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PLANT FIBERS FOR PAPERMAKING

by

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With a foreword by Marcia Morse and
botanical drawings by Virginia Kerwin

Liliaceae Press
McMinnville, Oregon 1981

HARVESTING OF PLANT FIBERS

All harvesting is done from fresh plants unless otherwise stated. Bast fibers, like milkweed for example, can be harvested after they have retted naturally in the field and the stems are dry. Fibers can be extracted from either fresh or dry plant parts. In cases where crop plants are being used for fiber, the fiber is usually harvested after the crop has been harvested. With regards to flowering garden plants, the fiber is usually harvested after the flowers have been enjoyed. Harvesting of fibers from shrubs or trees can be done while pruning. The branches to be harvested should be between 1/2 in. and 1 in. in diameter and about 6 ft. to 9 ft. in length. In the case of leaf fibers, the length of the fiber varies with the length of the leaf, so it is best to harvest from plants at least 2 years old with leaves 20 in. long or longer. It is difficult to give hard and fast rules because of climate differences: a Japanese mulberry stem might be harvested after 2 years of growth, while a Polynesian mulberry could be harvested after 9 months growth. Harvesting for an annual plant is probably best done in the late summer when one can assume that most of its growth has taken place. Obviously thicker stems will give a better fiber yield. They also contain a higher percentage of secondary fibers which are the softer finer fibers that lie next to the woody core. There are also primary fibers which lie between the secondary fibers and the outer bark; but these are more brittle.

When dealing with plant material, the most important thing to remember is that everything is variable. The season harvested affects the fiber length and paper color. The soil in which the plant grows affects the plant's growth, which in turn affects the fiber quality. Other influences are geographic location, differences in soil types, site quality, availability of moisture, and age of plant, shrub, or tree from which the fiber is being harvested. In addition to effects on fiber length, yield, and quality, the following items have an effect on the final paper color: using fiber from fresh or dry plant material, pre-cooking preparations like retting and fermentation, and the type of alkali used in the cooking process. It is quite possible to get several different paper colors from the same fiber, using different harvesting times and different preparation procedures.

At this point questions will arise about the identification of plants. Books like horticultural dictionaries and manuals of the flora of particular states with line drawings and color photos are very helpful, but they are no good to those of us who don't know what it is we are supposed to be looking for! A visit to a local herbarium, botanical garden, or arboretum might be helpful. If you have a plant that you think might be the one you are looking for, it can be taken to the home extension office at your county courthouse for identification. If the horticulturist there cannot identify it, he or she can send it to the botany department of your state university.

PURCHASING PLANT FIBERS FOR PAPERMAKING

By Mail Order

U.S. Sources

1. Elaine Koretsky, Carriage House Handmade Paper Works, 8 Evans Rd., Brookline, Mass. 02146 (partially prepared Crotolaria Indian hemp and abaca in dry sheets)

2. Lee Scott McDonald, P.O. Box 264, Charlestown, Mass. 02129 (flax, sisal, abaca, cotton, ramie, Japanese fibers, Western molds, synthetic mucilage)

Foreign Sources

3. Asao Shimura, Cannabis Press, 431 Fukuhara Kasama-shi, Ibaragi-ken 309-15, Japan (gampi, mulberry (kozo), mitsumata on special request, synthetic mucilage "tororo-aoi," Japanese screens)

By Direct Purchase

1. Hardware stores for Manila and sisal twine or rope

2. Weaving supply shops carry a wide variety of fibers including raffia, possibly true hemp, jute, sisal, Manila, sea grass, flax and ramie.

Please Note

Even though these purchased fibers are partially prepared, they still need cooking before beating even if they are going to be used in the Hollander beater. These raw fibers still contain small amounts of fat and pectin which prevent proper hydration of the fiber in the beating process. The only exceptions to the cooking requirement are the dry sheets of fiber which have already been cooked.

FIBER STORAGE

Fibers can be stored dry at various stages of their preparation. However, different paper colors can result, according to whether the fiber is used immediately after harvesting or is dried for future use when the rest of the preparation is completed.

1. Plant parts can be dried after harvesting and stored (leaves, stems/branches, grasses).

2. Bast fibers can be separated from their woody cores, then dried and stored; leaf fibers can be scraped, then dried and stored.

3. Bast fibers, after separation from their woody cores, can further have their outer barks removed by scraping or peeling, then can be dried and stored.

4. Once the fiber has been dried in any form, it should be soaked for 24 hours prior to continuing the preparation.

5. Drying a fiber that has been cooked with alkali is not recommended because the once dried fiber will never again absorb the same amount of water upon re-wetting.

6. Left-over cooked fibers can be stored in plastic bags or containers in the refrigerator for a week or in the freezer until needed.

YIELDS

Since many of the methods described in this work are not intended for production papermaking, priority has not been given to the final yield from a given amount of dry fiber. The amount of raw fiber to harvest is, of course, dependent on the needs of the final project and varies with the fiber type.

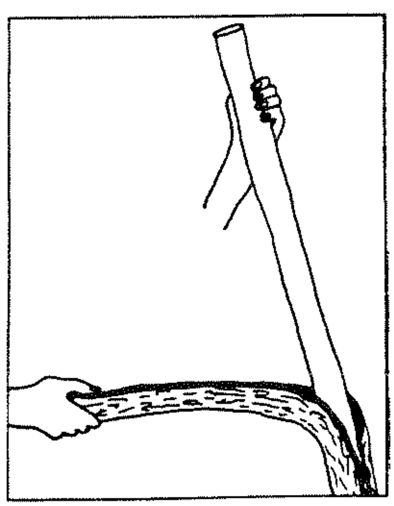
One-half pound of inner bast fibers will yield approximately 20 sheets of thin paper 8" x 11" in size, while one-half pound of grass fibers will yield approximately 3 or 4 sheets of thin paper 8" x 11" in size.

FIBER SEPARATION

General Information

The portion of a plant that papermakers are interested in is the cellulose fiber. All plants contain cellulose, some containing a higher percentage than others. In order to be made suitable for papermaking, the cellulose portion of the plant must first be separated from substances that are not cellulose; for example, lignin, pith, woody shives and cores, fats, etc. This is done by the procedures which I have outlined in the following pages. A fiber having a high cellulose content is generally considered more advantageous than one with a lower cellulose content because the fiber can be purified and made into pulp more easily. The presence of non-cellulose materials like lignin is considered undesirable because the lignin rejects water and resists bonding. In papermaking we are aiming for just the opposite: the absorption of water and the promotion of bonding, both of which make for a stronger sheet of paper. Fibers contained in the various plants fall into the following categories: (1) fruit fibers like cotton seed hairs, (2) wood fibers like those fibers from deciduous and coniferous trees, (3) bast fibers, (4) leaf fibers, and (5) grass fibers. I have restricted my research to the last three mentioned categories.

After the fibers have been separated, they can either be used immediately, stored in the refrigerator or freezer, or dried. Drying can be done by laying the fiber strips on an old window screen or by hanging over a clothes line or a pole either indoors or outdoors. There are various conflicting reports as to whether, when drying outdoors, the fiber should be dried in the sun to promote whitening of the fiber or in the shade to prevent darkening of the fiber due to the action of the ultraviolet rays on the lignin still contained in the cell walls.



Bast Fiber Separation

Retting

The harvested plant part is soaked in water or spread on the grass and exposed to the dew. Retting allows enzyme action to loosen the bark containing the fiber so that it can easily be stripped off the woody core. This is said to work best with a pH of 6.8 and above. The retting process can take several months; and if one is not careful, can result in moldy fibers. Some fibers are naturally retted by being left standing in the field; for example, milkweed and nettles. For more complete details on retting, see Mauersberger and Kirby listed in the bibliography.

Stripping

Using freshly harvested plants, a vertical cut is made immediately after harvesting down the center of the stem with a knife; and the bark is peeled from the woody core in one piece. The outer bark is then removed from the inner bark by peeling or soaking and scraping with a paring knife. The stripping method is only successful when the bark contains a high percentage of moisture, as in the spring, or in very humid climates. However, there are always exceptions: fig and willow barks always seem easy to strip from their woody cores.

Steaming

The harvested fresh or dry stems are cut into pieces and packed into a stainless steel pan. Water is added to cover, brought to a boil, and the stems are cooked over a medium heat for one or two hours. The stems are then rinsed and cooled to handle; and the fibers are stripped off the cores which are discarded. If the fibers cannot be stripped easily, further cooking is needed. This strip of fiber now needs to have the outer bark removed from the inner bark, and this is done by scraping or peeling it off with a paring knife. In some cases the outer bark is so thin that it is too difficult to remove: it is left on and usually is dissolved in the alkaline cooking process.

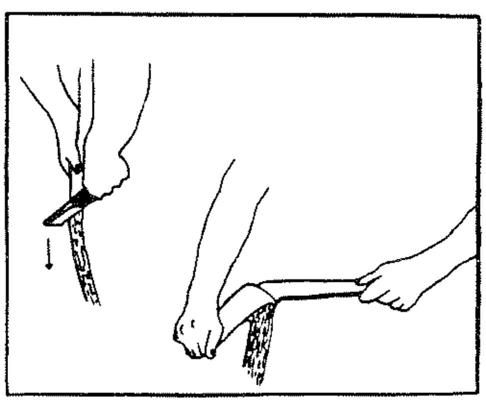
An alternative method of removing the outer bark is to peel or scrape it off with a potato peeler or paring knife <u>before</u> the bark is stripped or steamed from the woody core.

Leaf Fiber Separation

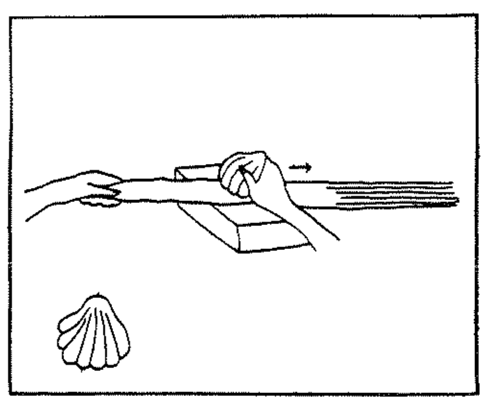
Many leaf fibers need no special separation other than cooking with a strong alkali in the regular cooking process. However, there are many leaf fibers with thin strong outer skins which need removing before the inner fibers can be released. This process is known as decortication and is done commercially by a machine called a decorticator. The leaves are fed into the machine no later than 24 hours after harvesting; otherwise the leaves become too dry and fiber separation becomes too difficult. The machine scrapes off the upper and lower skin, thus releasing the fibers. The machine decorticated leaves can be further treated by retting in water for several days. More ancient methods of leaf fiber separation involve scraping each leaf with a knife or shell till all chlorophyll and skin is removed, after which the fibers are washed, rinsed, and hung up to dry. The leaves can also be individually pounded with a rubber mallet or crushed between two stones and retted for a few weeks in fresh or salt water. A more contemporary version of this ancient process is to lay out the leaves across your driveway, and the action of parking in and leaving your driveway will decorticate your leaf fibers. Retting, which is optional, can also be done in alkaline solutions for a week or so.

Grass Fiber Separation

Generally no special separation is required for grass fibers. Some grass fibers which are high bulk and rather buoyant can be soaked and precooked in plain water for 1/2 hour. Bamboo, which is a woody grass, needs to have its stems pounded with a hammer or crushed between rollers in order to aid chemical penetration and free the large amount of air that the stems hold. Chinese papermakers used to ret bamboo stems in a pit for several months by placing lime between layers of stems and covering the whole stack with water.



Scraping or peeling the outer bark off the inner bark of a bast fiber



Leaf fiber separation by scraping off the outer skin with a shell

FERMENTATION

This is a process that takes the separated fiber and allows it to soak in a milk or water solution for several weeks. Air, warmth, and moisture are needed for bacterial action to eliminate any non-fibrous substances and can be used before cooking or in lieu of cooking. The soaking solution starts out by having an acid pH and ends up by being neutral or slightly on the alkaline side. Fermentation was used in lieu of cooking by early Chinese papermakers for the making of hemp paper and by the Hawaiians for the making of mulberry bark paper. The process is described in greater detail by Winifred Lutz in her chapter about fiber types in Timothy Barrett's book on the theory and practice of Japanese papermaking, listed in the bibliography. It is based on her own extensive tests with a number of fibers.

PRE-COOKING PREPARATION

After the fiber has been separated by retting, steaming, stripping, or decortication, soak it in water 24 hours prior to cooking. If a fiber has been dried for storage, it too needs to be soaked in clear water for 24 hours or more prior to cooking.

COOKING

All fibers need to undergo a cooking process prior to being beaten into pulp. Cooking frees and purifies the fibers by eliminating appreciable amounts of lignin, and other non-cellulose substances. As with the soaking process, the cooking process also helps swell the walls of the cellulose fibers so that they can take up even more water during the beating process, resulting in a stronger sheet of paper.

COOKING

In order to avoid adding any trace minerals to the pulp, it is essential that the cooking be done in a non-reacting pan, which is usually stainless steel. Pack the damp fibers into the pan and add cold water by the quart to cover the fibers. For each quart of water add 1 tablespoon of lye or washing soda according to the data sheet. Bring the water, with lye and fiber, slowly to the boil, and turn heat to low, cover the pan, and simmer for approximately 2 hours or as indicated on the data sheet. An important reminder here about the use of lye: protect eyes and hands when using and do all work in a well-ventilated area. A more accurate way of determining the amount of alkali to use is based on the dry weight of the fiber. For every 100 grams of dry fiber use 18 grams of lye. The fiber would need to be weighed prior to the soaking process. In cases when washing soda is being used instead of lye, 20 grams are used for every 100 grams of dry fiber. The pH of the alkaline solution needs to be between 12 and 14 in order to eliminate the non-cellulose substances.

For some fibers which require a longer cook, it may be advantageous to use a pressure cooker for cooking the fibers. Again, use a stainless steel pan. Since small fibers can clog the gasket and air vent, it is advisable to continually supervise the pressure cooking process and to use washing soda instead of lye, or dangerous explosions may occur.

After cooking is completed, the fiber is rinsed thoroughly to remove all traces of alkali. Wear rubber gloves and either rinse under a continuous slow stream of water, leaving the fiber in the pan under the faucet, or tip the fiber into a colander lined with organdy or sheer polyester to prevent the loss of the fine fibers, returning the fiber to a bucket of clean water and repeating the process four times or more until the water runs clear.

The rinsed, damp fibers can be dyed at this stage with either natural or synthetic dyes. If the fibers, either dyed or undyed, are not going to be used immediately, they can be stored in plastic bags in the refrigerator for a few days or in the freezer.

Further notes about alkalis

1. The most powerful alkali is caustic soda = sodium hydroxide = supermarket lye. Potassium hydroxide is similar in chemical properties to sodium hydroxide and can also be used.

2. A less powerful alkali is soda ash = sodium carbonate = supermarket washing soda.

3. Another less powerful alkali is lye of wood ashes = a solution made by treating wood ashes with water = potassium carbonate which is similar in chemical properties to sodium carbonate and can also be used.

The following information on beating methods, sheet formations, and casting techniques is an introductory outline to those not familiar with these papermaking processes. It is not intended to be an in-depth discussion. For more detailed information on these subjects, please consult books listed in the bibliography.

BEATING

In order for the cooked fiber to be made into a sheet of paper, it needs to undergo some kind of beating process to form a slurry or pulp. The damp fibers are taken from the refrigerator, and any remaining black specks and other impurities are removed. The fibers are then ready for beating. The beating process causes a roughening of the outside of the fiber surface, and the fiber swells as it takes up water. Fibers that have been properly beaten to achieve the right amount of roughening and swelling bond together better, thus forming a stronger sheet of paper. The length of time a fiber is beaten determines the kind of paper that is made. If the fiber is beaten a short time, a blotter type of paper results. If the fiber is beaten for a moderate amount of time, a crisp paper results. If the fiber is beaten for a long time, a tracing-type paper is produced.

Pounding Mallets

This non-mechanical method is a very ancient method of beating fibers into pulp and is best suited to the long bast fibers like milkweed and mulberry.

The damp fibers are placed on a hardwood or stone slab and pounded with wooden mallets or sticks for 1/2 to 2 hours depending on the amount of fiber. Water is sprinkled on the fiber from time to time to prevent the fibers from drying out. The mallets draw out, roughen, and help the long bast fibers soak up water as they are pounded. Very little cutting of the fiber occurs. The mallets should be made from a hardwood to avoid getting splinters in the pulp and may have grooved or smooth surfaces. A baseball bat makes an ideal pounding stick.

Mechanical Beating Devices

The Blender

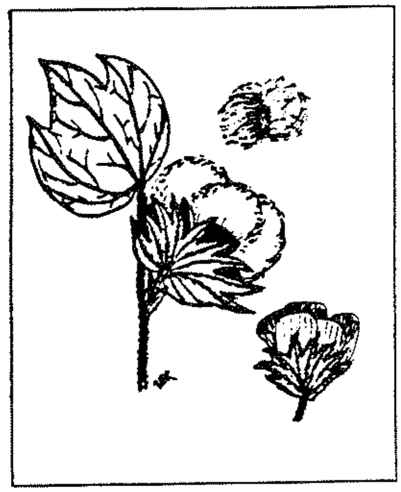
The blender doesn't do much hydrating and very little roughening and cutting of the fibers but rather acts to disperse them in water. Shorter fibers, like most grass and some leaf fibers, can be "beaten" in the blender. Blend 1 cup of water and 2 tablespoons of fiber for one minute. Bast fibers like gampi and daphne can also be "beaten" in the blender, but the longer bast fibers, like milkweed, need care and supervision to make sure that they don't get tangled under the blades and burn out the blender motor. For these fibers blend 1 cup water and 1 tablespoon fiber on the lowest blender speed. In all cases the damp fiber should be cut into 1/2 in. lengths before blending. In general a softer sheet of paper results from fibers prepared in the blender. The blender has a bad reputation in the papermaking world, but scientific tests have shown that it does an adequate job of roughening and hydrating some plant fibers for oriental methods of papermaking. A variable speed electric drill with a paint mixer attachment or a propeller-type lightening mixer can be used for doing a better job of hydrating larger batches of fiber.

The Hollander Beater

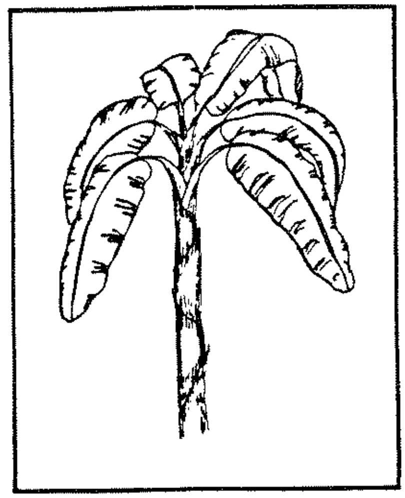
The Hollander beater cuts and hydrates large quantities of very long fibers as they pass between the beater roll and bedplate, while circulating in water around the beater tub. After the tub is filled with water, the fibers, which have been cut into 1/2 in. lengths, are fed slowly into the tub to prevent clogging as the motor runs. The beating time varies with the fiber type. Old cotton and linen rags do not need cooking or soaking before cutting and beating but should be laundered. All raw plant fibers, however, should be cooked prior to cutting and beating in the Hollander. Because this machine is so expensive, many artists have experimented with various substitutes like washing machines, garbage disposals, and hand-operated lawnmowers!

The Ball Mill

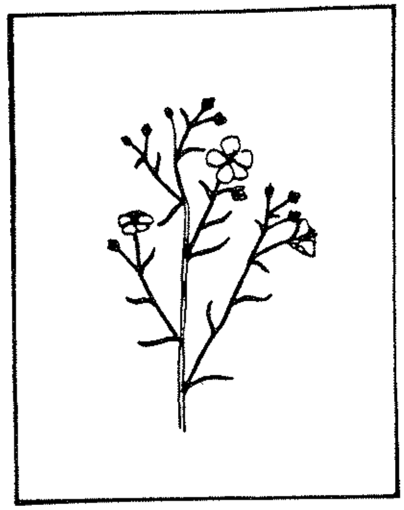
This beating method is generally more suitable for longer leaf fibers like sisal, Manila, and iris, and for some bast fibers like hops and hollyhock. The ball mill acts in a similar way to the old stampers by roughening, hydrating, and cutting the fibers as the pebbles pound them in water between the pebbles and the side of the rotating jar. The ball mill consists of a jar, grinding pebbles, a turntable, and a motor and can be purchased from ceramic and lapidiary supply houses. Several jars can be rotated at the same time on one large stand and motor. The ball mill is similar to the rock tumbler. Porcelain jars are being used instead of rubber barrels; and water, porcelain pebbles, and fiber are used instead of grit, rocks, and water.



Common name	Cotton
Botanical name	Gossypium hirsutum L.
Plant family	Malvaceae
Fiber length	0.7 to 4.2 mm
Fiber type	Bast
Plant location in the U.S.	Southeastern and southwestern states
Plant part used	Stem from annual or perennial herb
Season harvested	Summer, or after the cotton seed hair crop has been harvested
Fiber purchase	Not available
Pre-cooking preparation	Remove leaves, steam stems and strip fiber.
Cooking	2 hours with lye
Beating method	Blender, or ball mill
Sheet formation	Japanese
Paper color	Brown
Historical references	Cotton seed hairs have been used for fiber purposes since 3rd millenium B.C. Paper was made from cotton rags in Xativa, Spain in 1151.
Further notes	The stems are a crop residue and have been used for commercial papermaking.



Common name	Abaca, Manila hemp
Botanical name	*Musa textilis*
Plant family	Musaceae
Fiber length	3-7 mm
Fiber type	Leaf
Plant location in the U.S.	Other Musa spp. in Hawaii, Florida, California
Plant part used	Leaf stem of tall perennial herb
Season harvested	Summer
Fiber purchase	Available from weaving supply or hardware stores
Pre-cooking preparation	Cut into useable pieces and soak in clear water 24 hours prior to using. In the Philippines the leaf stems are decorticated.
Cooking	2 hours or more with lye
Beating method	Ball mill 4 1/2 hours, or Hollander
Sheet formation	Nepalese/Indian, Japanese or Western
Paper color	1. Cream if dry fiber was used 2. Pale yellow if rope was used 3. Tan if fresh leaf stems were used
Historical references	Textiles were being made in the Philippines from abaca when Magellan visited in 1521, also used in Japan for cloth. 1837 was first use of old Manila ropes for paper in the United States.
Further notes	The plant is indigenous to the Philippine islands. In 17th century Japan paper was made from Musa sapientum (Basho) in Okinawa. Basho paper is currently being made in Japan by Mr. Katsu. Musa spp. was cultivated in the Indus Valley by 327 B.C.



Common name	Flax, Linen
Botanical name	*Linum usitatissimum*
Plant family	Linaceae
Fiber length	33 mm approximately
Fiber type	Bast
Plant location in the U.S.	Various species, now mainly wild throughout the U.S.
Plant part used	Stems from annual herb or perennial weed
Season harvested	Summer/fall when stems are two thirds yellow
Fiber purchase	Available from weaving supply stores, either unbleached or bleached
Pre-cooking preparation	Commercial flax/linen is usually retted; if using fresh plants, remove leaves, steam stems and strip fiber; if using dry fiber, pre-soak in clear water for 24 hours before cooking.
Cooking	2 hour cook with lye, or longer
Beating method	Hollander beater
Sheet formation	Western
Paper color	Grey, buff, tan or white depending on variety and whether bleached
Historical references	Linen textile fragments date from 2500 B.C. First used for paper by the Chinese in 2nd to 4th centuries.
Further notes	

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