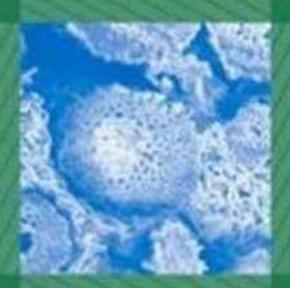
WOODHEAD PUBLISHING IN TEXTILES



Bast and other plant fibres

Edited by Robert R Franck







Bast and other plant fibres

Other titles in the Woodhead Publishing Limited series on fibres, published in association with The Textile Institute:

Series editor: Professor J E McIntyre

High performance fibres
Regenerated cellulose fibres
Silk, mohair, cashmere and other luxury fibres
Smart fibres, fabrics and clothing
Synthetic fibres

Details of these books and a complete list of Woodhead's textile technology titles can be obtained by:

- visiting our web site at www.woodheadpublishing.com
- contacting Customer Services

E-mail: sales@woodhead-publishing.com

Fax: +44 (0) 1223 893694

Telephone: +44 (0) 1223 891358

Post: Woodhead Publishing Limited, Abington Hall, Abington, Cambridge

CB1 6AH, England

Bast and other plant fibres

Edited by Robert R Franck





CRC Press Boca Raton Boston New York Washington, DC

WOODHEAD PUBLISHING LIMITED

Cambridge England

Published by Woodhead Publishing Limited in association with The Textile Institute Abington Hall, Abington Cambridge CB1 6AH England www.woodheadpublishing.com

Published in North America by CRC Press LLC 2000 Corporate Blvd, NW Boca Raton FL 33431 USA

First published 2005, Woodhead Publishing Limited and CRC Press LLC © Woodhead Publishing Limited, 2005
The authors have asserted their moral rights.

Every effort has been made to trace and acknowledge ownership of copyright. The publishers will be glad to hear from the copyright holders whom it has not been possible to contact concerning the following: Chapter 1, Tables 5, 7, 13, 17 and 18; Chapter 2, Figs 5 and 9; Chapter 3: Appendix G; Chapter 4, Figs 2 and 3; Chapter 6, Tables 3, 4, 10, 13–17, 24; Chapter 10, Fig. 2 and Table 3.

This book contains information obtained from authentic and highly regarded sources. Reprinted material is quoted with permission, and sources are indicated. Reasonable efforts have been made to publish reliable data and information, but the authors and the publishers cannot assume responsibility for the validity of all materials. Neither the authors nor the publishers, nor anyone else associated with this publication, shall be liable for any loss, damage or liability directly or indirectly caused or alleged to be caused by this book.

Neither this book nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming and recording, or by any information storage or retrieval system, without permission in writing from the publishers.

The consent of Woodhead Publishing Limited and CRC Press LLC does not extend to copying for general distribution, for promotion, for creating new works, or for resale. Specific permission must be obtained in writing from Woodhead Publishing Limited or CRC Press LLC for such copying.

Trademark notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation, without intent to infringe.

British Library Cataloguing in Publication Data A catalogue record for this book is available from the British Library.

Library of Congress Cataloging-in-Publication Data A catalog record for this book is available from the Library of Congress

Woodhead Publishing Limited ISBN: 1-85573-684-5

CRC Press ISBN: 0-8493-2597-8 CRC Press order number: WP2597

The publishers' policy is to use permanent paper from mills that operate a sustainable forestry policy, and which has been manufactured from pulp which is processed using acid-free and elementary chlorine-free practices. Furthermore, the publishers ensure that the text paper and cover board used have met acceptable environmental accreditation standards.

Typeset by Godiva Publishing Services Ltd, Coventry, West Midlands Printed by TJ International Limited, Padstow, Cornwall, England

Contents

	List of figures	xi
	List of tables	XV
	About the editor	xxi
	About the contributors	xxiii
	Contributor contact details	xxix
	Acknowledgements	xxxi
1	Overview	1
	R R FRANCK, Consultant, UK	
1.1	Introduction	1
1.2	Fibre prices	2
1.3	The Food and Agricultural Organisation's statistics	
	(www//FAOstat)	3
1.4	Comparative data on the physical and chemical characteristics	
	of bast and leaf fibres	3
1.5	Appendix: Comparative physical, chemical and	
	morphological characteristics of certain fibres	4
1.6	References	23
2	Jute	24
	K B KRISHNAN, I DORAISWAMY and	
	K P CHELLAMANI, SITRA, India	
2.1	Introduction	24
2.2	Fibre production and early processing	27
2.3	Physical and chemical properties	34
2.4	Yarn production	38
2.5	Fabric production, end-uses and specifications	52
2.6	Dyeing and finishing: modern developments in chemical	
	finishing	65
2.7	Economic and cost considerations	68

VI	Contents

2.8	Mark	et development	71
2.9		ronmental considerations	76
2.10	Healt	th and safety considerations	77
2.11	Ackn	owledgements	78
2.12		endices	78
	A	Jute's allied fibres: kenaf, roselle and urena	78
	В	Jute world fibre production	82
	C	Recent developments in retting methods	83
	D	Non-textile uses of jute	86
	E	Jute testing instruments developed by SITRA	90
2.13	Bibli	ography	91
2.14	Refer	rences	92
2.15	Gloss	sary of terms	92
3	Flax		94
	J SA	LMON-MINOTTE, Masters of Linen, France	
	a n d	R R FRANCK, Consultant, UK	
3.1		duction	94
3.2		flax plant	95
3.3	•	ical and chemical characteristics of flax fibres	101
3.4		vation and harvesting	107
3.5	Scuto		113
3.6		preparation and spinning	118
3.7	Weav	•	126
3.8	Knitt	· ·	130
3.9		c desizing, bleaching, dyeing and finishing	131
3.10		arel manufacture	137
3.11		acts and applications	137
3.12		omic and cost considerations	142
3.13	Mark		156
3.14		ronmental and health and safety considerations	158
3.15		lusion and future trends	158
3.16	Appe	endices	164
	A	Comparison of flax fibre yield in various countries	164
	В	World cotton production	166
	C	Flax cultivars – textile flax varieties approved by the	
		European Union	166
	D	Relationships between different common yarn count	
		systems	167
	E	The European Union's flax subsidy scheme (2003)	168
	F	Contractual relationships between flax growers and	
		their customers in France	168

		Contents	Vİİ
3.17	G Comparative labour costs (2002) H 'Masters of linen': technical criteria for finis	shed products	169 173 174
	Bibliography		174
3.18	References		174
3.19	Glossary of terms		1/4
4	Hemp		176
	J SPONNER, L TÓTH, S CZIGER, formerly	Hungarian	
	Hemp Trust and R R FRANCK, Consultant,	UK	
Part 1			
4.1	Introduction: hemp in Hungary		176
4.2	Hemp varieties and their cultivation		178
4.3	Physical and chemical characteristics of hemp		181
4.4	Primary processing of hemp stalks: fibre separatio	n	184
4.5	Hemp spinning and spinning machinery		188
4.6	Weaving		194
4.7	Fabric finishing		196
4.8	Production of other hemp products		196
4.9	Environmental and health and safety consideration	IS	197
4.10	Production and market trends		199
4.11	Conclusion		200
Part 2			
4.12	Present trends		201
4.13	Future trends		204
4.14	Bibliography		206
4.15	Glossary of terms		206
5	Ramie		207
	R KOZLOWSKI, M RAWLUK and J BARRI		
	Institute of Natural Fibres, Poland	,	
5.1	Introduction and history		207
5.2	Classification and description		209
5.3	Properties of the ramie fibre		210
5.4	Cultivation and harvesting		213
5.5	Primary processing		214
5.6	Spinning		220
5.7	Weaving and finishing		222
5.8	Applications of ramie		222
5.9	Conclusion		223
5.10	Appendices		224
	A Degumming: recipe and process		224
	B Non-textile uses of ramie		224

viii	Contents	
5.11	References	225
5.12	Bibliography	226
5.13	Glossary of terms	226
6	Sisal	228
	C YU, Donghua University, China	
6.1	Introduction: the plant and its anatomy	228
6.2	Chemical and physical fibre structure	229
6.3	Chemical treatment of sisal fibre	235
6.4	Production and early processing	240
6.5	Production and machinery	244
6.6	Products and applications	258
6.7	Economic and cost considerations	262
6.8	Marketing and consumption	262
6.9	Acknowledgements	269
6.10	Appendices	269
	A Non-textile applications of sisal	269
	B Testing sisal fibres for stiffness and compression	271
6.11	References and bibliography	272
6.12	Glossary of terms	273
7	Coir	274
	P M MATHAI, Coir Board, India	
7.1	Introduction and history	274
7.2	Chemical and physical fibre structure	275
7.3	Fibre production and early processing	277
7.4	Yarn production and machinery	280
7.5	Bleaching, dyeing, printing and finishing	284
7.6	Fabric production	287
7.7	Products and applications	291
7.8	Handle and wear characteristics	297
7.9	Economic and cost considerations	297
7.10	Marketing	298
7.11	Production and consumption	299
7.12	Environmental and health and safety issues	302
7.13	Conclusion	304
7.14	Appendices	304
	A Non-textile coir products	304
	B Chemical composition of new and old coconut fibres	305
	C World coir production	305
	*	
	D The manufacture of coir mats E Indian coir manufacturers and exporters trade associations	306 307

Contents	IX

F Quality codes and specifications of important varieties of coir mats and mattings	311
Glossary of terms	312
Abaca R R FRANCK, Consultant, UK	315
The plant and its cultivation	315
The fibres	316
Early processing	316
Textile manufacture and end uses	318
Production	319
	320
	320
Glossary of terms	320
Pineapple, curauá, crauá (caroá), macambira,	
nettle, sunn hemp, Mauritius hemp and fique	322
Pineapple	322
C YU, Donghua University, China and	
R R FRANCK, Consultant, UK	
Curauá	327
R LADCHUMANANANDASIVAM, University of Rio	
Grande, Brazil and R R FRANCK, Consultant, UK	
Crauá (caroá)	329
R R FRANCK, Consultant, UK	
Macambira	330
R R FRANCK, Consultant, UK	
Nettle	331
J DREYER, Faserinstitut, Bremen e.V., Germany	
*	343
	2.42
	343
R R FRANCK, Consultant, UK	
Bast and leaf fibre composite materials	345
J MÜSSIG, Faserinstitut Bremen e.V., Germany,	
M KARUS, European Industrial Hemp Association,	
Germany and R R FRANCK, Consultant, UK	
Introduction and background	345
	of coir mats and mattings Glossary of terms Abaca R R FRANCK, Consultant, UK The plant and its cultivation The fibres Early processing Textile manufacture and end uses Production Appendix: The uses of Philippine grades of abaca fibre for various end uses References Glossary of terms Pineapple, Curauá, crauá (caroá), macambira, nettle, sunn hemp, Mauritius hemp and fique Pineapple C YU, Donghua University, China and R R FRANCK, Consultant, UK Curauá R LADCHUMANANANDASIVAM, University of Rio Grande, Brazil and R R FRANCK, Consultant, UK Crauá (caroá) R R FRANCK, Consultant, UK Macambira R R FRANCK, Consultant, UK Nettle J DREYER, Faserinstitut, Bremen e.V., Germany and G EDOM, UK Sunn hemp R R FRANCK, Consultant, UK Mauritius hemp and fique R R FRANCK, Consultant, UK Bast and leaf fibre composite materials J MÜSSIG, Faserinstitut Bremen e.V., Germany, M KARUS, European Industrial Hemp Association, Germany and R R FRANCK, Consultant, UK

x Contents	
------------	--

10.2	The market, demand and supply	346
10.3	The influence of fibre properties and the possibilities of	
	measuring essential fibre characteristics	352
10.4	Manufacturing	367
10.5	The future, trends and conclusions	369
10.6	Acknowledgements	373
10.7	References	373
	Appendix I: List of fibre-producing plants	377
	Appendix II: References to Chapter 2	380
	Index	385

2.1	Cross-section through jute fibres.	28
2.2	Diagram of the anatomy of a jute stem.	29
2.3	Photomicrograph of cross-section of kenaf stem (x20).	30
2.4	Manual stripping of jute fibre from retted stem.	31
2.5	Process flowchart for spinning 100% jute yarn.	39
2.6	Process flowchart for fine jute and jute blended yarns.	45
2.7	Process flowchart for spinning jute/cotton blended yarns.	46
2.8	Proportions of jute fibres used for manufacturing different products in India (2001–2002).	52
2.9	Relative share of different diversified jute products.	55
2.10	Hand ribboning kenaf stems using bicycle wheel hub.	79
2.11	Alvan blanch ribboner.	79
2.12	Physical properties of jute stick particle board.	90
3.1	Line drawings of linseed and textile flax.	96
3.2	Flax seed pods.	96
3.3	Line drawing section of flax stem.	97
3.4	Line drawing of transverse section through a flax stem.	98
3.5	Cross-sectional diagrams of flax stalks showing (a) fibre	98
	bundles of a high-quality flax and (b) fibre bundles of a low-quality flax.	
3.6	Cross-section of flax stem \times 100 showing thickness of fibre walls and lumen.	102
3.7	Cross-section of flax stem \times 40 showing distinct fibre bundles.	102
3.8	Cross-section of flax stem \times 10 showing relative position of fibre bundles in the stem.	103
3.9	Stress-strain relationships for certain cellulosic fibres.	106
3.10	Flax seed pod.	107
3.11	Soil profile for good root development.	108
3.12	West European flax production flowchart.	109
3.13	Flax puller in action.	110

3.14	Scutching line.	113
3.15	Cross-section of scutching turbines.	115
3.16	Tow processing flowchart.	116
3.17	Wet and dry spinning flowchart.	118
3.18	Continuous flax hackling.	119
3.19	Line flax sliver being wound into 'can' after hackling.	120
3.20	Drafting and doubling.	121
3.21	'Linmack' drafting zone.	123
3.22	'Linimpianti' drafting zone.	124
3.23	World flax fibre production.	164
3.24	Relationship between common systems of yarn counts.	167
4.1	Photomicrographs of (a) hemp stalks and (b) longitudinal sections of hemp stalks.	181
4.2	The structure of hemp stalk.	182
4.3	Line drawing of (a) cross-section and (b) longitudinal section of hemp stalk (showing distribution of fibre bundles and joints between fibres by anastomosises. (b) Cross-section through hemp fibres (1 = fibre bundle; 2 = cortical parenchyma).	182
4.4	Hemp textile fibre production flowchart and yields.	184
7.7	Tremp textile hore production nowehalt and yields.	101
5.1	Cross-section through ramie fibres with lumen (cavity in fibre).	212
5.2	Mechanical harvester for bast fibres developed by the Institute of Natural Fibres, Poznan, Poland.	214
5.3	Schematic diagram of decortication line.	216
6.1	Sisal plants in the field.	229
6.2	(a) and (b) Longitudinal appearances of sisal fibre bundle.	230
6.3	X-ray of sisal fibre.	230
6.4	Infra-red spectrum of sisal fibre.	231
6.5	The distribution of length of single cells.	232
6.6	The distribution of width of single cells.	232
6.7	Distribution of length of fibre bundles.	234
6.8	The influence of concentration of NaOH on tenacity.	236
6.9	The influence of treatment time of NaOH on tenacity.	236
6.10	The ability of resistance to temperature (°C).	237
6.11	Resistance to salt (a) concentration (b) temperature.	238
6.12	The ability of resistance to sulphuric acid.	239
6.13	Harvesting sisal leaves.	240
6.14	Decorticating machines for sisal fibre (a) sisal fibre	242
	decorticator (b) sisal raspador (c) crane decorticator.	
6.15	Yarn tenacity (N) vs. oil content (%).	245
6.16	Softness (torsion-ability) of fibre vs. ageing time (days).	245
		0

	Figur	res xii	ii
6.17	Yarn quality of sisal vs. ageing time (a) and (b).	246	6
6.18	Yarn quality of sisal vs. oil content (a) and (b).	247	7
6.19	Drafting frame.	248	8
6.20	Schematic drawing of drafting line	249	9
6.21	Doubling machine.	249	9
6.22	Schematic drawing of doubling line.	250	0
6.23	Vertical ring frame for sisal spinning.	25	1
6.24	Vertical rope-making machine.	253	3
6.25	Weaving machine.	254	4
6.26	Carpet-weaving machine.	255	5
6.27	World sisal production and consumption 1985–2010.	264	4
6.28	World sisal production 1900–2020.	265	5
6.29	World sisal production by country.	265	5
6.30	Sisal production and twine output.	260	6
6.31	Major end uses of sisal and hard fibres.	260	6
6.32	Minor end uses of sisal and hard fibres, excluding abaca.	26	7
6.33	Sisal prices in current and constant 1995 US \$ values.	26	7
6.34	Long-term sisal prices in current and constant US \$ (2000=100%).	268	8
6.35	Hecogenin ($C_{21}H_{42}O_4$).	270	0
6.36	Tigoenin (C ₂₇ H ₄₄ O ₃).	270	0
7.1	(a) Photomicrographs of coir stalk cross- and longitudinal sections; (b) longitudinal section through a coconut (left) and plan view of stone (right).	27´d	7
7.2	Coconut dehusking spike.	278	8
7.3	World coir production 1900–2003 and forecast to 2020.	300	
8.1	Hand stripping tuxies from abaca.	31	7
9.1	A pineapple.	323	3
9.2	Nettle.	33	1
9.3	Photomicrograph of cross-section of nettle stem.	333	3
9.4	Photomicrograph of nettle fibres.	334	4
9.5	Photograph of cross-section of nettle fibre.	333	5
10.1	The relative price stability in percentage terms of hemp and flax fibres for use in composite products.	350	0
10.2	Processing technologies for natural fibre composites in Gernautomotive industry.	nan 352	2
10.3	Processing techniques for long fibre reinforced thermoplasts	. 350	6
10.4	The influence of fibre length on composite material characteristics.	350	6

xiv	Figures

10.5	The flexing resistance and IZOD impact resistance as a	357
	function of fibre content.	
10.6	From plant stalk to individual fibre.	358
10.7	The influence of fibre fineness on composite material characteristics.	359
10.8	The properties of one-directional composite materials.	360
10.9	Fibre and fibre bundle width distribution of cotton, coconut glass and hemp fibres.	363
10.10	Fibre width and fibre orientation distribution of ramie.	364
10.11	Tensile properties of selected fibres.	365
10.12	Percentage proportions of various processing techniques of natural fibre composites: 2000–2002.	368
10.13	Estimated natural fibre use in reinforced plastics.	370
10.14	An estimation of substitution/penetration for natural fibres to replace glass fibres in reinforced composites by 2010.	371
10.15	Future trends in natural fibre composite manufacturing technologies in 2005.	372

1.1	Properties of glass and natural fibres	6
1.2	Physical characteristics of flax, hemp and jute	7
1.3	Certain physical characteristics of bast fibres	8
1.4	Mechanical characteristics of certain fibres	9
1.5	Dimensions of some ultimate fibres	10
1.6	Mechanical properties of plant fibres	10
1.7	The range of some mechanical properties and densities of certain textile fibres	11
1.8	The lengths and widths of fibre cells reported by previous authors	11
1.9	Comparison of the Young's modulus of several bast and synthetic fibres	13
1.10	A comparison of various properties of E-glass and jute	13
1.11	Properties of selected natural fibres	14
1.12	Approximate chemical composition (%) of cellulosic fibres	14
1.13	Chemical composition (%) of plant fibres	15
1.14	Comparison of fibre properties of hemp, flax and cotton	15
1.15	Comparison of various characteristics of some natural fibres	16
1.16	Chemical composition of plant fibres by percentage mass (%)	17
1.17	Morphology of textile fibres	18
1.18	Microscopical differentiation of vegetable fibres	19
2.1	Area, yield and total production of jute/mesta in major producing countries (season 2001–2002)	24
2.2	World apparent consumption of jute, kenaf and allied fibres (2000)	26
2.3	World production of jute goods (1995)	27
2.4	Comparison between stem retting and ribbon retting process	33
2.5	Physical properties of jute fibres	36
2.6	Strength loss in jute due to soil burial	36
2.7	Unevenness for carded sliver (quality parameters)	40

XVI	Tables
X VI	Iduito

2.8	Unevenness of slivers at the drawing stages (quality parameters)	41
2.9	Specifications for sale yarn quality parameters (8–12 lb. (276–413 tex) yarn)	42
2.10	Specifications for sale yarn quality parameters (4.8–6 lb. (165–207 tex) yarn)	43
2.11	Quality characteristics of fine jute and jute blended yarns	46
2.12	Quality norms for jute/cotton blended yarns	47
2.13	Quality norms for jute/viscose blended yarns	47
2.14	Quality norms for jute/acrylic blended yarns (acrylic 1.5D)	48
2.15	Quality norms for jute/polyester blended yarns (polyester 1.4D)	48
2.16	Yarn quality attributes from JRC 321 fibres	51
2.17	Specification of handloom woven jute and jute blended fabrics	56
2.18	Application areas for technical textiles and suitable jute products	57
2.19	Specifications of jute household, soft luggage and decorative fabrics	59
2.20	Specifications of jute canvas cloth (usual range)	60
2.21	Specifications for jute tarpaulin cloth	60
2.22	Production of jute tarpaulin cloth	61
2.23	Jute soil saver fabrics for erosion control	61
2.24	Jute soil saver fabrics for river/canal embankments	62
2.25	Jute soil saver fabrics for drainage and filtration	62
2.26	Jute soil saver fabrics for road construction	63
2.27	Comparison of the fire protection performance of jute/kevlar	64
	blend protective garment and garments made from chemically treated conventional fabrics	
2.28	High-tenacity jute blended multi-component yarns for protective fabrics	64
2.29	Achievable efficiency at the carding stage	68
2.30	Achievable efficiency at the drawing stage	68
2.31	Spinning frame efficiencies for different qualities of jute yarns	69
2.32	Weaving hessian and sacking efficiencies	69
2.33	World exports of products of jute, kenaf and allied fabrics	70
2.34	Production of jute-like fibres by country (2003) (kenaf, roselle and urena)	80
2.35	World production of jute, kenaf and allied fibres 1998–2002	81
2.36	World production of jute 1964–2003	82
2.37	Production of jute by country (2003)	82
2.38	Physical properties of paper from jute pulp	88
2.39	Physical properties of laminated and non-laminated jute stick particle board	88

	Tables	xvii
2.40	Comparative properties of jute composites and medium-density fibre boards	89
2.41	Some quality characteristics of jute/polypropylene and polypropylene composites	89
3.1	Some varieties of flax grown in Western Europe	99
3.2	Chemical composition of flax stems and fibres at maturity	101
3.3	Physical characteristics of flax fibres	104
3.4	The crease recovery of fabrics under various conditions	106
3.5	Resistance to abrasion of various fabrics	106
3.6	Flax consumption by major end-uses	131
3.7	Fluidity and degree of polymerisation at various stages of manufacture	133
3.8	Price comparisons of various textile fibres	144
3.9	Flax, cotton and wool fibre prices January 1999-June 2003	147
3.10	(a) Line flax: stock, production and sales 1987/88–2001/02;(b) flax scutched tow: stock, production and sales 1987/88–2001/02	149
3.11	World line flax fibre production (2000–2002/3)	152
3.12	Exports of line flax from EU countries 1998–2000	153
3.13	Flax scutched tow: production of ten major producers (2000)	154
3.14	Imports and exports of scutched tow by country 1995-2000	155
3.15	Influence of Euro/US\$ exchange rate on the price of Western European line flax	156
3.16	Comparison of flax yields per hectare for several countries	165
4.1	The chemical constituents of hemp fibre	183
4.2	The physical characteristics of hemp fibre	184
4.3	Yields during primary processing	185
4.4	Yield of scutched hemp during hackling and cutting	191
4.5	Process weight loss during long fibre processing: (a) weaving; (b) twine manufacture	192
4.6	Process weight loss during fibre processing: (a) short fibre; (b) hemp tow	195
4.7	Hemp, flax and jute production 1960-1991	199
4.8	Hemp, flax and jute industry: number of employees	200
4.9	Hemp area under cultivation	200
4.10	World production of hemp fibre 1961–2003	201
4.11	World production of hemp fibre by country 1997–2003	202
4.12	Hemp areas harvested in certain countries outside the EU 1996–1999	202
4.13	Hemp areas harvested in certain countries of the EU 1996–2001/2	203

4.14	Russian federation: area cultivated and fibre produced 1995–1999	203
5.1	World production of natural fibres (million tonnes, average 1998–2000)	209
5.2	Classification of ramie	209
5.3	Some physical and chemical characteristics of ramie compared to other cellulosic fibres	211
5.4	Bacterial cultures for degumming	218
5.5	China: new classification of ramie fibres	221
6.1	The microstructure data of sisal fibre	230
6.2	The components of sisal fibre (% by weight)	231
6.3	Dimensions of single cells of sisal ultimate fibres (Hybrid 11648)	232
6.4	Dimensions of single cells of other Agave fibres	233
6.5	Dimensions of sisal fibre bundles	233
6.6	Tensile properties of sisal fibre	234
6.7	Compression properties of sisal fibre	235
6.8	The influence of NaOH on the properties of sisal fibre $(M:L = 1:20)$	237
6.9	The strength (N/g) of sisal fibre immersed in water	239
6.10	Average annual production (1,000 tonnes) areas (1,000 ha) of sisal fibre of the main producing countries	241
6.11	Quality standards of sisal long fibre	244
6.12	Yarn twist	251
6.13	Twine: relationship between the diameter and coefficient of experience	252
6.14	Ropes: relationship between the diameter and the coefficient of experience	252
6.15	The effects of bleaching agents (the raw whiteness of unbleached sisal fibre is 59.0)	255
6.16	The colour fastness of direct dyes	256
6.17	The parameters and formulae for dyeing with reactive dyes	257
6.18	The colourfastness of reactive dyes	257
6.19	The affinity of different reactive dyes on sisal fibre	258
6.20	Some sisal fabrics with their specifications	260
6.21	Comparison between sisal buff and cotton buff (for the polishing of tap made of brass)	260
6.22	Specifications of some sisal mattress materials	261
6.23	The profit (RMB) gained from one hectare per year of sisal and sugarcane planting	262
6.24	The export of sisal fibre and products in the world	263

	Tables	xix
6.25	Sisal baler and binder twine consumption, by country	264
6.26	Possible sisal consumption in 2010	266
6.27	End uses of sisal and henequen (1973/4, 1990 and 2000)	268
6.28	1993 projections to 2000 and estimated actual consumption 2000	269
6.29	The specification of hecogenin	271
6.30	The specification of tigoenin	271
7.1	Chemical composition of coir fibre	276
7.2	Properties of coir fibre	278
7.3	Specifications of important varieties of coir yarn	282
7.4	Standard mat sizes	288
7.5	Specifications of popularly used coir mesh matting	295
7.6	Comparative properties of a few natural fibres	297
7.7	Prices of comparable qualities of floor coverings made from coir, jute and sisal (prices in US\$/m² FOB)	298
7.8	Comparison of prices and other characteristics of coir and othe fibres	er 298
7.9	Import tariffs of major importing countries (May 2003)	299
7.10	Estimated production of coir products in India and Sri Lanka	300
7.11	World exports of coir and coir products (1996–2000)	300
7.12	Indian domestic consumption of coir	301
7.13	Major importing countries of coir products in 2000	302
7.14	World coir production 1964–2003	305
8.1	World abaca (manila hemp) fibre production (tonnes) by country (2002)	319
8.2	World abaca production 1961–2002	319
9.1	Microstructure of pineapple fibre	323
9.2	The chemical constituents of pineapple fibre: (a) chemical content of a pineapple fibre bundle (%); (b) chemical composition of processed pineapple fibres (%)	324
9.3	The physical properties of pineapple fibre: (a) physical characteristics of pineapple fibre; (b) leaf size of different varieties of pineapple	325
9.4	Properties of treated pineapple fibres	326
9.5	Properties of 100% and blended pineapple yarns	326
9.6	Length measurement with <i>almeterval 101</i> : (a) fibre length distribution by mass (M); (b) fibre length distribution by cross section (C)	335
9.7	Physical and chemical composition of nettle fibre before and after retting	336

XX	Tables	
9.8	World production of Agave fibres apart from sisal, henequen and maguey for selected years from 1968–2002	344
10.1	The use of natural fibres by the German automotive industry 1996–2010 (composites, excluding seat upholstery)	347
10.2	The use of natural fibre composites for serial parts in the automotive industry (1997–2001)	348
10.3	Physical characteristics of selected fibres	366

Robert R. Franck graduated from the now Faculty of Textiles of Heriot-Watt University, Edinburgh, Scotland in 1948 with various diplomas in textile manufacturing and design. After a short time as an Assistant Buyer with a London-based apparel manufacturer he joined the Fibres Division of Imperial Chemical Industries, Ltd (manufacturers of polyester and polyamide fibres) and was, successively in their marketing department, Sales Manager of their South American area in Buenos Aires, Marketing Section Leader in the UK, and Director of their French operations in Paris. He left ICI in 1976 and became the Commercial Director of the second-largest French worsted spinner after which he joined the Western European Flax and Hemp Association (CILC) as their Director for the UK and the Far East.

On retiring from the CILC in 1991 Robert Franck set up his own consultancy and has since been involved in projects in Eastern Europe, Asia, Australia and the UK. He joined the Textile Institute in 1958, is a Chartered Textile Technologist, a Fellow of the Textile Institute and of the Royal Society of Arts. He has also edited and part-authored a previous book in this Textile Institute-Woodhead Publishing series on textile fibres: *Silk, mohair, cashmere and other luxury fibres*.

Doctor K. P. Chellamani obtained his M.Tech (Textile Technology) Degree from Anna University and his Ph.D. from Bharathiar University, Coimbatore. He joined The South India Textile Research Association (SITRA) in 1981 soon after graduation and at present he is working as Deputy Director and Head of the Spinning Division, SITRA. Doctor Chellamani has to his credit over 200 research and review publications and he is also a co-author of ten books published by SITRA. He is a co-author of two of the Textile Progress Monographs on *Pineapple Leaf Fibres in Textile Scenario* and *Ginning – Art and Status*, published by The Textile Institute, Manchester in 1993. He is a Director of The South India Cotton Association (SICA), Coimbatore and a member of the Editorial Board of *Indian Journal of Fibre and Textile Research*, New Delhi.

Doctor Chellamani was awarded the F.T.A. by The Textile Association, India in the year 1991 and F.I.E. by the Institution of Engineers (India), Kolkata in 2003. He is a qualified Lead Assessor for ISO 9000 Quality Systems and has received thirteen awards in recognition of his work in the areas of pineapple leaf fibres, jute, quality control, manufacture of technical textiles, etc.

Sándor Cziger was born in 1941, in Dunafóldvár, Hungary. Sándor Cziger studied at the Textile College, the Technical University and the University of Economics, Budapest. He worked at the Hungarian Hemp Trust for many years and was also responsible for R & D at the Textile Research Institute. His last position before retiring was Chief Engineer at the Hird Spinning and Weaving company.

Ms Indra Doraiswamy obtained her B.Sc. Degree from Madras University and M.S. in Industrial Management in the USA. She joined The South India Textile Research Association (SITRA) in 1963 soon after graduation and her excellent work over the years has elevated her to the post of Director of SITRA. At present she is the Research Adviser of SITRA.

Ms Indra Doraiswamy has to her credit over 100 research publications and she is also a co-author of five books published by SITRA. She is the principal co-author of two Textile Progress Monographs on *Pineapple Leaf Fibres in Textile Scenario* and *Ginning – Art and Status*, published by The Textile Institute, Manchester in 1993. She is a past member of the Senate of Bharathiar University, Coimbatore, Tamil Nadu. She is member of various Committees/Boards of Educational and Research Institutions, etc., constituted by private bodies, State and Central Governments and also of other social service organisations. She was awarded the Fellowship of the Textile Institute, Manchester in 1987 and has received a number of National and International Awards in recognition of her outstanding work in various areas.

Doctor Jens Dreyer, born 1966, is a biologist who lives in Hamburg and works as a Post Doctor at the Technical University Hamburg-Harburg in the field of enzyme development and the enzymatic treatment of fibres. His doctorate research at the Institute of Applied Botany at the University of Hamburg examined the biology and agronomy of high fibre *Urtica dioica* L. cultivars, the study of which was first initiated by Prof Dr G. Bredemann in 1927. He started his work on nettles in 1992 and now has a small nettle-fibre company together with two partners.

Gillian Edom works as a field teacher for Chichester Harbour Conservancy, West Sussex. She has been researching the botany of the nettle (*Urtica dioica*) and its uses for over six years and is currently researching for a Master of Philosophy degree in nettle fibre extraction at De Montfort University, Leicester.

Michael Karus obtained his degree in Physics and Mathematics at the University of Cologne and majored in Nuclear Physics and Relativity. After graduating he worked as a teacher at the Universität Tübingen, in the tele-education programme, Ecology, as well as working as a part-time staff scientist at the KATALYSE-Umweltinstitut in Cologne. From 1989 until 1991 he worked as a member of the public relations staff at Flachglas Solartechnik, in Cologne where he focused on solar-thermal power plants. In 1991 he returned to the KATALYSE-Umweltinstitut, where he worked as a staff scientist and department manager, focusing on energy, ecology and electrosmog. He is a founding partner and director of the nova-Institut für politische und ökologische Innovation GmbH, in Hürth, and also manager of their renewable resources, market research and economy departments. Since 2000 he has been the coordinator of the European Industrial Hemp Association (EIHA), and since 2002 the Chief Editor of the news portal, www.renewable-resources.de.

Professor Ryszard Kozlowski graduated in Applied Chemistry at the University of Poznan in 1961. He did his Ph.D. in the area of the biochemistry of retting of flax and hemp. He went to work at the Institute of Natural Fibres,

where he is now General Director. He was awarded the degree of Professor of Technical Science at Poznan University in 1990.

In addition to his work at INF, Professor Kozlowski is co-ordinator of the FAO/ESCORENA Research Network on Flax and other Bast Plants and a member of several international organisations, including the Society for Sustainable Agriculture and Resource Management (SSARM) and the American Association for the Advancement of Science (AAAS).

Professor Kozlowski has received a number of awards for his research in the field of natural fibre resources, such as the Officer Cross of the Order of Restoration of Poland in 2000. In 2004 he received recognition from the American Chemical Society, Division of Polymer Chemistry for five years involvement and input in advancement of polymer science. He has authored or co-authored numerous books and over 250 papers.

K.B. Krishnan graduated (B.E. Mechanical) in 1961 from Madras University. After serving two years as Design Engineer in M/s Textool company, he joined the Lakshmi Machine company in 1963 and served in different positions including General Manager (Engineering), Technical Director-Development (Textiles), and Vice-President. He is, at present, Management Advisor R & D. He specialised in Textile Machinery design at M/s Rieter Machine Works Ltd, Switzerland in 1963–1965 and has published seven papers in the textile field.

He is the Chairman of the Technical and R & D committee of the Textile Machinery Manufacturers Association and a member of the advisory committees of other research organisations such as SITRA, BTRA, ATIRA, and NITRA and is also a Member of Council of the Textile Institute, Manchester, UK. He is the Chairman of the Spinning Preparatory, Spinning Doubling Machinery Sectional Committee TX of the Bureau of Indian Standards.

P.M. Mathai is a graduate physicist and was awarded the Secured First Rank and Gold Medal of the Coir Technology Course conducted by the Coir Board of India. He was then appointed to the Coir Board as Quality Control Inspector and promoted to Controlling Officer of this department. After years of experience Mr Mathai was appointed Deputy Director and was, in particular, resposible for recommending prices for Coir products to the Indian Government (at that time the government operated a scheme of minimum export prices). He was also responsible for preparing and implementing various schemes concerning the industry and was a visiting faculty member and external examiner of the National Training and Design Centre of the Coir Board of India. He was then promoted to the Joint Directorship and posted as Regional Officer responsible for the activities of the board in twelve states of the Republic of India. A short time ago he took voluntary retirement from his Coir Board activities and is now the General Manager of a major Coir company that is 100% export orientated.

Jörg Müssig obtained his degree in Mechanical Engineering at the Gerhard-Mercator University in Duisburg in 1995 and his doctorate from Bremen University in 2001.

After graduating in 1995 he joined the Faserinstitut Bremen e.V. From 1996 until 1996 he was a member of the 'New materials' working group of the Academy for the study of the consequences of scientific and technical advances at Bad Neuenahr-Ahrweiler GmbH, Germany. From 1998 to 2001 he carried out research in the areas of composites and fibres at the Department of Material Science of Bremen University and in 2001 rejoined the Faserinstitut Bremen as leader of the Bio-based Materials/Sustainability department.

Since 2000 he has been a member of the 'Quality' working group of the German Association of Natural Fibres (DNV) and of the 'Natural fibre composites' working group of the 'Consortium of reinforced plastics – technical federation' (AVK-T). Since 2001 he has been a member of the European cooperative research network on flax and other bast plants (Italy) and since 2002 of the sustainable composites network (GTB).

Since 2004 he has been an appointed member of the Young Academy at the Berlin-Brandenburg Academy of Sciences and Humanities and the German Academy of Natural Scientists Leopoldina.

Jack Salmon-Minotte is General Secretary of the Confederation Européenne du Lin et du Chanvre and Director of 'Masters of Linen' (the promotional organisation of European Linen). He is also a Graduate of the Ecole Superieure des Techniques Industrielles et Textiles (Villeneuve d'Asq, France) also of the Université Dauphine, Paris, in Business Studies.

Jack joined the French Linen Industries Trade Association after working for two years in the apparel sector and six years in a subsidiary of the Empain-Schneider group. He is a member of the Flax and Hemp Group of the European Commission and a Member of the Board of 'Expofil' (the yarn trade exhibition).

Jenó Sponner was born in 1937, in Moson, Hungary, and studied at the University of Economics, Budapest. After graduating he joined the Hungarohemp Magyar Kenderipari Trószt (Hungarian Hemp Trust). During his 42 years with this organisation, at first as an economic analyst, then as a factory director, he became Deputy General Manager of the Trust. He was then appointed General Manager of Elsó Magyar Kenderfonó in Szeged, the largest Hemp company in Hungary.

László Tóth was born in 1926, in Szeged, Hungary in 1926 and studied at the Textile College, Szeged and the Technical University, Budapest. He then joined the Hungarian Hemp Trust (cotton spinning and weaving), became Director of the weaving factory and subsequently R & D Director. He was then appointed General Manager of the Trust in Szeged, a position he held for 23 years.

Chongwen Yu was born in 1962, Ph.D, Professor and Head of Dept. Textile Engineering, College of Textiles, Donghua University, Shanghai, China. He has a Bachelor's degree in Textile Engineering, China Textile University (1980–1984), and a Master's degree in Textile Engineering (1987), China Textile University (1984-1987). He obtained a Ph.D. in Textile Engineering, China Textile University (1990–1994). He was Visiting Scholar, North Carolina State University, 1997–1998, and Associate Chairman of Bast and Leaf Fiber Processing Committee of China, Associate Chairman of New Spinning Committee and a Member of Standard of Textile Product Committee (Bast and Leaf Product Group) of China. He is a Member of the Fiber Society of the USA.

Chapter 1 Overview

Mr R. R. Franck 13 Garden Road Bromley, Kent BR1 3LU UK

Tel: +44 (0) 208 402 0307 Fax: +44 (0) 208 402 0308 E-mail: RobertRFranck@aol.com

Chapter 2 Jute

Ms Indra Doraiswamy and Dr K. P. Chellamani The South India Textile Research Association Coimbatore 641 014 India

Mr K. B. Krishnan Lakshmi Machine Works Ltd Coimbatore 641 018 India

E-mail: kbk23@rediffmail.com

Chapter 3 Flax

Mr J. Salmon-Minotte Masters of Linen 15, Rue du Louvre 75001 Paris France E-mail: jacksalmon.mol@wanadoo.fr

Chapter 4 Hemp

Mr J. Sponner, Mr L. Tóth,Mr S. CzigerElso Magyar Kenderfono RTH-6724 SzegedLondini Krt. 3Hungary

E-mail: vagoi@kender.ktv.tiszanet.hu

Chapter 5 Ramie

Professor Dr R. Kozlowski Institute of Natural Fibres Ul. Wojska Polskiego 71b 60-630 Poznan Poland

E-mail: sekretar@inf.poznan.pl

Chapter 6 Sisal

Professor Chongwen Yu College of Textiles Dong Hua University 1882, West Yan-an Road Shanghai 200051 China

E-mail: yucw@dhu.edu.cn

Chapter 7 Coir

Mr P. M. Mathai Pulickal House Kappamoodu Lane Opp. Telephone Exchange Alleppey 688001 Kerala S India

Fax: 91-477-2244884

E-mail: pmmathai2001@yahoo.com

Chapter 8 Abaca

Mr R. R. Franck 13 Garden Road Bromley, Kent BR1 3LU UK

Tel: +44 (0) 208 402 0307 Fax: +44 (0) 208 402 0308

E-mail: RobertRFranck@aol.com

Chapter 9 Pineapple, curauá, crauá, macambira, nettle, sunn hemp, Mauritius hemp and fique

Pineapple

Professor Chongwen Yu College of Textiles Dong Hua University 1882, West Yan-an Road Shanghai 200051 China

E-mail: yucw@dhu.edu.cn

Curauá

Professor Dr R Ladchumananandasivam Universidade Federal Do Rio Grande Rua Des Sinval Moreeira Dias 162 Natal 59075 340

Brazil

E-mail: rlsivam@ufrnet.br

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

Mr R. R. Franck 13 Garden Road Bromley, Kent BR1 3LU UK

Tel: +44 (0) 208 402 0307 Fax: +44 (0) 208 402 0308 E-mail: RobertRFranck@aol.com

Nettle

Dr J. Dreyer and Ms G. Edom Cobnor Cottage Chidham Chichester West Sussex PO18 8TE UK

Email: gillianedom@onetel.com

Chapter 10 Bast and leaf fibre composite materials

Dr J. Müssig Faserinstitut Bremen e.V. – FIBRE Building: IW3/Room: 2300 Am Biologischen Garten 2 28359 Bremen Germany

Email: muessig@uni-bremen.de

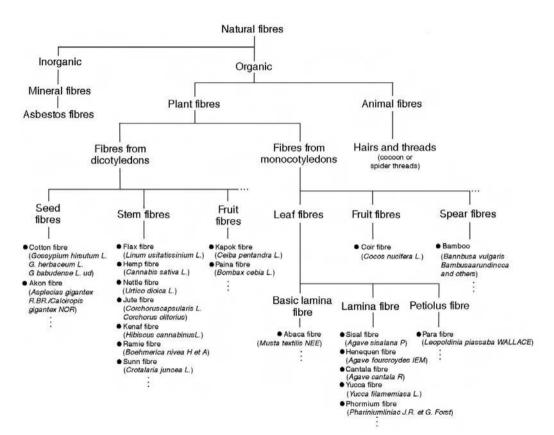
Dipl.-Phys. Michael Karus Managing Director nova-Institut GmbH Goldenbergstr. 2 50354 Hürth Germany

Email: michael.karus@nova-institut.de

I would like to acknowledge the help and support given to me during the preparation of this book by Mr Gordon Mackie and also for supplying the graphs that illustrate the history and outline the future of many of these fibres. His extensive experience in this area of the textile industry has been invaluable. Amongst the many other persons who have helped in many ways I would like to mention Mr Vivian Landon for information supplied concerning sisal, M. Janaas Balodas for details of Russian flax varieties and processing machinery and the Centre for Economic Botany, Royal Botanic Gardens, Kew for the list of textile fibre-producing plants.

I wish also to thank all the authors of the chapters in this book for the time and effort spent in researching and writing their contributions and without which this book would not exist.

> Robert Franck Ctext, FTI, FRSA Editor



Overview of natural fibres (Müssig, 2001, reproduced with permission).