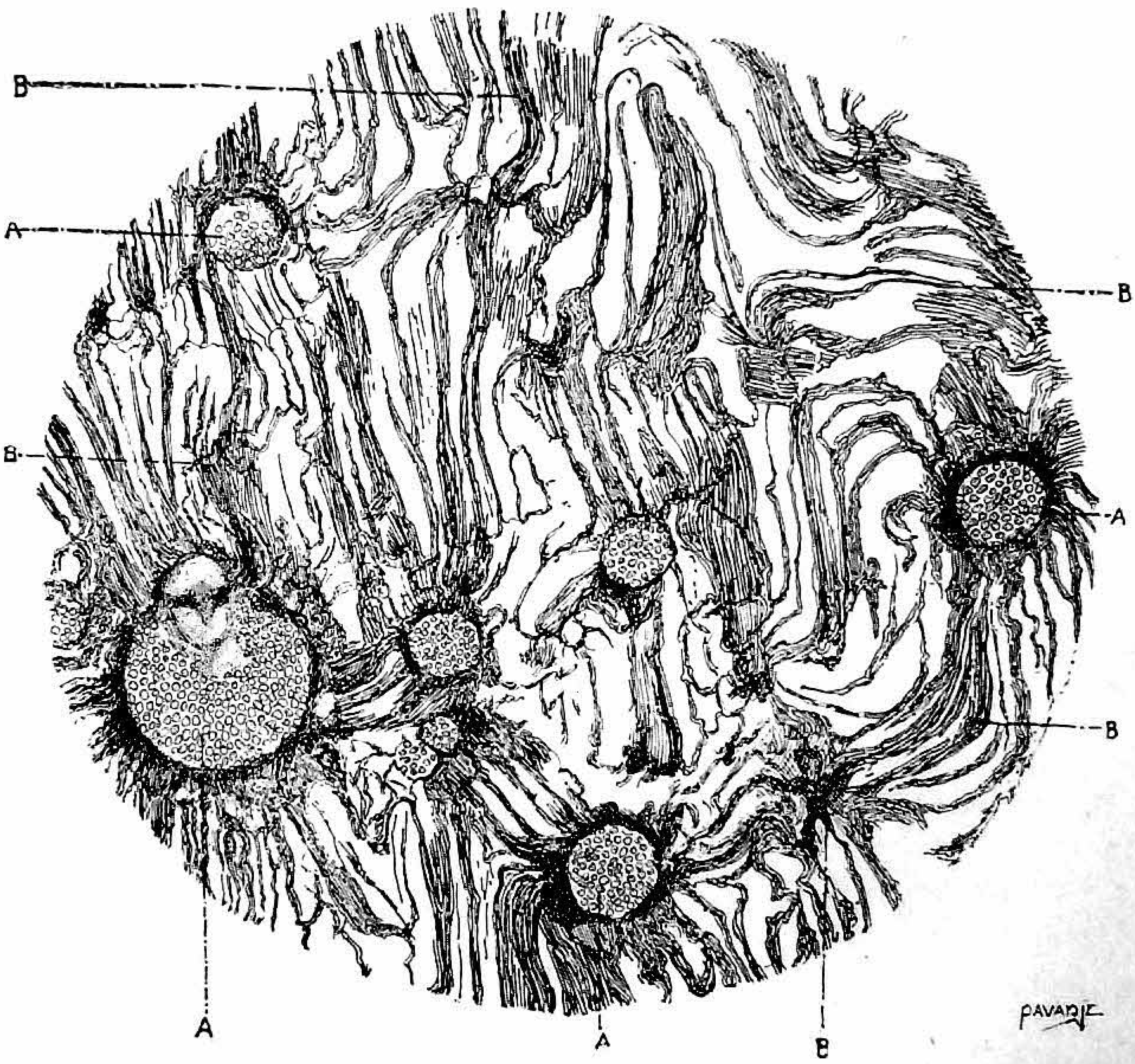
Examined under the microscope, the jelly-like mass was seen to consist entirely of conglomerated bacteria, in the form of sheathed rods, seemingly with mould sporangia, the whole intertwined to such an extent that the mass had the appearance of a jelly.

To prove that these bacteria were actually present originally in the coconut and did not come from an extraneous source, a flawless nut was selected, washed and scrubbed and passed through a hot flame to destroy any form of life on the surface. Incisions were then made and fibres were removed from an inner layer by means of sterilised instruments and the fibres embedded in a sterile nutrient medium and set aside in an incubator.

In a short time the bacteria carried by the fibres had developed and the growth was apparent along the edges; it was allowed to proceed and a drawing then made.

With a sterile needle a little of the growth was removed and a streak made on the surface of a solid nutrient medium which was also placed in the incubator. The result was highly interesting, for the organism grew regularly along the streak and appeared to be identical in form with that responsible for the jelly-like product in the retting-tank. From the regularity of the growth, it appeared that a practically pure culture was obtainable direct from the coconut husk and it was decided to take cuttings with all sterile precautions and see whether, working under sterile conditions, retting would take place in the same way as in our experimental retting-tank and in practice.

An inverted glass bell-jar was fitted with a cork carrying a syphon tube, and with a lightly fitting aluminium cover in which a



TRANSVERSE SECTION THROUGH A PORTION OF A COCOANUT HUSK MAGNIFIED
A = Fibres
B = Cellular cork like tissue removed by retting

glass tube was fixed in the centre for the supply of water. The whole apparatus together with a glass beaker for holding the husk-cuttings was sterilised by heating in a hot-air oven and the beaker then half-filled with small pieces from the inside layer of a husk, cut and removed with all precautions to prevent infection. A supply of boiled, cooled, and aerated tap-water was then passed through the apparatus at intervals and the progress of retting was followed. The first extracts were faintly brown and in a few days fluffiness and slime-formation was noticed on the surface of the cuttings; this increased until the water in the beaker and that which flowed away upon replenishment was quite turbid and deposited masses of flocks which the microscope showed to be the rod-bacteria already mentioned.

A comparative experiment was made with cuttings from (*a*) the hard tip and (*b*) the end near the stalk of the same husk to ascertain whether there was any difference in the rate of disintegration. Growth of organisms was more rapid in the vessel containing cuttings from the suspension-end and the cuttings became quite soft before the hard tips were materially affected, thus confirming the observation in practical retting on the large scale that the tips resist the action of bacteria longest, and indicating that the riper the coconut the more quickly can the retting be completed.

The growths in the various vessels were examined from time to time and sub-cultures made for comparison. During the period of vigorous growth large rod-like organisms predominated, accompanied by others of the same general appearance but smaller. Later, the larger forms appeared to be less numerous, the small ones predominating.

To decide whether these bacteria were really active in disintegrating the husk, it seemed advisable to replace the artificial medium such as the glucose-peptone or nutrient agar hitherto employed by a medium prepared from the husk itself. From a partly retted husk, after thorough rinsing, a quantity of the cork-like matter still adhering to the deeper layers was removed and boiled out with a little water followed by a very dilute solution of sodium carbonate. The pink solution was concentrated and thickened with agar. Water from the sterile experimental retting-vessel maintained in the laboratory was then suitably diluted and a portion mixed with agar extract and poured into a Petri dish. Characteristic colonies developed, proving that the extract of the husk could support the organisms; but sub-cultures could only be made with extreme difficulty. Transferred to nutrient agar and sub-cultured on this medium they grew well and showed the forms of colony obtained by direct cultivation from the retting-vessel on nutrient agar. From the cultures it would appear that the organisms contained in the husk and taking part in the retting process include at least three forms :

1. A comparatively long rod-bacterium.
2. A short rod-bacterium.
3. A mould.

At this stage it seemed advisable to study the coconut husk itself and attempt to determine the nature of the material binding the fibres together and susceptible to the attack of the bacteria.

The brown solution obtained on first soaking the husk had been examined and found to contain some sugar and tannin-matter; the strong smell of sulphuretted hydrogen noticed during retting indicated the presence of compounds containing sulphur, whilst nitrogenous products were revealed by the odour from the vessel in which the effect of steeping in stagnant water was being examined. This liquid emitted a pronounced 'farmyard' smell and gave with concentrated sulphuric acid the characteristic indication of skatole.

The material in the sterile tank was also tested roughly for enzymes which might be originally present or produced by the action of the bacteria, and gave definite evidence of the presence of an oxidase and indications of the presence of a peroxidase.

For more systematic study, cuttings from a fresh coconut husk were extracted with ether. The extract separated into two layers, an upper ethereal and a lower aqueous one derived from the juice contained in the husk. The ether extract was slightly acid and left a residue which was fat or wax. The aqueous layer gave the reactions for tannin.

The ether-extracted material was then extracted with alcohol. During extraction, the liquor progressively darkened; after proceeding for five days, extraction was interrupted and the extract evaporated under diminished pressure until a clear, reddish syrup remained. Treatment with ether removed from this a further quantity of fat or wax left in the husk owing to the previous ether-extraction being incomplete, and when taken up with water the syrup left a pale residue soluble in hot water and giving reactions for tannin. The dissolved syrup itself gave reactions for tannin and progressively darkened and deposited insoluble condensation products, reminiscent of the behaviour of the phlobaphene-yielding tannins of the catechol class. The residual solution was freed from tannin-matter by treatment with lead acetate, etc., thus yielding a pale syrup containing sugar. This reduced Fehling's solution and gave an osazone melting at 207°C and having the characteristic appearance of glucosazone.

After extraction with alcohol, the husk was treated several times with hot water until this was colourless. The extracts became intensely coloured upon evaporation and deposited phlobaphene-like products; besides tannin-matter, nothing could be identified excepting a small quantity of mineral matter containing calcium salts.

The husk, retaining its original form and hardness, was now heated under a pressure of 30–40 lbs. with water, given a final extraction at 75 lbs. and well washed with hot water. Under this treatment it suffered some disintegration and became soft. The aqueous extract was light-yellow and upon concentration showed signs of charring, with deposition of solid matter. A portion of the liquid treated with alcohol gave a gummy precipitate and gave the 'pentose' reaction on boiling with hydrochloric acid. Another portion was therefore hydrolysed by boiling with dilute sulphuric acid followed by treatment with barium carbonate and evaporation. The residue after extraction with alcohol contained barium and behaved like the barium salt of a gum-acid, whilst the alcohol left a syrup giving an osazone melting at 160°C. The syrup had the specific rotation of xylose and gave the cadmium bromide compound characteristic of xylose or 'wood sugar.'

The residual softened husk after autoclaving was then treated at a pressure of 40 lbs. with a 2 per cent. solution of sulphuric acid. The yellow extract was neutralised at once with barium carbonate, filtered and evaporated. The gummy residue was extracted with alcohol which left a residue containing barium (the barium salt of a gum-acid), and the alcoholic solution upon evaporation yielded a small quantity of syrup containing glucose, identified by the osazone.

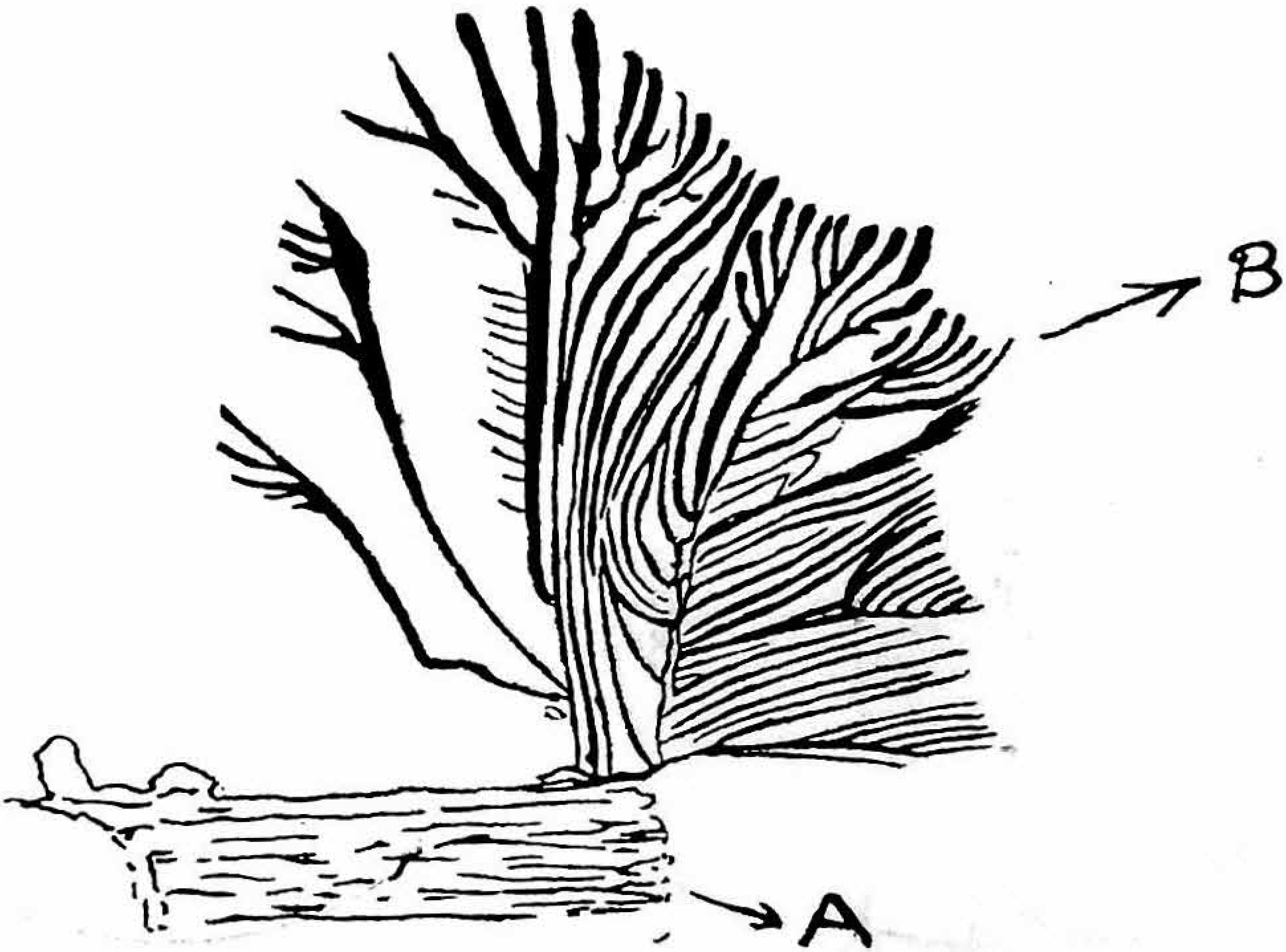
The cohesion of the husk had now been completely destroyed; fibres and 'cork' could be separated by pressing between the fingers, showing that the gummy or mucilaginous binding-matter can be resolved into reducing sugars and gum-acids by heating under pressure.

The question then arose whether the bacteria could attack this gum and grow upon it, and this appears to be the case, for a piece of fibre with adherent slime transferred from the sterile retting-tank to the extract obtained by heating with water under pressure, gave a pronounced growth and upon an agar slope of the extract a streak-culture grew rapidly. There is no doubt, therefore, that the retting-process employed in Malabar depends for its efficiency upon micro-organisms contained in the coconut husk itself, able to attack and destroy the gum or mucilage-yielding substance in the husk which binds the fibres together. For the sake of convenient supply, the experiments hitherto described were conducted upon coconuts grown in the neighbourhood of Bangalore and as these indicated that the coconut husk itself carried the organism which could disintegrate the husk on steeping it seemed advisable to compare the organisms in coconuts from widely separated districts. Four varieties of nut were obtained from Travancore and samples of another were obtained from the neighbourhood of Cocanada in the North of the Madras Presidency. During the examination of these a little difficulty was experienced arising from the desire thoroughly to preclude all risk of growth of organisms not inherent to the nut; the nuts having been plucked under unknown conditions and packed for transport the samples selected for examination at first were washed and thoroughly flamed to kill everything living on the surface. The result was that in some cases no growth of organism could be obtained from the cuttings taken and the conclusions became indefinite. The difficulty disappeared however when, in place of sterilisation in the naked flame we adopted a method of washing first with sterile water, secondly with a 10 per cent. solution of formalin, thirdly with alcohol and finally igniting the film of alcohol left after standing for a little time. The surface of the nut was thus thoroughly sterilised and the heat was insufficient to kill the bacteria in the lower layers of the husk. Upon now making incisions with a flamed knife and transferring lengths of fibre to sterile water, material free from extraneous organisms was obtained and, placed upon nutrient media, gave regular growths.

Upon nutrient agar the growth around the fibre generally proceeded with a 'lobed' appearance, as shown by the drawing on the opposite page, and a few hours after the commencement of the incubation period the bacteria were seen to be in rapid motion.

After eight to ten hours they lost their mobility. Isolated colonies sometimes appeared which had a 'furred' appearance, but under the microscope the organism appeared of one type, viz., a long rod-bacterium. Inoculated into nutrient agar and poured into a Petri dish, both the 'lobed' and 'furred' growths gave colonies of one type only; those which grew on the surface appeared round and globular with a granular texture, whilst those growing below the surface were denser in texture and were lenticular or pointed. Preparations from the growths on nutrient agar and from those in glucose-peptone medium showed the long rod-form of bacteria, generally growing in threads and at certain stages resembling *Sphaerotilus*, though its identity with any species of this has not been proved.

The four kinds of nut from Travancore and the nuts from Cocanada and Bangalore all showed this organism and there is little doubt, therefore, that it is the organism peculiar to the coconut irrespective of the locality in which the palm grows. A typical form is shown in the accompanying photograph.



DRAWING SHOWING TYPE OF GROWTH (B)
WHEN FIBRE OF HUSK (A) IS EMBEDDED IN NUTRIENT AGAR

PHOTOGRAPH OF BACTERIA

Three main forms or stages of growth were observed :—

(*a*) Long rods growing in chains, sometimes showing evidence of a sheath.

(*b*) Similar rods containing well-defined spores.

(*c*) Free-living spores.

With many nuts examined it was impossible to take cuttings which did not develop mould on cultivating in the different media, and it remains an open question whether this mould is an adventitious growth due to infection after plucking or really a part of the micro-flora of the nut.

As a result of the investigation we have formed the following opinions :—

1. That effective retting of the coconut husk requires only suitable water-conditions. The effective organisms reside in the husk itself, and can exert their full influence in water changing sufficiently frequently to prevent the organisms being poisoned by the products of their action, provided the change is not so violent as to remove too rapidly the accumulating bacteria, etc. That temperature plays a part, and that the influx of cold water retards the retting process by diminishing the activity of the organisms.

2. That the blue-black colour of the water and the dulling of the fibre are due to its coming into contact with ferruginous water brought down by fresh-water floods from inland, forming tannate of iron with the tannin-matter in process of extraction from the husk.

3. That the brown colour of the water on first setting to soak is due to the tannin-matter extracted with the juices, and that the reddening of the fibre is caused by exposure of the husk to the action of the air, the tannin-matter being highly oxidisable and readily convertible into coloured, insoluble phlobaphenes, similar to the oak-red obtained from the tannin of oak-bark. The growing organisms remove oxygen from the water, and if their activity is checked by fall of temperature, or they are washed away by too rapid a flow of water the dissolved oxygen in presence of oxidising enzymes suffices to oxidise some of the residual tannin and cause discoloration.

4. That the cork or pith of the husk is not itself the binding material, but that it is associated with a gum, mucilage or hemi-cellulose which is disseminated throughout its cells, is insoluble in water, and can be resolved by the action of bacteria or by treatment with water under pressure or by chemical agents. The nature of the

tannin-matter however will preclude the possibility of obtaining a coir equal in quality to that obtainable by natural retting unless it can be removed by working under anaerobic conditions.

For producing good coir the conditions near Anjengo appeared to be the best suited, as there the husks are soaked in submerged fields of a fair area, the water being sufficiently shallow for the warming effect of the sun to have full value in accelerating the rate of retting and the narrow openings in the bunds regulating the flow of water and preventing the change being too rapid. No appreciable oxidation of the tanning-matter in the husk can take place therefore and if the openings into the 'fields' could be closed at flood-time and clean water alone admitted, at high tide say, and any entry of ferruginous water thus prevented, there would be a diminished risk of 'blue' fibre being obtained.

As regards shortening of the period required for retting, experiments have shown that it might be feasible to set the husk to soak until the bacterial growth is well established and softening has commenced; then to lift, pass between heavy squeezing-rollers and return without delay the squeezed husk to another pit, already prepared. The bacteria could then more rapidly remove the binding matter and, since a period of five weeks sufficed for the complete disintegration of a husk in the laboratory the present requirement of ten or twelve months might be reduced to a period of at least three months.

Department of Bio-Chemistry,
Indian Institute of Science,
Bangalore.

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