篩選菌株 Gluconacetobacter sp. Wu3M 生產細菌纖維薄膜及動力學解析

羅凱軍、吳建一

E-mail: 362534@mail.dyu.edu.tw

摘 要

由Gluconacetobacter sp.菌株所生產之細菌纖維素是一生物 聚合物，具有獨特的結構、機械強度和化學穩定性。在本研究中， 由椰子汁中篩選具有生產細菌纖維素之菌株，經16S rDNA 鑑定 基因序列後屬於Gluconacetobacter sp.， 並且命名為Gluconacetobacter sp. Wu3M (NCBI JX088028)。為了探討培養因 子對Gluconacetobacter sp. Wu3M 菌株生產細菌纖維之影響，在本 研究中探討4 個變因，包含醋酸濃度、培養基表面積、培養器皿 壁面粗糙度及接菌量。實驗結果顯示，添加0.25%之試藥級醋酸 可增加細菌纖維薄膜產量。雖然增加大的表面積可以提高細菌纖 維產量，但其產率 (g BC/L medium volume)部分卻會下降。在表 面積22×30 cm2 下培養5 天可得1.64 g/L 之細菌纖維薄膜。純化 實驗結果顯示，二階段處理可以明顯改善細菌纖維素色度之去除。 在動力學部分別以Logistic model 以及Luedeking-Piret model 模擬 微生物生長，細菌纖維素生產和基質消耗。結果顯示，細菌纖維 素的生產屬於生長相關。將細菌纖維速乾膜浸泡於奈米銀與 benzalkonium chloride 溶液中製備抗菌薄膜。分析此薄膜對 Bacillus subtilis 和Escherichia coli.菌株之抑制活性。實驗結果顯示，細菌纖維素抗菌薄膜可有效抑制Bacillus subtilis 和Escherichia coli.菌株生長。

關鍵詞 : 細菌纖維素、Gluconacetobacter sp. Wu3M、動力學、 純化、抗菌薄膜

目錄

參考文獻

1. 方正中。2009。以實驗設計優化細菌纖維素之醱酵條件。南 台科技大學工業管理研究所碩士論文。台南。 2. 田蕙萍。2009。以Acetobacter xylinum WU1 生產細菌纖維素 之最適培養條件及其抗菌應用之研究。大葉大學生物產業科 技學系碩士論文。彰化。 3. 何佳倫。1995。以醋酸菌發酵柑桔果汁生產細菌纖維素之研 究醋酸菌。國立臺灣大園藝學研究所碩士論文。台北。 4. 吳政樺。2010。木糖同步異構化醱酵生產細菌纖維素。國立 臺灣科技大學化學工程系碩士論文。台北。 5. 沈玟.。2007。細菌纖維素生產菌之篩選及其最適培養條件 之研究。中興大學食品暨應用生物科技學系。台中。 6. 食品工廠建築及設備設廠標準。行政院衛生署食品衛生處。 中華民國九十年五月三日。衛署食字第０九０００一八九０ ０號令公告。經(九０)工字第０九００四六０九二公告 7. 張佩瑜。利用篩選菌株Gluconacetobacter sp. WU2及WU3M生產 細菌纖維素之研究。大葉大學生物產業科技學系碩士論文。彰 化。 8. 許啟南。2004。細菌纖維素之生產條件與物理性質。國立台 灣海洋大學食品科學系。基隆。 9. 黃文哲。2007。醋酸菌Acetobacter sp. X02 利用改良式SH 培養基生產細菌纖維素之研究。中興大學食品暨應用生物科技 學系。台中。 -146- 10. 黃伶妃。1998。利用醋酸菌(Acetobacter xylinum) 發酵楊桃渣 生產細菌纖維素之研究。東海大學食品科學研究所。台中。 11. 黃得為。2007。細菌纖維素生產培養基配方改良暨規模放大之研究。中興大學食品暨應用生物科技學系。台中。 12. 鄧昕昕。2008。以基因同源交換方式去除木質醋酸菌之葡萄 糖脫氫.提升細菌纖維素產量。國立臺灣科技大學化學工程 系碩士論文。台北。 13. 謝榕庭。2009。以Gluconacetobacter xylinus 生產細菌纖維素 之研究。臺灣大學化學工程學研究所碩士論文。台北。 14. Aziz, S. H. and Ansell, M. P. 2004. The effect of alkalization and fibre alignment on the mechanical and thermal properties of kenaf and hemp bast fibre composites: part 2-cashew nut shell liquid matrix. Composites Science and Technology 64: 1231-1238. 15. Bae, S. and Shoda, M. 2004. Bacterial cellulose production by fed-batch fermentation in molasses medium. Biotechnology Progress 20: 1366-1371. 16. Ben-Bassat, A., Bruner, R., Shoemaker, S. P., Aloni, Y., Wong, H., Johnson, D. C. and Naogi, A. N. July 1987. European patent no. 86308092.5. 17. Ben-Bassat, A., Buner, R., Shoemkaer, S., Aloni, Y., Wong, H. C., Johnson, D. C. and Neogi, A. N. 1992. U.S. patent no. 5079162. 18. Benziman, M. and Eisen, N. 1971. Pyruvate phosphate dikinase and the control of gluconeogenesis in Acetobacter xylinum. The Journal of Biological Chemistry 246: 57-62. 19. Benziman, M., Haigler, C. H., Brown, R. M. J., White, A. R. and Cooper, K. M. 1980. Cellulose biogenesis: polymerization and crystallization are coupled -147- 20. process in Acetobacter xylinum. Proceedings of the National Academy of Sciences of the United States of America 77: 6678-6682. 21. Bertocchi, C., Delneri, D., Signore, S., Weng, Z. and Bruschi, C. V. 1997. Characterization of microbial cellulose from a high-producing mutagenized Acetobacter pasteurianus strain. Biochimica et Biophysica Acta 1336: 211-217. 22. Bielecki, E. S., Krystoynowicz, Turkiewicz, M. and Kalinowska, H. 2001. Bacterial Cellulose. Biopolymers 5:

37-46. 23. Bielecki, S., Krystynowicz, A., Turkiewicz, M. and Kalinowska, H. 2005. Bacterial Cellulose, in: Polysaccharides and Polyamides in the Food Industry, A. Steinbuchel and S. K. Rhee (Eds.). Wiley- VCH Verlag, Weinheim, Germany pp. 31-85. 24. Bochner, B. R. and Ames, B. A. 1982. Complete analysis of cellular nucleotides by two-dimensional thin layer chromatography. The Journal of Biological Chemistry 257: 9759-9769. 25. Borysiak, S. and Garbarczyk, J. 2003. Applying the WAXS method to estimate the supermolecular structure of cellulose fibres after mercerisation. Fibres and Textiles in Eastern Europe 11(5): 104-106. 26. Brown Jr., R. M. 1987. The biosynthesis of cellulose. Food Hydrocolloids 1: 345-351. 27. Brown Jr., R. M. and Saxena, I. M. S. 2000. Cellulose biosynthesis: a model for understanding the assembly of biopolymers. Plant Physiology and Biochemistry 38: 57-67. 28. Brown Jr., R. M., Haigler, C. H., Suttie, J., White, A. L., Roberts, E., Smith, C., Itoh, T. and Cooper, K. 1983. The biosynthesis and degradation of cellulose. Journal of Applied Polymer Science 37: 33-78. 29. Brown Jr., R. M., Willison, J. H. M. and Richardson, C. L. 1976. Cellulose biosynthesis in Acetobacter xylinum: Visualization of the site of synthesis and direct measurement of the in vivo process. Proceedings of the National Academy -148- of Sciences of the United States of America 73: 4565-4569. 30. Brown, A. J. and Chem, J. 1886. XLIII-On an acetic ferment which forms cellulose. Journal of the Chemical Society, Transactions 49: 432-439. 31. Brown, E. E. and Laborie, M.-P. G. 2007. Bioengineering bacterial cellulose/poly (ethylene oxide) nanocomposites. Biomacromolecules 8: 3074-3081. 32. Bungay, H. R. and Serafica, G.C. 1999. United States Patent 5955326. 33. Canale-Parola, E. 1970. Biology of sugar-fermenting sarcinae. Bacteriological Reviews 34: 82-97. 34. Canale-Parola, E. and Wolfe, R. S. 1964. Synthesis of cellulose by Sarcina ventriculi. Biochimica et Biophysica Acta 82: 403-405. 35. Castro, C., Zuluaga, R., Putaux, J.-L., Caro, G., Mondragon, I. and Ganana, P. 2011. Structural characterization of bacterial cellulose produced by Gluconacetobacter swingsii sp. from Colombian agroindustrial wastes. The Journal of General Microbiology 84(1): 96-102. 36. Castroa C., Zuluaga R., Putauxc J.-L., Caroa G., Mondragond I.,Ganan P. 2010. Structural characterization of bacterial cellulose produced by Gluconacetobacter swingsii sp. From Colombian agroindustrial wastes. Carbohydrate Polymers. 37. Chao, Y., Ishida, T., Sugano, Y. and Shoda, M. 2000. Bacterial cellulose production by Acetobacter xylinum in a 50-l internal- loop airlift reactor. Biotechnology and Bioengineering 68(3): 345-352. 38. Chao, Y., Mitarai, M., Sugano, Y. and Shoda, M. 2001. Effect of addition of water-soluble polysaccharides on bacterial cellulose production in a 50-L airlift reactor. Biotechnology Progress 17: 781-785. 39. Chawla, P. R., Bajaj, I. B., Survase, S. A. and Singhal, R. S. 2009. Microbial cellulose: fermentative production and applications. Food Technology and Biotechnology 47(2): 107-124. 40. Czaja, W. K., Young, D. J., Kawecki, M. and Brown, R. M. 2007. The future prospects of microbial cellulose in biomedical applications. Biomacromolecules -149- 8: 1-12. 41. Czaja, W., Krystynowicz, A., Bielecki, S. and Brown, R. M. J. 2006. Microbial cellulose – The natural power to heal wounds. Biomaterials 27: 145-151. 42. Czaja, W., Krystynowicz, A., Kawecki, M., Wysota, K., Sakiel, S., Wroblewski, P., Glik, J., Nowak, M. and Bielecki, S. 2008. Selected Articles on the Synthesis, Structure, and Applications of Cellulose, in: Cellulose Molecular and Structural Biology. , R. M. J. Brown and I. M. Saxena (Eds.). 43. Czaja, W.K., D.J. Young, M. Kawecki and R.M. Jr. Brown. 2007. The future prospects of microbial cellulose in biomedical applications. Biomacromolecules, 8: 1-12. 44. Deinema, M. H. and Zevenhuizen, L. P. T. M. 1971. Formation of cellulose fibrils by gram-negative bacteria and their role in bacterial flocculation. Arch Mikrobiol 78: 42-57. 45. Delmer, D. P. 1987. Cellulose biosythesis. Annual Review of Plant Physiology 38: 259-290. 46. Delmer, D. P. and Amor, Y. 1995. Cellulose biosynthesis. Plant Cell 7: 987-1000. 47. Dictionary of Descriptive Terminology. 2012: http://palimpsest.stanford.edu/don/ don.html. 48. Dudman, W. F. 1959. Cellulose production by Acetobacter acetigenum in defined medium. Journal of General Microbiology 2: 327-337. 49. Dudman, W. F. 1960. Cellulose production by Acetobacter strains in submerged culture. The Journal of General Microbiology 22: 25-30. 50. Edison, P., Danilo, M., Younes, M. and Sidney, J. L. R. 2008. Bacterial Cellulose from Glucanacetobacter xylinus: Preparation, Properties and Applications, in: Monomers, Polymers and Composites from Renew Resources, N. B. Mohamed and G. Alessandro (Eds.). Typeset by Charon Tec Ltd (A Macmillan Company), Chennai, India, pp. 369-383. 51. Eichhorn, S. J., Dufresne, A., Aranguren, M., Marcovich, N. E., Capadona, J. R., -150- Rowan, S. J., Weder, C., Thielemans, W., Roman, M., Renneckar, S., Gindle, W., Veigel, S., Keckes, J., Yano, H., Abe, K., Nogi, M., Nakagaito, A. N., Mangalam, A., Simonsen, J., Benight, A. S., Bismarck, A., Berglund, L. A. and Peijs, T. 2010. Review: current international research into cellulose nanofibres and nanocomposites. Journal of Material Science 45: 1-33. 52. Elder, R. L. 1989. Final report on the safety assessment of benzalkonium chloride. Journal of the American College of Toxicology 8(4): 589-625. 53. Evans, B. R., O'Neill, H. M., Malyvanh, V. P., Lee, I. and Woodward, J. 2003. Palladium-bacterial cellulose membranes for fuel cells. Biosensors and Bioelectronics 18: 917-923. 54. Fontana, J. D., De Souza, A. M., Fontana, C. K., Torriani, I. L., Moreschi, J. C., Galliotti, B. J., De Souza, S. J., Narcisco, G. P., Bichara, J. A. and Farah, L. F. X. 1990. Acetobacter cellulose pellicle as a temporary skin substitute. Applied Biochemistry and Biotechnology 24/25: 253-264. 55. Forng, E. R., Anderson, S. M. and Cannon, R. E. 1989. Synthetic medium for Acetobacter xylinum that can be used for isolation of auxotrophic mutants and study of cellulose biosynthesis. Applied and Environmental Microbiology 55: 1317-1319. 56. Franz, G. and Baschek, W. 1990. Chapter 8 Cellulose, in: Methods in Plant Biochemistry. Academic Press, pp. 91-322. 57. French, A. D. 1985. Physical and theoretical methods for determining the supramolecular structure of cellulose, in: Cellulose chemistry and its applications, R. P. Nevell and S. H. Zeronian (Eds.). Ellis Horwood Ltd., Chichester, England., pp. 84-111. 58. Gea, S., Reynolds, C. T., Roohpour, N., Wirjosentono, B., Soykeabkaew, N., Bilotti, E. and Peijs, T. 2011. Investigation into the structural, morphological, mechanical and thermal behaviour of bacterial cellulose after a two-step purification process. Bioresource Technology 102(19). -151- 59. Gilbert, R. D. and Kadla, J. F. 1998. Polysaccharides-Cellulose, in: Biopolymers from Renewable Resources, D. L. Kaplan (Ed.). Springer Verlag, Berlin, pp. 47. 60. Gindl, W. and Keckes, J. 2004. Tensile properties of cellulose acetate butyrate composites reinforced with bacterial cellulose. Composites Science and Technology 64: 2407-2413. 61. Godin, C. and Engasser, J. M. 1988. Improved stability of the continuous production of acetone-butanol by Clostridium acetobutylucum in a two-stage process. Biotechnology Letters 10: 389-392. 62. Grande, C. J., Torres, F. G.,

Gomez, C. M., Troncoso, O. P., Canet-Ferrer, J. and Martinez-Pastor, J. 2008. Morphological characterisation of bacterial cellulose-starch nanocomposites. Polymers and Polymer Composites 16: 181-185. 63. Greenburg, R. 2005. The Ocean Moon: Search for an Alien Biosphere. Springer Praxis Books. 64. Gromet-Elhanan, Z. and Hestrin, S. 1963. Synthesis of cellulose by Acetobacter xylinum. VI. Growth on citric acid-cycle intermediates. Journal of Bacteriology 85: 284-292. 65. Guideline on Validation of the Limulus Amebocyte Lysate Test as an End-Product Endotoxin Test for Human and Animal Parenteral Drugs, Biological Products, and Medical Devices. U.S. Department of Health and Human Services, Public Health Service, Food and Drug Administration, December 1987. 66. Harding, N. E., Cleary, J. M., Cabanas, D. K., Rosen, I. G. and Kang, K. S. 1987. Genetic and physical analyses of a cluster of genes essential for xanthan gum biosynthesis in Xanthomonascampestris. Journal of Bacteriology 169: 2854-2861. 67. Heberlein, G. T., DeLey, J. and Titgat, R. 1967. Deoxyribonucleic acid homology and taxonomy of Agrobacterium, Rhizobium, and Chromobacterium. Journal of Bacteriology 94: 116-124. -152- 68. Helenius, G., Backdahl, H., Bodin, A., Nannmark, U., Gatenholm, P. and Risberg, B. 2005. In vivo biocompatibility of bacterial cellulose. Journal of Biomedical Materials Research Part A. 76(2): 431-438. 69. Hestrin, S. and Schramm, B. M. 1954a. Factors affecting production of cellulose at the air/liquid interface of a culture of Acetobacter xylinum. The Journal of General Microbiology 11: 123-129. 70. Hestrin, S. and Schramm, B. M. 1954b. Synthesis of cellulose by Acetobacter xylinum 2. Preparation of freeze-dried cells capable of polymerizing glucose to cellulose. The Biochemical Journal 58: 345-352. 71. Hirai, A., Tsuji, M. and Horii, F. 2002a. TEM study of band-like cellulose assemblies produced by Acetobacter xylinum at 4 ° C. Cellulose 9(2): 105-113. 72. Hirai, T., Heymann, J. A., Shi, D., Sarker, R., Maloney, P. C and Subramaniam, S. 2002b. Three-dimensional structure of a bacterial oxalate transporter. Nature Structural and Molecular Biology 9(8): 597-600. 73. Hoare, T. R. and Kohane, D. S. 2008. Hydrogels in drug delivery: Progress and challenges. Polymer 49(8): 1993-2007. 74. Hong, F. and Qiu, K. 2008. An alternative carbon source from konjac powder for enhancing production of bacterial cellulose in static cultures by a model strain Acetobacter aceti subsp. xylinus ATCC 23770. Carbohydrate Polymers 72(3): 545-549. 75. Hornung, M., Biener, R. and Schmauder, H.-P. 2009. Dynamic modelling of bacterial cellulose formation. Engineering in Life Sciences 9(4): 342-347. 76. Hornung, M., Ludwigl, M. and Schmauderl, H.-P. 2007. Optimizing the production of bacterial cellulose in surface culture: a novel aerosol bioreactor working on a fet batch pringiple (Part 3). Engineering in Life Sciences 7(1): 35-41. 77. Hornung, M., Ludwigl, M., Gerrard, A. M. and Schmauder, H.-P. 2006b. Optimizing the Production of BacterialCellulose in Surface Culture: Evaluation -153- of Product Movement Influences on the Bioreaction (Part 2). Engineering in Life Sciences 6(6): 546-551. 78. Hornung, M., Ludwigl, M., Gerrard, A. M. and Schmauder, H.-P. 2006a. Optimizing the production of bacterial cellulose in surface culture: Evaluatio of substrate mass transfer influences on the bioreaction (Part 1). Engineering in Life Sciences 6(6): 537-545. 79. Hwang, J. W., Yang, Y. K., Hw ang, J. K., Pyun, Y. R. and Kim, Y. S. 1999. Effects of pH and dissolved oxygen on cellulose production by Acetobacter xylinum BRC5 in agitated culture. Journal of Bioscience and Bioengineering 88: 183-188. 80. Ifuku, S., Mogi, M., Abe, K., Handa, K., Nakatsubo, F. and Yano, H. 2007. Surface modification of bacterial cellulose nanofibers for property enhancement of optically transparent composites: dependence on acetyl-group DS. Biomacromolecules 8: 1973-1978. 81. Iguchi, M., Yamanaka, S. and Budhiono, A. 2000. Bacterial cellulose-A masterpiece of nature's arts. Journal of Materials Science 35: 261-270. 82. Ishida, T., Sugano, Y., Tomonori, N. and Shoda, M. 2002. Effect of acetan on production of bacterial cellulose by Acetobacter xylinum. Bioscience Biotechnology and Biochemistry 66(8): 1677-1681. 83. Ishikawa, A., Matsuoka, M., Tsuchida, T. and Yoshinaga, F. 1995. Increase in cellulose production by sulfaguanidine-resistant mutants derived from Acetobacter xylinum subs. sucrofermentans. Bioscience, Biotechnology and Biochemistry 59(12): 2259-2262. 84. Ishikawa, A., Okano, T. and Sugiyama, J. 1997. Fine structure and tensile properties of ramie fibres in the crystalline form of cellulose I, II, IIII and IV. Polymer 38(2): 463-468. 85. Jin, W. J., Lee, H. K., Park, W. H. and Youk, J. H. 2005. Preparation of polymer nanofibers containing silver nanoparticles by using poly(N-vinylpyrrolidone). -154- Macromolecular Rapid Communications 26(24): 1903-1907. 86. Johnson, D. C., and A. M. Neogi. September 1989. U.S. patent no. 4863565. 87. Jung, J. Y., Park, J. K. and Chang, H. N. 2005. Bacterial cellulose production by Gluconoacetobacter hansenii in an agitated culture without living non-cellulose producing cells. Enzyme and Microbial Technology 37: 347-354. 88. Kalogiannis, S., Iakovidou, G., Liakopoulou-Kyriakides, M., Kyriakidis, D. A. and Skaracis, G. N. 2003. Optimization of xanthan gum production by Xanthomonas campestris grown in molasses. Bioscience Biotechnology and Biochemistry 60(4): 575-579. 89. Keshk, S. M. A. S. and Sameshima, K. 2005. Evaluation of different carbon sources for bacterial cellulose production. African Journal of Biotechnology 4: 478-482. 90. Keshk, S. M. A. S.and Sameshima, K. 2006. The utilization of sugar cane molasses with/without the presence of lignosulfonate for the production of bacterial cellulose. African Journal of Biotechnology 5(17): 1519-1523. 91. Kim, Y. J., Kim, J. N., Wee, Y. J., Park, D. H. and Ryu, H. W. 2007. Bacterial cellulose production by Gluconacetobacter sp. PKY5 in a rotary biofilm contactor. Applied Microbiology and Biotechnology 72: 291-296. 92. Klemm, D., Schumann, D., Udhardt, U. and Marsch, S. 2001. Bacterial synthesized cellulose-Artifi cial blood vessels for microsurgery. Progress in Polymer Science 26: 1561-1603. 93. Kondo, T. and Kondo, M. 1996. Efficient production of acetic acid from glucose in a mixed culture of Zymomonas mobilis and Acetobacter sp. . Journal of Fermentation and Bioengineering 81(1): 42-46. 94. Kongruang, S. 2008. Bacterial cellulose production by Acetobacter xylinum strains from agricultural waste products. Applied Biochemistry and Biotechnology 148: 245-256. 95. Kotzamanidis, C., Roukas, T. and Skaracis, G. 2002. Optimization of lactic acid -155- production from beet molasses by Lactobacillus delbrueckii NCIMB 8130. World Journal of Microbiology and Biotechnology 18: 441-448. 96. Kouda, T., Naritomi, T., Yano, H. and Yoshinaga, F. 1997a. Effects of oxygen and carbon dioxide pressures on bacterial cellulose production by Acetobacter in aerated and agitated culture. Journal of Fermentation and Bioengineering 84(2): 124-127. 97. Kouda, T., Yano, H. and Yoshinaga, F. 1997b. Effect of agitator configuration on bacterial cellulose productivity in aerated and agitated culture. Journal of Fermentation and Bioengineering 83(4): 371-376. 98. Kouda, T., Yano, H., Yoshinaga, F., Kaminoyama, M. and Kamiwano, M. 1996.

Characterization of non-Newtonian behavior during mixing of bacterial cellulose in a bioreactor. Journal of Fermentation and Bioengineering 82(4): 382-386. 99. Krystynowicz, A., Czaja, W., Jezierska, A. W., Mimkiewicz, M. G., Turkiewicz, M. and Bielecki, S. 2002. Factors affecting the yield and properties of bacterial cellulose. Journal of Industrial Microbiology and Biotechnology 29: 189-195. 100. Kuga, S., Takagi, S. and Brown, R. M. J. 1993. Native folded-chain cellulose II. Polymer 34: 3293-3297. 101. Kurosumi, A., Sasaki, C., Yamashita, Y. and Nakamura, Y. 2009. Utilization of various fruit juices as carbon source for production of bacterial cellulose by Acetobacter xylinum NBRC 13693. Carbohydrate Polymers 76: 333-335. 102. Laszkiewicz, B. 1997. Solubility of bacterial cellulose and its structural properties.67, 1871-1876. Journal of Applied Polymer Science 67: 1871-1876. 103. Lee, M. H., Park, H. S., Yoo, K. J. and Hauser, P. J. 2004. Enhancing the durability of linen-like temperature mercerized cotton. Textile Research Journal 74: 146-154. 104. Legeza V.I., Galenko-Yaroshevskii V.P., Zinov ' ev E.V., Paramonov B.A., Kreichman G.S., Turkovskii I.I., Gumenyuk E.S., Karnovich A.G., and -156- Khripunov A.K. 2004. Effects of new wound dressings on healing of thermal burns of the skin in acute radiation disease. Bulletin of Experimental Biology and Medicine 138(3): 311-315. 105. Lin, F. C., Brown, R. M. J., Cooper, J. B. and Delmer, D. P. 1985. Synthesis of fibrils in vitro by a solubilized cellulose synthase from Acetobacter xylinum. Science 230: 822-825. 106. Lynd, L. R., Wyman, C. E. and Gerngross, T. U. 1999. Biocommodity engineering. Biotechnology Progress 15: 777-793. 107. Macedo, N. L., Matuda, F. S., Macedo, L. G. S., Monteiro, A. S. F., Valera, M. C. and Carvalho, Y. R. 2004. Evaluation of two membranes in guided bone tissue regeneration: Histological study in rabbits. Brazilian Journal Of Oral Sciences 3: 395-400. 108. Masaoka, S., Ohe, T. and Sakota, N. 1993. Production of cellulose from glucose by Acetobacter xylinum. Journal of Fermentation and Bioengineering 75: 18-22. 109. Matsuoka, M., Tsuchida, T., Matsushita, K., Adachi, O. and Yoshinaga, F. 1996. A synthetic medium for bacterial cellulose production by Acetobacter xylinum subsp. sucrofermentans. Bioscience Biotechnology and Biochemistry 60(4): 575-579. 110. Matthysse, A. G., Holmes, K. V. and Gurlitz, R. H. G. 1981. Elaboration of cellulose by Agrobacterium tumefaciens during attachment to carrot cells. Journal of Bacteriology 145: 583-595. 111. McCabe, W. R. 1980. Endotoxin: microbiological, chemical, pathophysiologic and clinical correlations. Seminars in Pediatric Infectious Diseases 3: 38-88. 112. McCartney, A. C., and Wardlaw, A. C. 1985. Endotoxic activities of lipopolysaccharides, p. 203 – 238. In D. E. S. Stewart-Tull and M. Davis (ed.), Immunology of the bacterial cell envelope. John Wiley and Sons Ltd., London. 113. Miyamoto, T., Takahashi, S., Ito, H. and Inagaki, H. 1989. Tissue biocompatibility of cellulose and its derivatives. Journal of Biomaterials -157- Research 23: 125-133. 114. Moharram, M. A. and Mahmoud, O. M. 2008. FTIR spectroscopic study of the effect of microwave heating on the transformation of cellulose I into cellulose II during mercerization. Journal of Applied Polymer Science 107: 30-36. 115. Moigne, N. L. and Navard, P. 2010a. Dissolution mechanism of wood cellulose fibres in NaOH-Water. Cellulose 17: 31-15. 116. Moigne, N. Le and Navard P. 2010b. Physics of cellulose xanthate dissolution in sodium hydroxide-water mixtures: a rheo-optical study. Cellulose Chemistry and Technology 44(7-8): 217-221. 117. Moon, S.-H., Park, J.-M., Chun, H.-Y. and Kim, S.-J. 2006. Comparisons of physical properties of bacterial celluloses produced in different culture conditions using saccharified food wastes. Biotechnology and Bioprocess Engineering 11: 26-31. 118. Mormino, R. and Bungay, H. 2003. Composites of bacterial cellulose and paper made with a rotating disk bioreactor. Applied Microbiology and Biotechnology 62: 503-506. 119. Morrison, D. C., and Ryan, J. L. 1987. Endotoxins and disease mechanisms. Annual Review of Medicine 38: 417-432. 120. Mosaska, S., Ohe, T. and Sakota, N. 1993. Production of cellulose from glucose by Acetobacter xylinum. Journal of Fermentation and Bioengineering 75: 18-22. 121. Moser, A. and Steiner, W. 1975. The influence of the term kd for endogenous metabolism on the evaluation of Monod kinetics for biotechnological processes. European Journal of Applied Microbioligy 1: 281-289. 122. Muhlethaler, K. 1949. he structure of bacterial cellulose. Biochimica et Biophysica Acta 3(3): 527-535. 123. Nakagaito, A. N. and Yano, H. 2008. Toughness enhancement of cellulose nanocomposites by alkali treatment of the reinforcing cellulose nanofibers. Cellulose 15: 323-331. -158- 124. Nakagaito, A. N., Iwamoto, S. and Yano, H. 2005. Bacterial cellulose: the ultimate nano-scalar cellulose morphology for the production of high-strength composites. Applied Physics A: Materials Science and Processing 80: 93-97. 125. Naritomi, T., Kouda, T., Yano, H. and Yoshinaga, F. 1998a. Effect of lactate on bacterial cellulose production from fructose in continuous culture. Journal of Fermentation and Bioengineering 85: 89-95. 126. Naritomi, T., Kouda, T., Yano, H. and Yoshinaga, F. 1998b. Effect of ethanol on bacterial cellulose production from fructose in continuous culture. Journal of Fermentation and Bioengineering 85: 598-603. 127. Neeta L., L., Ramakrishnan, R., Li, B., Subramanian, S., Barhate, R. S., Liu, Y.-J. and Seeram, R. 2007. Fabrication of nanofibers with antimicrobial functionality used as filters: Protection against bacterial contaminants. Biotechnology and Bioengineering 97(6): 1357-1365. 128. Nishi, M., Sanke, T., Nagamatsu, S., Bell, G. I. and Steiner, D. F. 1990. Islet amyloid polypeptide. A new beta cell secretory product related to islet amyloid deposits. The Journal of Biological Chemistry 265 (8): 4173 – 6. 129. Nishi, Y., Uryu, M., Yamanaka, S., Watanabe, K., Kitamura, N., Iguchi, M. and Mitsuhashi, S. 1990b. The structure and mechanical properties of sheets prepared form bacterial cellulose. Part 2: Improvement of the mechanical properties of sheets and their applicability of electroacoustic transducers. Journal of Materials Science 25: 2997-3001. 130. Noro N., Sugano Y., Shoda M. 2004. Utilization of the buffering capacity of corn steep liquor in bacterial cellulose production by Acetobacter xylinum. Applied Microbio lo gy and Biotechno logy 64: 199-205. 131. Novaes, A. B. J. and Novaes, A. B. 1992. MZ implants placed into extraction sockets in association with membrane therapy (Gengiflex) and porous hydroxyapatite: A case report. International Journal of Oral and Maxillofacial Implants 7: 536-540. -159- 132. Nussinovitch, A., Nussinovitch, M., Shapira, R. and Gershon, Z. 1994. Influence of immobilization of bacteria, yeasts and fungal spores on the mechanical-properties of agar and alginate gels. Food Hydrocolloids 8: 361-372. 133. Oh, S. Y., Yoo, D. I., Shin, Y., Kim, H. C., Kim, H. Y., Chung, Y. S., Park, W. H. and Youk, J. H. 2005. Crystalline structure analysis of cellulose treated with sodium hydroxide and carbon dioxide by means of X-ray diffraction and FTIR spectroscopy. Carbohydrate Research 340: 2376-2391. 134. Park, J.K., Jung, J.Y. and Park, Y. H. 2003. Cellulose production by Gluconacetobacter hansenii in a medium containing ethanol. Biotechnol Lett 25:

2055-2059. 135. Pegues, D. A., Oettinger, C. W., Bland, L. E., Oliver, J. C., Arduino, M. J., Aguero, S. M., McAllister, S. K., Gordon, S. M., Favero, M. S. and Jarvis, W. R. 1992. A prospective study of pyrogenic reactions in hemodialysis patients using bicarbonate dialysis fluids filtered to remove bacteria and endotoxin. Journal of the American Society of Nephrology 3:1002-1007. 136. Pinches, A. and Pallent, L. J. 1986. Rate and yield relationship in the production of xanthan gum by batch fermentation using complex and chemically defined growth media. Biotechnology and Bioengineering 26: 1484-1496. 137. Pinto, R. J. B., Marques, P. A. A. P., Martins, M. A., Pascoal Neto, C. and Trindade, T. 2007. Electrostatic assembly and growth of gold nanoparticels in cellulosic fibers. Journal of Colloid and Interface Science 312: 506-512. 138. Ramana, K. V., Tomar, A. and Singh, L. 2000. Singh, Effect of various carbon and nitrogen sources on cellulose synthesis by Acetobacter xylinum. World Journal of Microbiology and Biotechnology 16: 245-248. 139. Richmond, P. A. 1991. Occurrence and Functions of Native Cellulose, in: Biosynthesis and Biodegradation of Cellulose, C. H. Haigler and P. J. Weimer (Eds.). Marcel Dekker, Inc, New York, USA, pp. 5-23. 140. Roberts, E. M., Hardison, L. K., Brown, R. M., Jr. 1986. European Patent no. -160- 0186495 141. Roberts, E. M., Saxena, I. M. and Brown, R. M. J. 1989. Biosynthesis of cellulose II in Acetobacter xylinum, in: Cellulose and Wood: Chemistry and Technology, C. Schuerch (Ed.). John Wiley and Sons, New York, pp. 689-704. 142. Robinson, D. K. and Wang, D. I. C. 1988. A transport controlled bioreactor for the simultaneous production and concentration of xanthan gum. Biotechnology Progress 4: 231-241. 143. Ross, P., Mayer, R. and Benziman, M. 1991. Cellulose biosynthesis and function in bacteria. Microbiological Reviews 55(1): 35-58. 144. Roukas, T. 1998. Pretreatment of beet molasses to increase pullulan production. Process Biochemistry 33: 805-810. 145. Sakurada, I., Nukushima, Y. and Ito, I. 1962. Experimental determination of elastic modulus of crystalline regions in oriented polymers. Journal of Polymer Science 57: 651-660. 146. Sandford, P. A. and Baird, J. 1983. Industrial utilization of polysaccharides, in: The polysaccharides G. O. Aspinall (Ed.). Academic Press, Inc., New York, pp. 411-490. 147. Sannino, A., Demitri, C. and Madaghiele, M. 2009. Biodegradable cellulose-based hydrogels: Design and applications. Material 2(2): 353-373. 148. Sawyer, L. H. and George, W. 1982. Comparisons between synthetic and natural microfiber systems, in: Cellulose and other natural polymer systems, R. M. J. Brown (Ed.). Plenum Publishing Corp., New York, pp. 429-457. 149. Schneider, S., Merkle, R., Jones, M. and Furlan, S. 2001. Oxygen transfer on β-D-galactosidase production by Kluyveromyces marxianus using sugar cane molasses as carbon source. Biotechnology Letters 23: 547-550. 150. Schramm, M. and Hestrin, S. 1954. Factors affecting production of cellulose at the air/liquid interface of a culture of Acetobacter xylinum. Journal of General Microbiology 11: 123-129. -161- 151. Serafica, G. C. 1997. Production of bacterial cellulose using a rotating disk film bioreactor by Acetobacter xylinum, PhD-Thesis, Rensellaer Polytechnic Instituite, Troy, N. U., USA. 152. Serafica, G., Mormino, R. and Bungay, H. 2002. Inclusion of solid partivle in bacterial cellulose. Applied Microbiology and Biotechnology 58:756-760. 153. Seto, A., Saito, Y., Matsushige, M., Kobayashi, H., Sasaki, Y., onouchi, N., Tsuchida, T., Yoshinage, F., Ueda, K. and Beppu, T. 2006. Effective cellulose production by a coculture of Gluconacetobacter xylinus and Lacetobacillus mali. Applied Microbiology and Biotechnology 73: 915-921. 154. Setyawati, M. I., Chien, L.-J. and Lee, C.-K. 2007. Expressing Vitreoscilla hemoglobin in statically cultured Acetobacter xylinum with reduced O2 tension maximizes bacterial cellulose pellicle production. Journal of Biotechnology 132: 38-43. 155. Shah, J. and Brown Jr, R. M. 2005. Towards electronic paper displays made from microbial cellulose. Applied Microbiology and Biotechnology 66: 352-355. 156. Sheoran, A., Yadav, B. S., Nigam, P. and Singh, D. 1998. Continuous ethanol production from sugarcane molasses using a column reactor of immobilized Saccharomyces cerevisiae HAU-1. Journal of Basic Microbiology 38: 123-128. 157. Shoda, M. and Sugano, Y. 2005. Recent advances in bacterial cellulose production. Biotechnology and Bioprocess Engineering 10(1): 1-8. 158. Sill, T. J. and von Recum, H. A. 2008. Electrospinning: Applications in drug delivery and tissue engineering. Biomaterials 29(13): 1989-2006. 159. Singh, L., Ramana, K. V., Banerjee, S., Dubey, V. and Chauhan, R. S. 1996. Studies on bacterial cellulose membrane production and its structureal properties, Proceedings IMSXIV in. 160. Son, H. J., Heo, M. S., Kim, Y. G. and Lee, S. J. 2001. Optimization of fermentation conditions for the production of bacterial cellulose by a newly -162- isolated Acetobacter sp. A9 in shaking cultures. Biotechnology and Applied Biochemistry 33: 1-5. 161. Son, H. J., Kim, H. G., Kim, K. K., Kim, H. S., Kim, Y. G. and Lee, S. J. 2003. Increased production of bacterial cellulose by Acetobacter sp. V6 in synthetic media under shaking culture conditions. Bioresource Technology 86: 215-219. 162. Son, W. K., Youk, J. H. and Park, W. H. 2006. Antimicrobial cellulose acetate nanofibers containing silver nanoparticles. Carbohydrate Polymers 64(4): 430-434. 163. Song, C., Du, J. Zhao, J., Feng, S. Du, G. and Zhu, Z. 2009. Hierarchical porous core-shell carbon nanoparticles. Chemistry of Materials 21(8): 1524-1530. 164. Steinbuchel, A. and Doi, Y. 2005. in: Biotechnology of Biopolymers, M. Elnashar (Ed.). WILEY-VCH Verlag GmbH and Co., Weinheim, pp. 381. 165. Stockmann, V. E. 1972. Developing a hypothesis: native cellulose elementary fibrils are formed with metastable structure. Biopolymers (11). 166. Sugiyama, J., Ok