

ELLIS HORWOOD SERIES IN POLYMER SCIENCE AND TECHNOLOGY

# CELLULOSE SOURCES AND EXPLOITATION

**industrial utilization, biotechnology,  
and physico-chemical properties**

J. F. Kennedy, G. O. Phillips,  
P. A. Williams



# **CELLULOSE SOURCES AND EXPLOITATION**

## **Industrial Utilization, Biotechnology and Physico-Chemical Properties**

Editors

**J. F. KENNEDY** B.Sc., Ph.D., D.Sc., C.Biol., C.Chem., F.B.I.M., F.I.Biol. F.I.F.S.T., F.R.S.C.

Director of the Research Laboratory for the Chemistry  
of Bioactive Carbohydrates and Proteins, School of Chemistry  
University of Birmingham, and Professor of Applied Chemistry  
North East Wales Institute of Higher Education

**G. O. PHILLIPS** B.Sc., Ph.D., D.Sc., F.R.S.C.

Executive Principal  
North East Wales Institute of Higher Education

**P. A. WILLIAMS** B.Sc., Ph.D., C.Chem. M.R.S.C.

Head of the Polymer and Colloid Chemistry Group  
North East Wales Institute of Higher Education



**ELLIS HORWOOD**

NEW YORK LONDON TORONTO SYDNEY TOKYO SINGAPORE

First published in 1990 by  
**ELLIS HORWOOD LIMITED**  
Market Cross House, Cooper Street,  
Chichester, West Sussex, PO19 1EB, England



A division of  
Simon & Schuster International Group  
A Paramount Communications Company

© Ellis Horwood Limited, 1990

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form, or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission, in writing, of the publisher

Printed and bound in Great Britain  
by Hartnolls, Bodmin, Cornwall

---

British Library Cataloguing in Publication Data

---

Cellulose sources and exploitation: Industrial utilization, biotechnology and physico-chemical properties

1. Cellulose

I. Kennedy, John F. (John Frederick) 1942- II. Phillips, Glyn O. (Glyn Owain) 1927- III. Williams, Peter A. (Peter Anthony)  
547.782

ISBN 0-13-121955-3

---

Library of Congress Cataloging-in-Publication Data available

---

# **CELLULOSE SOURCES AND EXPLOITATION**

## **Industrial Utilization, Biotechnology and Physico-Chemical Properties**



**Ellis Horwood Series in  
POLYMER SCIENCE AND TECHNOLOGY**

*Series Editors:* T. J. KEMP, University of Warwick  
J. F. KENNEDY, University of Birmingham

This series, which covers both natural and synthetic macromolecules, reflects knowledge and experience from research, development and manufacture within both industry and academia. It deals with the general characterization and properties of materials from chemical and engineering viewpoints and will include monographs highlighting polymers of wide economic and industrial significance as well as of particular fields of application.

- |   |   |
|---|---|
| Bodor, G.   | Structural Investigation of Polymers                                  |
| De, S.K. and Bhowmick, A.K.                           | Thermoplastic Elastomers from Rubber-Plastic Blends                   |
| Epton, R.   | Chromatography of Synthetic and Biological Polymers: Vols 1 & 2       |
| Hearle, J.W.S.  | Polymers and their Properties: Vol. 1                                 |
| Hearle, J.W.S.  | Polymer Materials   |
|   | Vol. 1: Structure, Properties and Performance                         |
|   | Vol. 2: Complex Systems   |
| Hearle, J.W.S., Lomas, B., Cooke, W.D., Duerdon, I.J. | Fibre Failure and Wear of Materials                                   |
| Hongu, T. & Phillips, G.O.                            | New Fibres  |
| Kennedy, J.F., <i>et al.</i>                          | Cellulose and its Derivatives   |
| Kennedy, J.F., <i>et al.</i>                          | Wood and Cellulosics  |
| Kennedy, J.F., <i>et al.</i>                          | Cellulose: Structural and Functional Aspects                          |
| Kennedy, J.F., <i>et al.</i>                          | Cellulose Sources and Exploitation:                                   |
|   | Industrial Utilization, Biotechnology and Physico-Chemical Properties |
| Lazár, M., <i>et al.</i>                              | Chemical Reactions of Natural and Synthetic Polymers                  |
| Nevell, T.J.  | Cellulose Chemistry and its Applications                              |
| Štěpek, J. <i>et al.</i>                              | Polymers as Materials for Packaging                                   |
| Švec, P. <i>et al.</i>                                | Styrene-based Plastics and their Modifications                        |

## Acknowledgements



### CELLUCON CONFERENCES AND THE CELLUCON TRUST

Cellucon Conferences were initiated in 1984 with their first conference, Cellucon '84, which set out to establish the strength of British expertise in the field of cellulose and its derivatives. This lay the foundation for subsequent conferences in Wales in 1986 and Japan in 1988 which have a truly international audience drawn from the major industries involved in the production and use of cellulose pulp and the derivatives of cellulose, plus representatives of academic institutions and government research centres. This diverse audience has allowed the cross fertilization of many ideas which has done much to give cellulose an important boost for the future. Cellucon Conferences, now established as a charitable trust, The Cellucon Trust, is continuing to extend the knowledge of all aspects of cellulose worldwide.

#### *MEMBERS OF THE ORGANISING COMMITTEE – CELLUCON '89*

This meeting owed its success to the invaluable assistance of the Organising Committee:

<b>Prof. G. O. Phillips</b> ( <i>Chairman</i> )	The North East Wales Institute
<b>Prof. J. F. Kennedy</b> ( <i>Vice Chairman &amp; Treasurer</i> )	The North East Wales Institute & University of Birmingham
<b>Dr M. B. Huglin</b> ( <i>Hon. Sec.</i> )	University of Salford
<b>Dr P. A. Williams</b> ( <i>Secretariat</i> )	The North East Wales Institute
<b>Mr H. Hughes</b> ( <i>Secretariat</i> )	The North East Wales Institute
<b>Dr W. B. Banks</b>	University College of North Wales
<b>Dr C. Bucke</b>	Polytechnic of Central London

<i>Dr H. L. Chum</i>	American Chemical Society (Cellulose, Paper and Textile Division)
<i>Mr K. Geddes</i>	Crown Decorative Products Ltd.
<i>Mr A. Grayson</i>	Forestry Commission
<i>Mr T. M. Greenway</i>	Berol Nobel Ltd.
<i>Dr A. Henderson</i>	DOW Chemicals Europe
<i>Dr T. J. Lewis</i>	RARDE, Ministry of Defence
<i>Mr J. Meadows</i>	The North East Wales Institute
<i>Prof. Y. Nakamura</i>	Gunma University, Japan
<i>Mr W. B. Painting</i>	Hoechst (UK) Ltd.
<i>Mr A. Poyner</i>	Aqualon (UK) Ltd.
<i>Mr R. Price</i>	Shotton Paper Co. Ltd.
<i>Mr A. Reveley</i>	Courtaulds Chemicals
<i>Dr J. Roberts</i>	Institute of Science and Technology University of Manchester
<i>Dr C. A. White</i>	Chembiotech Ltd.

The Organising Committee would like to express appreciation to those companies and Institutions who gave their financial assistance and support to the Conference and to Mr H. Hughes for assisting in the smooth running of the meeting and manuscript preparation.

**The Conference was sponsored by:**

The Biochemical Society – Chembiotech Ltd. – Hoechst UK Ltd. – The North East Wales Institute – USAF European Office of Aerospace Research and Development – US Army Research, Development and Standardisation Group, UK – Welsh Development Agency

**The Conference was supported by:**

The American Chemical Society (Cellulose, Paper and Textile Division) – Aqualon (UK) Ltd. – Berol Kemi (UK) Ltd. – Courtaulds Chemicals and Plastics – Ministry of Defence – Crown Decorative Products – DOW Chemicals – The Forestry Commission – Shotton Paper Company Ltd.

## Preface

The Cellucon-89 Conference, which this book documents, deals with the sources and exploitation of cellulose. The native and processed cellulose structures and their characterisation are authoritatively reviewed. New solvent systems developed for cellulose processing and applications have transformed the range of new applications and at the same time preserved the unique cellulosic properties. The specific application areas considered in the book are:

- **Paper and Pulp Technology**
- **Textile Fibre Technology**
- **Wood Derivatives: Composites & Laminates**
- **Industrial Cellulose Derivatives**

The environmental benefits of cellulose are now becoming even more apparent. Consequently, the special symposium on **"Biodegradation and Utilisation of Phytomass"** was extremely timely. The current emphasis is happily on utilisation rather than disposal, and in this respect the lignin component of wood is proving a valuable partner to cellulose in new areas of product development. The review by Dr H. Hatakeyama on the new high performance materials which can now be derived from lignocellulose demonstrates clearly that the long period of speculation about lignin's potential is about to end.

Above all, the value and versatility of lignocellulose from various sources is demonstrated in this book. It is required reading by those wishing to keep abreast of this rapidly moving subject.

**PROFESSOR GLYN O. PHILLIPS**  
Chairman, Organising Committee



# Table of Contents

Acknowledgements .....	xvii
Preface .....	xix
<b>PART 1: CELLULOSE: STRUCTURE AND DISSOLUTION</b>	
<b>1</b>	
Aspects of cellulose structure .....	3
H. Chanzy	
<i>Centre de Recherches sur les Macromolécules Végétales, CNRS,</i>	
<i>B.P. 53X, 38041 Grenoble Cedex, France</i>	
<b>2</b>	
Thermal analysis of bound water in polysaccharides .....	13
Tatsuko Hatekeyama, Kunio Nakamura* and Hyoe Hatakeyama**	
<i>Research Institute for Polymers and Textiles, Higashi, Tsukuba,</i>	
<i>Ibaraki 305, Japan, *Ohtsuma Women's University, Chiyoda-ku,</i>	
<i>Tokyo 102, Japan, and **Industrial Products Research Institute,</i>	
<i>Higashi, Tsukuba, Ibaraki 305, Japan</i>	
<b>3</b>	
Preparation of microcrystalline cellulose from cellulose	
of deciduous wood species and its properties .....	21
N. E. Kotelnikova and G. A. Petropavlovsky	
<i>Institute of Macromolecular Compounds of the Academy of</i>	
<i>Sciences of the USSR, Leningrad</i>	

<b>4</b>		
<b>The structure of bacterial cellulose – dye complex .....</b>	<b>33</b>	
Akira Kai, Ping Xu, Norikazu Ishida and Sachiko Ishikita		
<i>Department of Industrial Chemistry, Faculty of Technology,</i>		
<i>Tokyo Metropolitan University, Tokyo, Japan</i>		
<b>5</b>		
<b>Molecular weight determination of cellulose using</b>		
<b>high performance size exclusion chromatography</b>		
<b>[HPSEC], gel permeation chromatography [GPC]</b>		
<b>and viscometry .....</b>	<b>41</b>	
J. M. Lawther <sup>1</sup> , Z. S. Rivera <sup>2</sup> , K. Jumel <sup>2</sup> , and C. A. White <sup>2</sup> *		
<sup>1</sup> <i>Biocomposites Centre, University of Wales, Bangor, N. Wales, and</i>		
<sup>2</sup> <i>Chembiotech Ltd., University of Birmingham Research Park, Vincent</i>		
<i>Drive, Birmingham, B15 2SQ, UK</i>		
<b>6</b>		
<b>The cellulose/N-methylmorpholine-N-oxide/H<sub>2</sub>O</b>		
<b>solution system; degradation aspects .....</b>	<b>49</b>	
J. T. Guthrie and C. S. Manning		
<i>Department of Colour Chemistry, University of Leeds,</i>		
<i>Leeds LS2 9JT, UK</i>		
<b>7</b>		
<b>Direct solvents for cellulose .....</b>	<b>59</b>	
Annette V. Augustine, S. M. Hudson and J. A. Cuculo		
<i>Fiber and Polymer Science Graduate Program, College of Textiles,</i>		
<i>North Carolina State University, Raleigh, NC 27695-8302, USA</i>		
<b>8</b>		
<b>Alternative variants of dissolving cellulose in new organic</b>		
<b>solvent systems .....</b>	<b>67</b>	
W. Berger and M. Keck		
<i>Dresden University of Technology, Department of Chemistry,</i>		
<i>Dresden, GDR</i>		
<b>PART 2: PULP AND PAPER TECHNOLOGY</b>		
<b>9</b>		
<b>Recent developments in pulp production and their suitability</b>		
<b>for use in industrial processes in developing countries .....</b>	<b>81</b>	
Manfred Judt		
<i>Senior Industrial Development Officer, United Nations Industrial</i>		
<i>Development Organization [UNIDO], Vienna, Austria</i>		
<b>10</b>		
<b>Pulping and fibre characteristics of</b>		
<b>non-woody plants in Kenya .....</b>	<b>89</b>	
R. Murali		
<i>Department of Wood Science and Technology, Moi University, Kenya</i>		

<b>11</b>		
<b>Alkali-oxygen pulping of rice straw .....</b>	<b>95</b>	
K. Chen, K. Tosaka, and J. Hayashi		
<i>Department of Applied Chemistry, Faculty of Engineering, Hokkaido University, Hokkaido, Japan</i>		
<b>12</b>		
<b>Rubberwood chemithermomechanical pulp [ctmp] for newsprint production .....</b>	<b>101</b>	
Jalaluddin Harun <sup>1</sup> and Nyi Nyi Than <sup>2</sup>		
<sup>1</sup> <i>Faculty of Forestry, Universiti Pertanian Malaysia, Serdang, 43400 Selangor, Malaysia</i> and <sup>2</sup> <i>Pulp and Paper Department, Central Research Organization, Rangoon, Burma</i>		
<b>13</b>		
<b>Pulp and paper properties of <i>Acacia mangium</i> [Wild.] and variation with soil compaction .....</b>	<b>113</b>	
Jalaluddin Harun <sup>1</sup> , Mohd. Basri Hamzah <sup>1</sup> , David Alloysius <sup>2</sup> and Mohd. Nor Yusof <sup>3</sup>		
<sup>1</sup> <i>Faculty of Forestry, Universiti Pertanian Malaysia, Serdang, 43400 Selangor, Malaysia</i> , <sup>2</sup> <i>Forestry Graduate, UPM, Serdang, Selangor, Malaysia</i> , and <sup>3</sup> <i>Research Officer, Forest Research Institute of Malaysia [FRIM], Kepong, Kuala Lumpur, Malaysia</i>		
<b>14</b>		
<b>Cotton – a fibre of distinction .....</b>	<b>123</b>	
K. R. Wadhams		
<i>Department of Paper Science, UMIST, PO Box 88, Manchester, M60 1QD</i>		
<b>15</b>		
<b>Surface treatment of paper with cationic starch .....</b>	<b>129</b>	
A. A. Procter		
<i>Technical Manager, Starches, Cerestar UK Ltd.</i>		
<b>16</b>		
<b>Initial wettability of paper .....</b>	<b>137</b>	
Raysabro Oye		
<i>Faculty of Agriculture, Tokyo University of Agriculture and Technology, Tokyo, Japan</i>		
<b>17</b>		
<b>White-rot fungi for treatment of pulp and paper industry wastewater .....</b>	<b>143</b>	
J. Pellinen <sup>1</sup> and T. W. Joyce <sup>2</sup>		
<sup>1</sup> <i>Visiting Scholar, STFI, Box 5604, S-11486, Stockholm, Sweden</i> , and <sup>2</sup> <i>Professor, North Carolina State University, Department of Wood and Paper Science, Box 8005, Raleigh, NC 27695-8005, USA.</i>		

<b>18</b>		
<b>The ligninolytic system of white-rot fungi and potential applications in the treatment of bleach plant effluents .....</b>		<b>149</b>
A. I. Hatakka <sup>1</sup> , V. P. Lankinen <sup>1</sup> , T. K. Lundell <sup>1</sup> , P. Hietanen <sup>1</sup> , B.-O. Fabricius <sup>1</sup> and J. Pellinen <sup>2</sup>		
<sup>1</sup> <i>Department of Microbiology, University of Helsinki, SF-00710, Helsinki, Finland and</i> <sup>2</sup> <i>STFI, Box 5604, S-11486, Stockholm, Sweden</i>		
<b>19</b>		
<b>Biobleaching of paper and pulpmill effluents .....</b>		<b>155</b>
P. K. Khanna <sup>1</sup> , Dev Mittar <sup>1</sup> , S. S. Marwaha <sup>2</sup> and J. F. Kennedy <sup>3</sup>		
<sup>1</sup> <i>Department of Microbiology, Punjab Agricultural University, Ludhiana-141004, India,</i> <sup>2</sup> <i>Department of Microbiology, Punjabi University, Patiala-147002, India, and</i> <sup>3</sup> <i>Research Laboratory for the Chemistry of Bioactive Carbohydrates and Proteins, Department of Chemistry, University of Birmingham, Birmingham B15 2TT, UK</i>		
<b>20</b>		
<b>Trends in the viscose and dissolving pulp technology .....</b>		<b>163</b>
E. E. Treiber		
<i>Consultant, Lidingö, Sweden</i>		
<b>PART 3: TEXTILE FIBRE TECHNOLOGY</b>		
<b>21</b>		
<b>Preparation of viscose fibres from concentrated solutions of sodium cellulose xanthate .....</b>		<b>171</b>
B. Laszkiewicz, P. Wcislo and B. Domasik		
<i>Technical University of Lodz, 90-924 Lodz, Poland</i>		
<b>22</b>		
<b>Some aspects of viscose fibres modified by microcrystalline chitosan .....</b>		<b>177</b>
Henryk Struszczyk and Pertti Nousiainen*		
<i>Institute of Chemical Fibres, 90-570 Lodz, 19 C. Sklodowska Str., Poland and</i> * <i>Research Department, Kemira Oy Sateri, SF-37600 Valkeakoski, Finland</i>		
<b>23</b>		
<b>Prospect of cellulose industries in Japan .....</b>		<b>189</b>
Tatsuya Hongu		
<i>Nisshinbo Industries Inc., Yokoyama, Nihonbashi, Chuo-ku, Tokyo 103, Japan</i>		
<b>24</b>		
<b>New cellulose fiber from aq. alkali cellulose solution .....</b>		<b>197</b>
Takashi Yamashiki, Kenji Kamide and Kunihiro Okajima		
<i>Fundamental Research Laboratory of Fibers and Fiber-Forming Polymers, Asahi Chemical Industry Co. Ltd., Osaka, Japan</i>		

25

**Effect of fine structure and morphology on the properties of crosslinked cellulosic fibres ..... 203**

S. H. Zeronian, N. R. Bertoniere\*, M. S. Kim and Q. Xie

*Division of Textiles and Clothing, University of California,**Davis, CA 95616, USA and \* USDA, ARS, Southern**Regional Research Center, New Orleans, LA 70179, USA*

26

**The pH inside the fibre wall ..... 211**

A. M. Scallan

*Pulp and Paper Research Institute of Canada, Pointe Claire,**Quebec, H9R 3J9, Canada*

27

**Bioactive viscose fibres ..... 217**

Henryk Struszczyk, Antoni Niekraszewicz and Pawel Kucharski

*Institute of Chemical Fibres, 90-570 Lodz, 19 C. Sklodowska Str.,**Poland***PART 4: WOOD DERIVATIVES, COMPOSITES  
AND LAMINATES**

28

**Derivatisation of wood ..... 221**

W. B. Banks

*School of Agricultural and Forest Sciences, Division of Wood**Science, University of Wales, Bangor, N. Wales, UK*

29

**The effect of surface treatment on the properties of sisal-epoxy composites ..... 235**

E. T. N. Bisanda\* and M. P. Ansell

*School of Materials Science, University of Bath, Bath, UK*

30

**The preservation in the long-term of an union set [52 wooden casks] on outdoor display at the Bass Museum of Brewing History, Burton-on-Trent, Staffordshire ..... 241**

Maureen A. Robson

*Consultant Conservator, Birmingham, UK.***PART 5: CELLULOSE DERIVATIVES AND THEIR INDUSTRIAL APPLICATIONS**

31

**Mesophases of cellulose and cellulose derivatives ..... 251**

Richard D. Gilbert

*Fiber and Polymer Science Program, North Carolina**State University, Raleigh, NC 27695, USA*

## 32

**Homogeneous derivatization of cellulose via reactive organo-soluble intermediates ..... 257**

B. Philipp<sup>1</sup>, W. Wagenknecht<sup>1</sup>, I. Nehls<sup>1</sup>, D. Klemm<sup>2</sup>,  
M. Schnabelrauch<sup>2</sup>, and A. Stein<sup>2</sup>

<sup>1</sup> *Academy of Sciences of the GDR, Institute of Polymer Chemistry "Erich Correns", Teltow, GDR, and* <sup>2</sup> *Friedrich-Schiller-University, Jena, GDR*

## 33

**Some conclusions drawn from a study of cellulose nitration in technical mixed acids by X-ray photoelectron spectroscopy [XPS] and <sup>13</sup>C nuclear magnetic resonance [NMR] ..... 263**

R. D. Short<sup>1</sup> and H. S. Munro<sup>2</sup>

<sup>1</sup> *School of Materials, Sheffield University, Northumberland Road, Sheffield, S10 2TZ, and* <sup>2</sup> *Courtaulds Research, Lockhurst Lane, Coventry CV6 5RS, UK*

## 34

**The use of cellulose derivatives in the paint and building industries ..... 269**

Dr J. L. Mondt

*Hoechst AG, Wiesbaden, Germany*

## 35

**New cellulose in the construction industry ..... 279**

T. Podlas and D. Schweizer

*Aqualon, Wilmington, DE, USA.*

## 36

**The use of hydroxy ethyl cellulose in emulsion polymerisation ..... 287**

K. R. Geddes

*Crown Berger Europe Ltd., PO Box 37, Crown House, Hollins Road, Darwen, Lancashire, BB3 0BG, UK*

## 37

**Rheological characteristics of cellulosic and non-cellulosic associative thickeners ..... 295**

P. A. Williams, J. Meadows, G. O. Phillips and C. Senan

*Polymer and Colloid Chemistry Group, Faculty of Science and Innovation, North East Wales Institute, Connah's Quay, Deeside, Clwyd, UK*

## 38

**Natrosol<sup>®</sup> Plus hydrophobically modified hydroxyethyl cellulose ..... 303**

J. S. van Arkel

*Aqualon BV, PO Box 71, 3330 AB Zwijndrecht, The Netherlands*

<b>39</b>		
<b>Rheology and structure of a novel gelling system .....</b>	<b>317</b>	
A. Carlsson <sup>1</sup> *, B. Lindman <sup>1</sup> , G. Karlström <sup>2</sup> and M. Malmsten <sup>1</sup>		
<sup>1</sup> Physical Chemistry 1, Chemical Center, Lund University, PO Box 124, S-221 00 Lund, Sweden and <sup>2</sup> Theoretical Chemistry, Chemical Center, Lund University, PO Box 124, S-221 00 Lund, Sweden		
<b>40</b>		
<b>Phase behaviour in silica sols containing cellulose derivatives .....</b>	<b>323</b>	
M. J. Snowden <sup>1</sup> , P. A. Williams <sup>1</sup> , G. O. Phillips <sup>1</sup> , M. J. Garvey <sup>2</sup> and J. H. S. Rennie <sup>2</sup>		
<sup>1</sup> Research Division, The North East Wales Institute, Deeside, Clwyd, CH5 4BR and <sup>2</sup> Unilever Research, Port Sunlight Laboratory, Bebington, Merseyside, L63 3JW, UK		
<b>41</b>		
<b>Degradation of cellulose esters during ageing and processing measured by gel permeation chromatography .....</b>	<b>331</b>	
M. A. Bohn, D. Müller and F. Volk		
Fraunhofer-Institut für Chemische Technologie, ICT, D-7507 Pfinztal, FRG		
<b>42</b>		
<b>A new packing material for the GPC analysis of water soluble cellulose derivatives .....</b>	<b>339</b>	
L. L. Lloyd <sup>1</sup> , F. P. Warner <sup>1</sup> , E. Meehan <sup>1</sup> , K. Jumel <sup>2</sup> , J. F. Kennedy <sup>3</sup> and C. A. White <sup>2</sup>		
<sup>1</sup> Polymer Laboratories Ltd., Essex Road, Church Stretton, Shropshire, SY6 6AX, <sup>2</sup> Chembitech Ltd., Institute of Research and Development, University of Birmingham, Research Park, Vincent Drive, Birmingham, B15 2SQ and <sup>3</sup> Research Laboratory for the Chemistry of Bioactive Carbohydrates and Proteins, School of Chemistry, University of Birmingham, PO Box 363, Birmingham, B15 2TT, UK		
<b>43</b>		
<b>The surface chemical characterisation of cellulose derivatives by SIMS .....</b>	<b>345</b>	
M. C. Davies, R. C. Rowe and R. D. Short		
Department of Pharmaceutical Sciences, Nottingham University, Nottingham, NG7 2RD, UK		
<b>44</b>		
<b>Supramolecular structure and virus separability of porous regenerated cellulose multi-layered hollow fiber membranes .....</b>	<b>353</b>	
Kenji Kamide, Hideki Iijima and Kazuko Sogawa		
Fundamental Research Laboratory of Fibers and Fiber-Forming Polymers, Asahi Chemical Industry Co. Ltd., Osaka, Japan		

<b>45</b>	<b>Cellulose and amylose trisphenylcarbamates as chiral stationary phases for optical resolution by HPLC .....</b>	<b>359</b>
	Yoshio Okamoto, Ryo Aburatani, Yuriko Kaida and Koichi Hatada <i>Department of Chemistry, Faculty of Engineering Science, Osaka University, Toyonaka, Osaka 560, Japan</i>	
<b>46</b>	<b>Determination of sequence distribution of substituted and unsubstituted glucopyranose units in water-soluble cellulose acetate chain as revealed by enzymatic degradation .....</b>	<b>365</b>
	Kenji Kamide, Hideki Iijima and Keisuke Kowsaka <i>Fundamental Research Laboratory of Fibers and Fiber-Forming Polymers, Asahi Chemical Industry Co. Ltd., Osaka, Japan</i>	
<b>47</b>	<b>Determination of industrial grade carboxy-methyl cellulose in crude and detergent formulations by a chemical method .....</b>	<b>371</b>
	J. F. Kennedy and E. H. M. Melo <i>Research Laboratory for the Chemistry of Bioactive Carbohydrates and Proteins, Department of Chemistry, University of Birmingham, PO Box 363, Birmingham, B15 2TT, UK</i>	
<b>48</b>	<b>An enzymatic approach to the determination of industrial grade carboxymethyl cellulose in crude and detergent formulation forms .....</b>	<b>377</b>
	J. F. Kennedy and E. H. M. Melo <i>Research Laboratory for the Chemistry of Bioactive Carbohydrates and Proteins, Department of Chemistry, University of Birmingham, PO Box 363, Birmingham, B15 2TT, UK</i>	
<b>PART 6: BIODEGRADATION AND UTILISATION OF PHYTOMASS</b>		
<b>49</b>	<b>The degradation of cellulose by thermal, chemical and biochemical techniques .....</b>	<b>385</b>
	A. Blazej, M. Kosik and I. Spilda <i>The Slovak Technical University, Bratislava 812 37, Czechoslovakia</i>	
<b>50</b>	<b>Fungal degradation of wood .....</b>	<b>397</b>
	J. F. Levy <i>Emeritus Professor of Wood Science, Imperial College, London, UK</i>	
<b>51</b>	<b>The role of hydrogen peroxide in cellulose-degrading cultures of wood-rotting basidiomycetes .....</b>	<b>409</b>
	R. G. Veness and Christine S. Evans	



*School of Biological Sciences, Thames Polytechnic,  
Wellington Street, London SE18 6PF, UK*

52

**Cellulolytic enzymes produced by *Aspergillus Fumigatus*  
[IMI 255091] grown on various substrates** ..... 415

Lesley A. Hamilton and D. A. John Wase  
*Biochemical Engineering Division, School of Chemical  
Engineering, University of Birmingham, PO Box 363,  
Birmingham, B15 2TT, UK*

53

**The cellulose-binding domains of  
*Cellulomonas Fimi* cellulases** ..... 423

J. M. Greenwood, E. Ong, N. R. Gilkes, D. G. Kilburn,  
R. C. Miller, Jr. and R. A. J. Warren  
*Department of Microbiology, University of British Columbia,  
300-6174 University Blvd., Vancouver, BC, V6T 1W5, Canada*

54

**Immunogold-cytochemical labelling of lignocellulolytic  
enzymes in hyphae of *Coriolus Versicolor*** ..... 429

Imelda M. Gallagher and Christine S. Evans  
*School of Biological Sciences, Thames Polytechnic,  
London, SE18 6PF, UK*

55

**Microbial degradation of lignin** ..... 435

S. L. Pedlar and W. B. Betts  
*Department of Biology, University of York, York, UK*

56

**The applicability of the steam explosion process to  
achieve separation of the major polymeric components  
of spruce softwood** ..... 443

J. Meadows, M. R. Vignon\*, G. O. Phillips and M. Rinaudo\*  
*North East Wales Institute of Higher Education, Deeside,  
Clwyd, CH5 4BR, North Wales and \* Centre de Recherches  
sur les Macromolécules Végétales, CNRS, BP 68X,  
F-38402 St Martin D'Heres, France*

## PART 7: UTILIZATION OF LIGNIN AND CELLULOSIC WASTES

57

**Conversion of cellulose-containing materials into  
useful products** ..... 453

Raimo Alén  
*Laboratory of Fuel Processing Technology, Technical  
Research Centre of Finland, SF-02150 Espoo, Finland*

58

**High-performance materials from lignocellulose** ..... 465