9

Pineapple, curauá, craua (caroá), macambira, nettle, sunn hemp, Mauritius hemp and fique

9.1 Pineapple

C YU and R R FRANCK

The pineapple (*Ananas comosus*) is a member of the Bromeliaceae family, which has some 1,300 species, most of which are native to South America. It is now widely cultivated for fruit in tropical and sub-tropical regions of the world. As with sisal fibre, pineapple fibre is extracted from the fresh leaf of the plant, and the appearance of the pineapple plant is also similar to the sisal plant except in so far as the fruit is concerned. Compared to sisal, the fresh leaves of the pineapple, with saw-toothed edges, are narrower, shorter, and therefore lighter. The length of pineapple fresh leaves varies within the range of 55–75 mm; the width of the leaves is usually in the range of 3–6 mm; the average weight of each leaf is 15–50 g.

The fibre yield of pineapple (extracted from fresh leaves of one to one-and-a-half-year-old plants[1]) is in the range of 1.55–2.5%. In the case of pineapple plants specially cultivated for fibre (not for fruit) the fibre yield is a little higher and the fibres are of better quality. In most cases the fresh pineapple leaves are a by-product of fruit production, and as such provide an added revenue source to the producers. As pineapple fibres are a natural and environmentally friendly product their use is expected to develop in many fields. Fifty years ago, in such countries as the Philippines, fibres extracted from fresh leaves were used to make clothing, but larger quantities were used to make ropes and twines.

9.1.1 Fibre structure and properties

The surface of a pineapple fibre shows numerous longitudinal cracks. The bundle is made up of smaller fibre bundles containing many fibres cemented together by gums. The cross-section of single fibres is irregularly round and the fibres have lumens. The microstructure of pineapple fibre is shown in Table 9.1. The chemical constituents of pineapple fibre is shown in Table 9.2. The chemical compositions of decorticated, retted and degummed fibre are also given in ref. 1 on page 327.

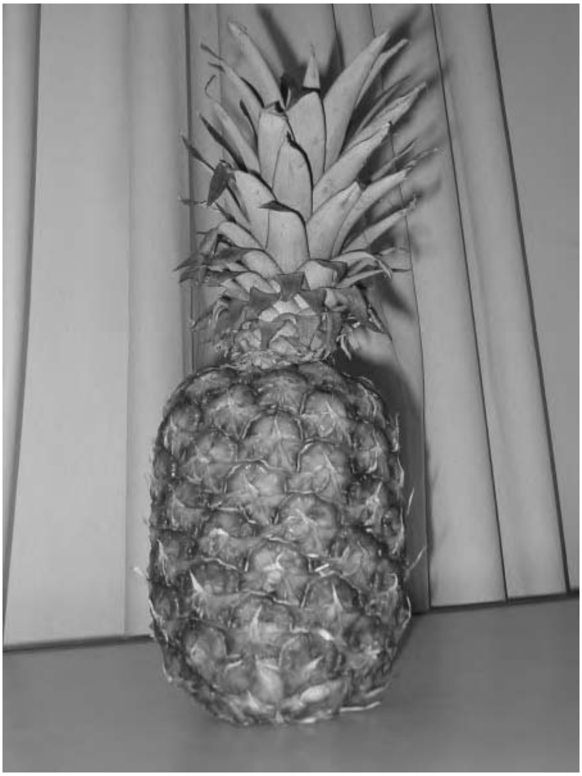

Figure 9.1 A pineapple. Courtesy: Ben Morriss, 2004.

The fibre bundle is comprised of many single fibres which are bonded together by gums such as pectins and other substances. The data in Table 9.2 shows that the chemical content of a pineapple fibre bundle is similar to that of other bast and leaf fibres. The lignin content is a little higher than that in ramie and flax, and is lower than in jute, kenaf and sisal. The physical properties of pineapple fibre are shown in Table 9.3.

Test results indicate that the properties of pineapple fibre are much closer to those of jute than to those of sisal, in other words the raw or fibre bundles extracted from fresh leaves are finer, weaker and softer than sisal fibre bundles. However, pineapple fibres are stronger and softer than jute fibre.

Table 9.1 Microstructure of pineapple fibre

Orientation		Crystallinity	Birefringence	Density
Factor (f_x)	Angle (°)	(%)		(g/cm^3)
0.85–0.97	5	0.55–0.75	0.058	1.543

Table 9.2 The chemical constituents of pineapple fibre

(a) chemical content of a pineapple fibre bundle (%)

Cellulose	Hemi-cellulose	Pectin	Lignin	Water soluble materials	Fat and wax	Ash
55–68	15–20	2–4	8–12	1–3	4–7	2–3

(b) chemical composition of processed pineapple fibres (%)

	Alpha cellulose	Hemi-cellulose	Lignin	Ash	Alcohol/ benzene
Decorticated fibre	79.36	13.07	4.25	2.29	5.73
Retted fibre	87.36	4.58	3.62	0.57	2.27
Degummed fibre	94.21	2.26	2.75	0.37	0.77

Source: I. Doraiswamy and P. Chellamani, 'Pineapple Leaf Fibres', *Textile Progress*, 24 (1) The Textile Institute, UK, 1993.

9.1.2 Processing and products of pineapple fibre

After cultivation, the fresh leaves are harvested and the fibres extracted. There are two methods used to extract the fibre from fresh leaves: (i) extracting fibre using decorticating machines, similar to the methods used for sisal fibre extraction; (ii) retting the leaves in water for 24–48 hours at temperatures of 15–30 °C after which the fibres can be easily separated from the leaves. This involves steeping the fresh pineapple leaves in water for five to ten days. Retting causes less damage to the fibres and maintains the high cellulose content of the extracted fibres than does decortication, at the cost of longer retting time.

The shape of the pineapple leaf is similar to that of sisal except that it has no 'saw-teeth' on the edges. Its size is smaller, which means the length of a pineapple fibre bundle is shorter and the fibre finer. The yield of fibre from pineapple leaves is usually in the range of 2–2.5% less than that of sisal which is about 5%. Decorticating machines used for sisal can also be used for pineapple fibre, except for small changes in the processing parameters because the pineapple fibres are shorter, and finer, and therefore weaker than sisal fibres. After this early processing the extracted pineapple fibres, whose appearance is usually white and lustrous, can then be further processed according to the requirements of the end uses envisaged. [*Editor's note*: Decorticating machines specific to pineapple leaves have also been developed; these are described in ref. 1.]

For the purpose of rope and twine manufacture the pineapple fibre is usually processed on the jute processing system. In blended yarns the quality of the

Table 9.3 The physical properties of pineapple fibre

(a) physical characteristics of pineapple fibre

Single cell	
Length (mm)	3–8
Diameter (μm)	7–18
Fineness (tex)	2.5–4
Fibre bundle	
Length (mm)	10–90
Fineness (tex)	2.5–5.5
Tenacity (cN/tex)	30–40
Elongation (%)	2.4–3.4
Initial modulus (cN/tex)	570–700
Density (g/cm^3)	1.543

(b) leaf size of different varieties of pineapple

Variety	Length (cm)	Width (cm)	Thickness (cm)
Assam local	75	44.7	0.21
Cayenalisa	55	4.0	0.21
Kallara local	56	3.3	0.22
Kew	73	5.2	0.25
Mauritius	55	5.3	0.18
Pulimath local	68	3.4	0.27
Selangor green	55	3.1	0.18
Simhachalam	59	3.7	0.22
Smooth cayenne	58	4.7	0.21
Thaliparamba local	67	3.5	0.23
Valera moranda	65	3.9	0.23

Source: I. Doraiswamy and P. Chellamani, 'Pineapple Leaf Fibres', *Textile Progress*, 24 (1) The Textile Institute, UK, 1993.

yarns and their spinnability during processing will improve with the increase of the pineapple fibre content. For high-quality products of pineapple fibre, such as apparel, the raw pineapple fibres need to be further refined usually by degumming with chemicals or enzymes. The chemical degumming of pineapple can be processed according to the following procedures: preparation (immersion in acid, H_2SO_4) – washing – boiling in NaOH solution – washing – bleaching – water extraction – oiling – drying. It should be noted that the degumming process must avoid the complete removal of the gums because the single fibres, if separated from each other without the gum, cannot be spun due to their short length (as shown in Table 9.3). The effects of chemical degumming on pineapple fibres are shown in Table 9.4, which shows that the treated fibre has been improved in some properties, such as the softness,

Table 9.4 Properties of treated pineapple fibres

	Fineness (tex)	Length (mm)	Tenacity (cN/tex)	CV% of tenacity	Elongation (%)	Initial modulus (cN/tex)
Degummed fibre	1.86	–	37.52	30.52	3.85	8.78
Increment (%)	−38	–	−11.92	−9.43	−12.57	−12.11

elongation and the fineness of the fibre, at the cost of a decrease in strength and length of the fibres.

In general, the effects of sodium hydroxide concentration, treatment temperature, and time on the properties of pineapple fibre are similar to that of other fibres such as sisal, jute and ramie. The higher the concentration of sodium hydroxide, the higher the temperature and the longer the time of treatment, the greater the loss of weight and strength and the increase in the softness of the fibres. After degumming and or chemical treatment the pineapple fibre can be processed on both the cotton or worsted spinning systems. For pineapple fibres to be spun on the cotton system it is necessary to cut the pineapple fibre to a certain length, say about 30–50 mm, so that it can be blended with cotton or other fibres of appropriate length, both natural and manmade.

Fibres to be processed on the worsted system are, after being degummed or treated, already of appropriate length (between 50 mm and 70 mm) for this type of machinery. In China and India considerable research work on the processing of pineapple fibres both in cotton and worsted spinning systems is taking place. Some test results on the yarn are shown in Table 9.5.

Fabrics made from 100% pineapple yarns are usually stiff and have good air and water permeability because of the hard, coarse fibres and rapid absorption and release of water by the fibres. The appearance of the fabric is almost same as

Table 9.5 Properties of 100% and blended pineapple yarns

	100% P.*yarn	Cotton 65/P35	Polyester 70/P30	Wool 50/P50
Fineness (tex)	100	32	20	125
Tenacity (cN/tex)	10.91	10.1	7.89	7.71
CV% of tenacity (%)	14.6	13.8	15.0	23.11
Elongation (%)	3.2	3.14	3.7	3.58
Evenness of yarn (CV%)	–	33.15	28.5	16.67
Thicks (1/400m)	–	972	1434	–
Thins (1/400m)	–	1164	352	–
Neps (1/400m)	–	1664	2530	–

* Pineapple.

that of ramie and flax fabrics. The handle of pineapple fabrics is harsher than that of these fabrics, but softer than those of jute and kenaf. Therefore the pineapple fabrics, especially in blended fabrics, are considered to have potential applications in apparel, besides applications in upholstery. The dyeing performance of pineapple fibres and products is similar to that of other vegetable fibres such as flax and ramie.

Readers are referred to Doraisswamy and Chellamani's monograph on pineapple fibres, referred to in the text and published by the Textile Institute, Manchester UK (*Textile Progress*, vol. 24 no. 1) for more detailed information and discussion on this fibre, its processing and the possibilities of blends with other fibres.

9.1.3 Reference

1. Doraisswamy, I. and Chellamani, P. *Textile Progress*, Vol. 24, No. 1, Textile Institute, Manchester, UK.

9.2 Curauá

R LADCHUMANANANDASIVAM and R R FRANCK

[*Editor's note*: I am indebted to Prof. Dr R. Ladchumananandasivam of the Univesidade Federale Do Rio Grande, Brazil for much of the information in this section on curauá and similar fibres. Others who have been most helpful are Mr M. Nesbitt, of the Royal Botanical Gardens, Kew, UK and Mr Gordon Mackie. Literature sources have included *Vegetable Fibres* by R. H. Kirby and Leão. J. C., *et al.*, *Natural Polymers and Agrofibers Composites* and Leão. J. C., *et al. Natural Polymers and Agrofibers Composites*.[1]

9.2.1 Introduction and plant description

Curauá (*Ananas erectifolius*) belongs to the family Bromeliaceae (as does the pineapple) order Bromeliales. It is an economically important plant found in the Amazon region of Brazil. The fibre extracted from it is used for various purposes such as paper production, twines, ropes, hammocks, nets and today mainly for the automotive industry. The number of leaves varies from 70 to 100 per plant, according to the growing conditions during its lifetime of five years and each plant can produce up to seven scions (seedlings) per year. The length of each leaf varies from 70–150 cm, with an average width of around 5 cm, average thickness of 3–5 mm and the leaves are almost flat. The fruit is similar to pineapple with a similar taste but smaller in size. The fibre yield is around 6–7% of the weight of the leaf. One hectare with twenty thousand plants, will produce from 2.4–3 tonnes per year.

Many projects are being developed at the present time in order to cultivate this plant in local communities as a cash crop with the objective of helping to eradicate poverty as well as to discourage the devastation of the rain forest.

9.2.2 End uses

Curauá fibres are used for the manufacture of hammocks, twines, and fishing nets by the local people in remote areas of the State of Amazônia. The yarns are also used for making baskets, handicrafts, etc. These hand-made products are sold or exchanged for other products. Nowadays, there are government schemes through FUNAI (a government organism responsible for indigenous people) that helps to sell these products in the locally set up co-operative centres for tourists as well as for the local people. The fibres are now also used as a source of cellulose for the manufacture of paper and the automotive industry uses the fibre as a packing material in car production. It is also used as a substitute for coir and, blended with other lignocellulose fibres, for the manufacture of composites.

9.2.3 Cultivation and yield

The young plants are set in manured soil. The density of planting is in the range of 1.5 m × 50 cm spacing in two rows. There are 20,000 plants per hectare. Up to 1 kg of fibre is extracted from 12 leaves and the production can be in the order of 1.5 tonnes per hectare. Around 6% of dry fibre is extracted from each leaf. The present local demand in Brazil is around 370 tonnes of fibre per month. The Federal University of Pará State, in the north of Brazil, is producing about 200,000 seedlings per month, with the aim of increasing this to 3 million per month as part of a poverty eradication programme called 'POEMA' ('Poverty and Environment in Amazonia'). These plants will be cultivated by the local communities of the region.

9.2.4 Fibre processing

Curauá is well known in the western region of the State of Pará but now it is also being cultivated on a large scale in the northern part of the state, in the districts of Santo Antonio do Taúá and Lagoa Grande, with the help of local and indigenous inhabitants. The leaves are cut manually and transported to a centre for the extraction of the fibres by mechanical decortication. The machine is called, in Portugese, a 'desfibradeira'. The extracted fibres are washed in tanks with running water and put out for drying in the sun. In certain places drying chambers are set up to accelerate the drying process. Fibre yield is between 1,000 kg and 1,500 kg per ha per year. Some characteristics of curauá fibre[4] are:

Ultimate fibre length	0.40 cm
*Ash	0.79%
*Solubility in hot water	1.03%
*Solubility in NaOH 1%	19.3%
*Cellulose	70.7%
Lignin	12.7%
Crystallinity index	75.6

*Water free

The wet fibre has an average elongation of 4.5%, MOE of 10.5 GPa and MOR 439 MPa. Oven dried fibre values are 3.7%, 9.7 GPa and 117 MPa respectively.

9.2.5 Bibliography

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9.3 Crauá (caroá)

R R FRANCK

9.3.1 Description and botanical classification

This is the plant referred to by Kirby and others and found mainly in the north-east of Brazil (in the States of Pernambuco, Ceará, Paraíba, Rio Grande do Norte, Piauí). It is called crauá or caroá and its botanical name is *Neoglazovia variegata* (Arr. Camara) Mez. The leaves are thorny on their borders unlike curauá leaves. The rhizome and the fruits are used for animal and human consumption. The fibres are used for the manufacture of sacks for cereals, bags, mats, hats, hammocks, twines and yarns.

9.3.2 Fibre characteristics[1]

This fibre has the following characteristics:

Average length of fibre	1.35 m
Average width	1.2827 mm
Length to width ratio	10.524
Average weight per metre	1.194 mg
Moisture regain	10.86%

Average dry resistance	254.94 g
Average wet resistance	194.72 g
Average dry elongation	1.342 mm
Average wet elongation	8.720 mm
Torsional resistance (dry)	154.89 turns
Torsional resistance (wet)	211.69 turns
Composition	
Hydrocelulose (a)	17.02%
(b)	24.55%
Number of plants/m^2	5
Number of plants per hectare	50,000
Number of leaves per plant	5
Number of leaves per hectare	200,000
Weight of each leaf	83.1 g
Weight of dry fibre/leaf	5.5%
Production of fibre/ha	980 kg (this value varies according to the number of plants/ha from 30,000 to 80,000 plants)

9.3.3 Reference

1. O Coroá, Lauro P. Xavier, EMPARN/Fundação Guimarães Duque, Natl-RN, Brazil, 1982.

9.4 Macambira

R R FRANCK

There is another type of plant belonging to the family Bromeliaceous and known as Macambira (mainly found in the north-east of Brazil). The botanical classification is *Bromelia laciniosa*. The rhizome and the fruits are used for feeding animals. The leaves are used for the extraction of fibres and the nuts as food for human consumption. Some characteristics are:

Thickness of leaves	2–3 mm
Width of leaves	2.5–4.5 cm
Weight of leaves	30 to 100 g
Length of leaves	180 cm
Number of leaves per plant	70–80.

The fibres have similar characteristics to caroá fibre and the leaves are thorny. The method of extraction of the fibres from the leaves of all these plants is very similar; using a 'desfibradeira' or decorticator. The extracted fibres are first washed, dried and spun and woven by processes similar to sisal and jute.

9.5 Nettle

J DREYER and G EDOM

9.5.1 Introduction and history

It seems incredible that the painful and annoying stinging nettle (*Urtica dioica* L.) should ever be considered of value as a cultivated crop that can provide sufficient and high quality fibre for textiles. History teaches that when raw materials were less diverse and abundant, the nettle had a role to play and was a particular focus during times of political or economic crisis. There are approximately 500 members of the Urticaceae family distributed worldwide. Plants in this family belonging to the *Girardinia*, *Boehmeria*, *Laportea* and *Urtica* genera are well known for their fibre-yielding properties. In Europe we are most familiar with the *Urtica* species, particularly *Urtica dioica*, although in Russia and Siberia *Urtica cannabina* has long been used as a source of fibre and is sometimes referred to as Swedish Hemp.

The stinging nettle or common nettle (*Urtica dioica*) is a frequent and unpopular perennial weed of Northern Europe (Fig. 9.2). Its unendearing

Figure 9.2 Nettle.

qualities are its unpleasant sting and the difficulty of eradicating the plant once it is established. It thrives on phosphates and nitrates and can be found growing where the soil has been disturbed and human beings have left their waste. The nettle prefers rich, damp soil and a shady habitat and propagates itself by seed or by extending rhizomes from the parent plant.

The fibre from several plant species of the Urticaceae family has been used throughout the course of history. The abundant *Urtica dioica* has always been a source of fibre for cordage or textiles and assumptions have been made about the extent of its use based on limited archaeological finds, historical records, folklore, literature and etymology. Nettles have certainly been used for fibre in Europe, but mostly as a handcraft and sometimes alongside other fibrous plants. However, whenever there was a bigger revival of interest in the plant, beautiful textiles were often produced as a result, for example in Denmark, during the 18th and 19th centuries.

The first attempt to commercialise the production of nettle fibre was in Germany during the 1720s. Since then there have been frequent efforts in several European countries to cultivate nettles and develop a method of extracting the fibre that could be applied on a large scale. Most of this research was carried out in Germany, particularly during the 19th century. Unfortunately, there does not seem to have been a successful, cost-effective method of nettle fibre extraction resulting from all this activity. It was Dr Gustav Bredemann who turned the tide with his research from 1927 to 1950. He interbred selected plants of *Urtica dioica* and produced several high fibre clones that could be cultivated. The criteria for selecting the plants were that they should be frost-resistant, have long, straight stems with minimal branching and of course a high percentage of fibre in the stem.[1] These varieties were given the name Fibre Nettle. Bredemann's work was quietly forgotten for many years after his book *Die Große Brennessel* was published in 1950.

During the 1990s Dr Jens Dreyer from the Institute of Applied Botany in Hamburg re-identified the individual fibre nettle clones that still survived in the Institute and revived and tested Bredemann's research. The fibre nettle is now being used as a basis for several commercial nettle fibre projects in Europe and advances in technology are making it possible to process the nettle more successfully and cost effectively. The use of the wild nettle for fibre is still also possible. The Kalajokilaakso Nettle Fibre Project in Finland has demonstrated this by producing a nettle fibre yarn from wild nettles that have been carefully selected and cultivated.

The use of nettles for fibre is just one possible application for the plant. For centuries the nettle has been employed in a myriad of ways. It has value as a food, tonic, herbal medicine, homeopathic remedy and animal feed. It has been used to make tea, beer, wine, cordials, cosmetics and in cheese-making. Research has confirmed the effectiveness of all parts of the nettle plant for a number of medical conditions and supplies are increasingly required for commercial preparations. Most raw materials for herbal teas, veterinary products and animal feed are imported from eastern Europe. Smaller companies requiring nettles of a particular standard either cultivate them or select carefully from the wild. It is feasible that cultivated nettles could supply a variety of markets.

9.5.2 Chemical and physical properties

Research into the chemical and physical properties of nettle fibre has been taking place for the last five years. All the available information has been gathered together from projects in Finland, England and Germany and where possible a comparison has been made between the wild nettle (*Urtica dioica*) and the cloned fibre nettle (*Urtica dioica convar. Fibra*). Fibre nettles can be

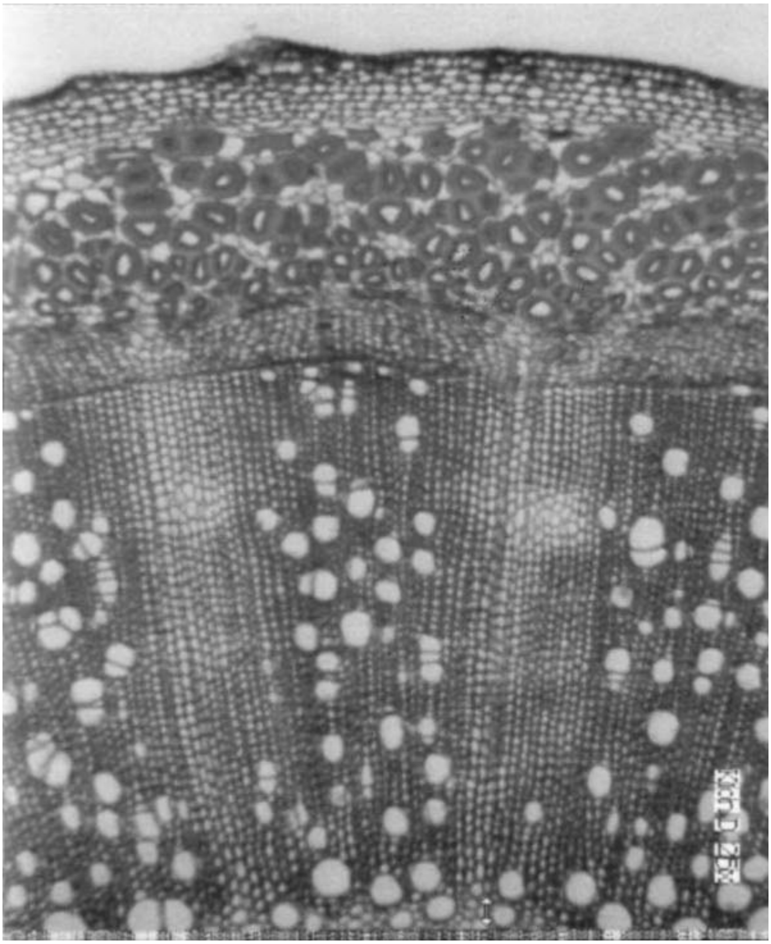

Figure 9.3 Photomicrograph of cross section of nettle stem.

distinguished from wild nettles by their larger quantity of individual fibre cells with bigger cell walls. The plants are selected because of their lack of branching from the stem, they have only a few stinging hairs and will lose most of their leaves in August which gives fewer problems of biomass in the straw. Most work on the characteristics of fibre has been done by the Faserinstitut Bremen e.V, although much of the data is still unpublished.

Hemp, flax and nettle all have fibres that lie along the length of the stem beneath the surface of the outer bast layer. These lengths of fibre are known as fibre bundles in flax and hemp, but a more accurate description for nettle fibre should be 'fibre groups'.[2,3] They are less compacted together and as a result are easier to separate from the bast material.[1] The individual fibre cells are composed of cellulose and held together in their groups by pectins and hemicellulose. The shape of the cells is oval to round polygonal.[3] The oldest and thickest fibres are in the outer part of the bark. The length and diameter of the long fibre is influenced by the species of nettle, its level of maturity and nutrition, where it is found on the plant and the method of extraction.[2] After mechanical separation the average measurement of length is 4–7 cm and 40–50 μm in diameter. There is no information on the combing of the long fibres to separate the long from the short. Treatment by alkali or enzymes leads to 40% of the fibres measuring 4–5 cm long and 25% measuring 5–6 cm long, when the fibre length distribution by mass is calculated. Their fineness is approximately 15–25 m in diameter.[4] The average measurement of fibre length by the Bremen Faserinstitut was between 5 and 7 cm with a high degree of variation.

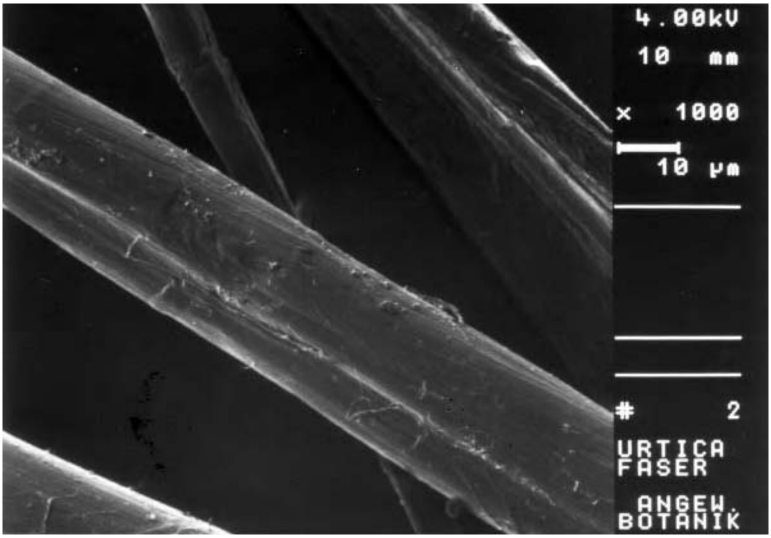

Figure 9.4 Photomicrograph of nettle fibres.

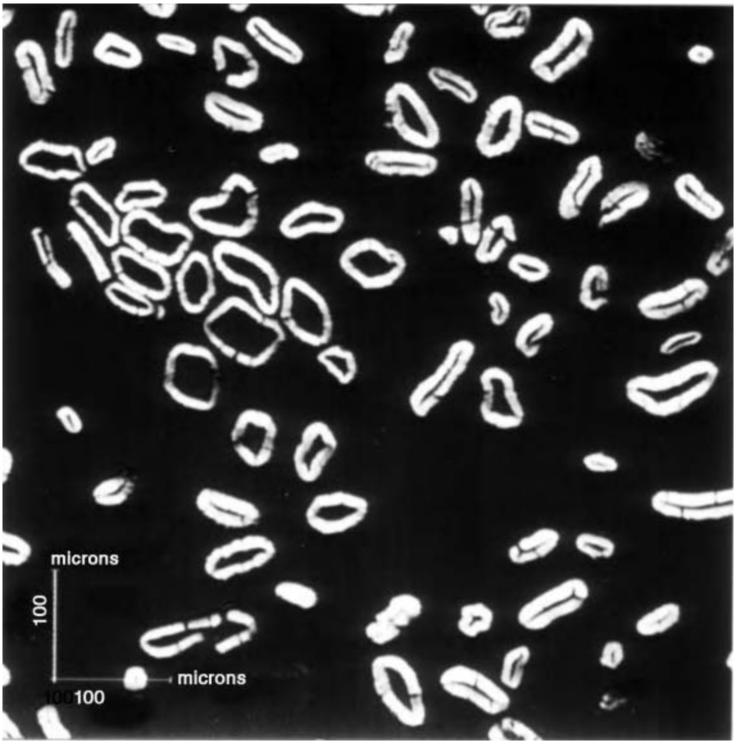

Figure 9.5 Photograph of cross section of nettle fibre.

The pure fibre content of the best-cultivated nettle plants from Hamburg is about 15% of dry mass, therefore six tonnes of harvested dry stems would give an average yield of approximately 900 kg of fine fibre.[2] This high quantity of fibre can be harvested as a result of the long period of breeding of selected nettles undertaken by Professor Bredemann during the 1920s and 1930s.[1] Wild nettle is approximately 3–8% of dry mass.[4] Fibre from nettle is known as nettle wool due to its softness[1] and the natural colour is cream/white, so it is easy to apply a coloured dye to the fibre or fabric.[1]

The Degree of polymerisation (DP) of the cellulose in the cell wall is about 2280.[5] Nettle is a strong fibre with 50 cN/tex, as measured by the Stelometer method at the Bremen Faserinstitut, but the method of spinning is important.[1] A

Table 9.6 Length measurement with *almeter al 101*: (a) fibre length distribution by mass (M)

Middle length	ML(M)	69.7 mm
Coefficient of variation	CV(M)	50.8%
Fibre content < 25 mm	L(M) < 25 mm	8.6%
Length at 25% of measured M	L(M) 25%	92.7 mm

Table 9.7 Physical and chemical composition of nettle fibre before and after retting[7]

Parameter	Before retting	After retting
Fibre strength (N/mm^2)	740 (WV)	
Fibre strength (cN/tex)	50 (FB)	25–35 (FB)
Fineness (dtex)	5 (WV)	
E-Modulus (GPa)	64.8 (WV)	
Strain (%)	1.2 (WV)	
Cell wall density (g/cm)	1.51 (WV)	
Length of fibre (mm)	40–50, but lengths up to 215 can be found (FB)	
Cellulose (%)	54	88
Hemicellulose (%)	10	4
Pectin (%)	4.1	0.6
Lignin (%)	9.4	5.4
Wax and fats (%)	4.2	3.1
Water-soluble products (%)	18	2.1

Compiled from: Wurl and Vetter (1994), Faserinstitut Bremen, Dreyer (1994) and Diploma Thesis.

lot of the strength can be destroyed if the machinery used is too aggressive, which is possible, for example with mechanical fibre extraction. The fibre can be separated mechanically and then with enzymes to get strengths of 23–35 cN/tex in comparison with cotton that has a strength of about 20 cN/tex.[6] Nettle fibre is very fine with only 5 dtex (the equivalent of about 50–80 μm in diameter). This is similar to ramie, which is the best natural fibre for spinning. The strain is important for spinning, but as with most plant fibres it has a low value of only 1.2%, so there is not much flexibility. The Emodul (elasticity module) is about 65 GPa and can be compared with E glass or good separated flax fibres. It is much higher than jute or banana. Moisture absorption is about 11%. No data exists on the electrical properties or specific heat of nettle fibre.

The fibres contain about 54% pure cellulose and about 10% of arabinane, xylane, galacturonane and other hemicelluloses. Nettle fibre contains about 4% pectin. This is an important factor because it has to be removed from the fibre to get a good and fine yarn. This can be done with sodium hydroxide or by more environmentally sound methods of enzymatic retting. By using pectinases (polygalacturonase, esterases, etc.) the pectin can be broken down thus freeing the individual fibres.

9.5.3 Fibre production and early processing

The nettle (*Urtica dioica*) is adapted to survive in a wide range of climatic conditions in Europe and moderate climates in other parts of the world except the tropics and polar region. The plant depends on a good water supply. It prefers loamy, clayey soils[8] and a moist, partly shaded position rather than open, dry and sunny.[9] If there is enough water (750 mm/m^2 per year) the nettle can be highly productive in a sunny habitat. Nettles need good soil conditions with a sufficient supply of nitrogen and a pH of 6.5. It is the host plant to a variety of indigenous invertebrates,[10] and only grasses are able to compete with its growth when the best conditions for growing nettles exist.[9]

There are considered to be a number of benefits associated with the cultivation of nettles. The nettle is a perennial and can be harvested year after year without replanting. A life span of 10–15 years for a cultivated crop has been suggested where optimum soil conditions are maintained, the application of some fertiliser and the control of grass weeds.[11] Nettles require low levels of fertiliser and little or no herbicide to control grasses.[11] They have the potential to process farmyard and liquid manure and the potassium nitrate of the soil increases as the result of nettle growth.[8]

Research has shown that nettles may be propagated by various methods; seed, seedlings, cuttings and the planting of rhizome pieces, although there is very little information regarding the last method. The advantage of growing by seed is that it is economical, but germination is unequal and the seed needs constant moisture after planting. Seedlings can be planted in May with vegetable planters when they have reached five to six weeks' growth.[9] The fibre nettle (*Urtica dioica convar. Fibra*) is propagated by stem cuttings. The cuttings require four to eight weeks pre-culture and can then be planted out by machine.[12] Weed control is particularly important at this time. The recommended number of plants per hectare is between 30,000–40,000 and the planting distances recommended range from between 25 cm apart with 50 cm between rows[12] to 30 cm apart with 60 cm between rows.[11] Weed control should start before planting and a pre-crop such as potatoes or maize put in to prepare the ground. Another method of cultivation is to plant the seedlings in potato ridges. The machine used to do this can then weed between the ridges. The nettle rhizomes are then protected within the ridges from damage by the machine.[9]

There are varied assessments as to the right levels of NPK fertiliser that should be applied to cultivated nettles. Nettles require easy access to nitrogen in the early stage of growth to maximise the height and weight of the stem. Clovergrass (*Trifolium repens*) planted between the rows also leads to a very high stem weight per plant.[11] Harvesting of the plants may be done from mid-August until early September.[8,9,12] One method of assessing whether the crop is ready to be harvested is to look for a large amount of leaf fall, but before the formation of new sprouts takes place.[12]

The possible yield of fibre from a cultivated crop of nettles must take into consideration the type of nettle planted (either wild or a fibre nettle clone, each of which has a different potential). One must also consider the method and year of harvesting. It is generally agreed that harvesting in the second year of cultivation yields a greater mass of fibre than in the first. For example, the fibre yield for one year was 335–411 kg/ha and in the second, 743–1,016 kg/ha.[13] This means a stem yield of about six tons per ha. Harvesting during the first year of growth will exhaust the nettles. The final value of the fibre should compensate for the extended waiting time before the first harvest. The nettle is an indigenous plant and therefore more robust in inclement conditions than other crops. A high fibre content (about 13%) in the stem is important for the effective and efficient mechanical decortication of fibres from the woody core.[14] On the other hand, a large quantity of leaves is not desirable because it slows the drying process.[14]

After harvesting the stems should be dried thoroughly and carefully before further processing, but retaining approximately 15% moisture. Literature shows that the stems were sometimes processed in their green state,[15] but generally they were dried first. This can be done by stacking in the field[1] or artificially with a warm dryer.[9] Until recently the fibre extraction methods used have been by dew or water retting, decorticating machine or the use of chemicals. Effective mechanical decortication is by using a pair of rollers and the separation of the woody parts from the fibre with machinery used in flax processing. The resulting fibre is then treated by enzymatic retting and research is ongoing to identify appropriate enzymes. The future success of nettle fibre extraction would appear to be through enzymatic retting and research is ongoing to identify appropriate enzymes. Further trials are also needed to produce finer yarns and textiles by this extraction method.

9.5.4 From fibre to fabric

Little information exists about the process of turning nettle fibre into cloth. Comparisons may be made with ramie, flax and hemp, although nettle stems are irregular in their size and the fibres are prone to break at the point where the stem branches. There are very few positively identified textiles remaining from the past and the most up-to-date research on nettle fibre is still at an incomplete stage. The traditional view of nettle fibre cloth was that it was soft, hardwearing and warm to the skin. This opinion has been reinforced by more recent research.[16,8] As with flax, nettle fibre has finer fibres than coir, sisal and hemp and forms a softer, better integrated material.[17] The Kalajokilaakso Nettle Fibre Project in Finland has produced yarn and textiles from nettle fibre extracted from cultivated indigenous species of *Urtica dioica*. The nettle fibre is mixed with other fibres that include cotton, silk, viscose and flax and up to 80% nettle fibre has been used in some of the blends. The fibres have been processed by retting with industrial enzymes and selected microbes.[18] Other European nettle fibre projects have produced nettle fibre textiles that have the appearance of linen.

The retting process not only separates the fibres from the plant stem, but also breaks down many of the fibre groups into single fibre cells or ultimate fibres. The consistency of well-retted nettle fibre is something between fine wool and cotton, but it is possible to extract longer fibres by retaining the individual fibres in their groups. A minimum retting period would be needed for this method and the emphasis would be on decortication.

The nettle fibres extracted in the Finnish project were formed into yarn by first putting them through a scutching machine originally made for cleaning short flax fibres. They were then carded twice on a flax card to open the fibres and remove the shiv. Fibre blending took place when the fibres were put through a wool card and the mixed fibres split into slivers before spinning on a woollen spinning frame.[18,19] Enzymes could be used to wash yarn and fabric to soften it.[14] Where enzymes were not used, scouring and bleaching of the fibres appeared to be successful in reducing the shiv and dust of basic decorticated fibres.[20] Another purpose of bleaching is to remove the lignin,[5] but as the lignin content in nettle fibre is little or non-existent, in this case the process would be unnecessary.

The dyeing process is similar to flax and other bast fibres. It has been found that if nettle fibre is dyed with reactive colours it requires the same dye recipe as flax, but less dye in the solution than cotton to get the same colour tone.[19] It is generally recommended that as with other bast fibres, nettle fibre yarn is woven rather than knitted into fabric. The machine knitting of nettle fibre yarn can be successful, although the irregularity of the fibre can cause 'catching' on the machine.[19] Hydroentanglement of nettle fibre is another successful alternative method of producing non-woven fabrics in order to produce finer preformed webs and a better fabric finish.[20] Very little research has been completed on the properties of nettle fibre and fabric, although it has been observed that the fine fibres formed a good 'bat' of fibre suitable for needling which held together well during handling.[17]

9.5.5 End products

It has been assessed that technical and textile grade fibres can be extracted from the stem.[14,20] The long fibres can be technically upgraded to be competitive with wool and cotton, if shiv monitoring and control could be improved.[21] Nettle fibre has the potential for replacing glass fibre as reinforcement fibre in some application areas for polymer matrix composites and is 30–40% lighter and more flexible than glass.[14] It is suitable for composite mats for the interiors of cars[22] and UF-bonded particleboard.[20] The Kalajokilaakso project aimed to produce nettle fibre yarn and cloth for use in the luxury textiles and handcraft market.[19] The woody matter obtained during fibre production can be used to make cellulose and produce special grades of paper.[8]

9.5.6 Problems

One problem for nettle fibre that limits its acceptability (as in the processing of hemp or flax) is the presence of dust and shiv during decortication,[16,20] although some mechanical treatment and enzymatic retting improves the level of cleanliness of the fibre. Water retting is inappropriate because it is highly polluting and the bacteria work too fast on nettles. The ease of turning fibre into fabric may improve if the machinery used is designed for the purpose instead of depending on machinery designed for the processing of other fibres.

9.5.7 Economic and cost considerations

An evaluation of the cost of the cultivation and processing of nettle fibre and its end products is not possible at the moment until an ongoing infrastructure to produce and sell nettle fibre textiles is securely in place.

9.5.8 Environmental issues

The nettle species *Urtica dioica* is an indigenous plant of Britain and Europe. As such it is an important food plant for native invertebrates and promotes the population diversity of local flora and fauna. The nettle is a perennial plant and its long-term cultivation will decrease soil erosion.[23] It requires a low input of resources, including minimal fertiliser and pesticide[14] and may improve soils containing high levels of nitrates and phosphates.[23] Nettle fibre is an environmentally friendly alternative to cotton and synthetics. It can be cultivated locally and different parts of the plant used for a variety of products. All waste is therefore minimal and biodegradable. Enzyme retting of nettle fibre requires a low water temperature and the liquor may be recycled.[11]

9.5.9 Health and safety issues

In the textile industry in the past there was a link between working with plant fibres and the lung disease Byssinosis. This was thought to be because the retting of the fibres caused a high degree of microbial activity. If the method of fibre extraction gives rise to the possibility of dust inhalation, then facemasks should be used.

There is anecdotal evidence that handling fresh nettle plants might cause an allergic reaction similar to hay fever in some people.[24]

9.5.10 Nepalese nettle

There are several nettle species in the Urticaceae that produce fibre. A particularly well known one is the Nepalese Nettle, *Girardinia diversifolia.* Products made from this nettle are available in this country. The long tradition of removing the fibre from this plant and using it for textiles has continued up to the present. However, the fibre from this species should be distinguished from that of *Urtica dioica*. Each of these plants has its own distinctive geography and culture. *Girardinia diversifolia* is a perennial that grows at an altitude of between 1,200 and 3,000 metres in Nepal. It reaches from one to three metres high and is covered with very large stinging hairs. It prefers a natural habitat of partial shade in damp soil.[25] The local name for *Girardinia diversifolia* is Allo and the fibre has traditionally been woven on a backstrap loom to make cloth for bags, sacks, jackets, porters' headbands and mats. It has also been made into cordage for ropes and fishing nets by indigenous groups such as the Rais, Sherpas, Magars and Gurungs.[26]

The nettles are harvested between September and December. The bark is stripped from the stem and boiled for approximately three hours in wood ash and simmered overnight. The fibre is then beaten and washed to remove extraneous plant material. Finally it is rubbed with a micaceous soil and dried in the sun.[27] Because this plant grows predominantly in forested areas, its continued use for fibre should be encouraged to ensure that the high forests are not depleted. The products made from the fibre are also an important commodity to the communities living in mountainous regions, who do not possess land suitable for crop cultivation. In 1984 a group of women weavers in the Sankhuwasabha district sought help from KHARDEP (Koshi Hill Area Rural Development Programme) to improve methods of extracting and processing nettle fibre and to expand the quantity and variety of items that were produced. This initiative spread and efforts are continuing to improve the processing method and to establish a secure market for the finished products.[28]

9.5.11 References

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9.6 Sunn hemp

R R FRANCK

Sunn hemp (*Crotalaria juncia*) fibre is also known as Indian, Bombay and Jubblepore. It is a plant of the Leguminosae family, Papilionatae subfamily. It grows in both temperate and tropical climates and when cultivated reaches a height of three metres in most kinds of soil, as long as they are well drained. Apart from its use in textiles sunn fibres are also used to make paper. The plant is also grown as animal fodder. As it is a Leguminosae it roots fix nitrogen and it is thus a useful rotation crop. Its main source is India although some is grown in Pakistan and Bangladesh.

Some of the principal characteristics and a morphological description of the fibres can be found in Tables 1.6, 1.8a. 1.8b, 1.10 and 1.12 in the appendix to Chapter 1. The fibre, after retting, is extracted manually from the plant, dried and hand combed.[1] Sunn hemp is used for the same kind of end-uses as jute and it is difficult to understand why it is not included in the group of 'jute-like' fibres. Perhaps the reason is that it would seem that most of the fibre intended for textiles is manually processed and used locally. Its annual production is estimated at several thousand tonnes.

9.7 Mauritius hemp and fique[1]

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The Amaryllidacaea (Narcissus) family of plants, to which these two species belong, is closely related to the Agaves and their appearances are similar. Their fibres are also processed in the same way as sisal and sisal-like fibres. Mauritius hemp (*Furcraea gigantea*), as its name would indicate, is produced in Mauritius and also in Reunion and Central and South America. The Mauritius hemp fibre is whiter, finer, softer. and longer than sisal, but weaker. The ultimate fibre lengths range from 1.3–6 mm with a mean of 2.9. Their diameters range from 18–32 microns, with a mean of 23 microns. Fique (*Furcraea macrophilia*) is grown in Colombia. The fibres are similar to sisal but, as with Mauritius hemp, it is said to be finer, softer and longer.

Table 9.8 World production of agave fibres apart from sisal, henequen and maguey for selected years from 1968–2002

Year	Tonnes
1968	39,648
1978	62,365
1988	58,258
1998	52,110
1999	54,983
2000	54,825
2001	54,163
2002	54,275

Source: FAOstat.

It is difficult to assess the scale of the annual production of these fibres because they are grouped with other fibres in the FAO statistics but it seems unlikely that their production exceeds several thousand tonnes per year. Many other species of fibre producing *Furcraea* grow wild in Central and South America and the Carribean Islands. These include *F. cabaya*, *F. andina*, *F cubensis* and *F. humboltiana*.

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