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

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摘 要

由革蘭陰性細菌Acetobacter xylinum WU1可分泌生產出細菌纖維(BC)，具有特殊的物理、化學和機械特性，包括高結晶度、高含水力、且主要是由奈米纖維絲組成的表面、有彈性、機械強度和 生物相容性。細菌纖維具有特殊的物理化學特性，因此可應用在 紙張和食品工業，同樣的也可應用在醫學領域上，如人工皮膚、 血管替代物。

本研究主要是研究Acetobacter xylinum WU1在30℃中，以靜置批次發酵下，探討不同培養條件包括碳源、氮源、pH、溫度、有機酸(檸檬酸、琥珀酸和醋酸)、酒精濃度(0-10%)、醋酸濃度(0-20%)、地瓜濃度(0-20 g/L)和曝氣量(0.5-2 L/min)。生產細菌纖維時，也會受到各種環境因子之影響，如pH和溫度，結果顯示pH 5.5與溫度為30℃為最適合細菌纖維的生產條件。另一方面，實驗 顯示在pH為5.5的5 L發酵槽條件下，當曝氣量控制在1.5 L/min、葡萄糖濃度為20 g/L時，細菌纖維最大乾重可達3.7 g/L。

在此亦探討細菌纖維經不同鹼液處理和各種不同乾燥方式處理後，細菌纖維物性結構的改變。處理前/處理後的細菌纖維特 性都是以XRD (X-ray diffractometry)、FTIR (Fourier Transform Infrared spectroscopy)、FE-SEM (Field-emission scanning electron microscope)進行分析。此外，利用色差計(Hunter lab colour parameters)分析經不同鹼液處理後細菌纖維色澤上的變化。整體實驗顯示，凍乾後的薄膜會有較高的L值。另一方面，利用NaOH和Na2CO3鹼液處理細菌纖維時，也會有較高的L值，分別為101.8和97.1。凍乾後薄膜在XRD圖譜上顯示的相對強度波峰訊號較小。相反的，在空氣乾燥中的薄膜，其相對強度則明顯較高。由XRD的結果發現，經鹼液處理後並不會直接影響到細菌纖維的結晶度。

細菌纖維是一個受注目的傷口敷料材料，因為它可以提供傷口潮濕的環境以利復原。但細菌纖維本身不具抗菌力，為避免傷口 感染，抗菌效用，利用將細菌纖維浸泡於AgNO3溶液中，使奈米銀吸附於細菌纖維上。形成的奈米銀利用SEM觀察得知。乾燥後的奈米銀與細菌纖維複合物對Escherichia coli (格蘭氏陰性菌)與Bacillus subtilis (格蘭氏陽性菌)具有很強的抗菌力。

關鍵詞 : Acetobacter xylinum、細菌纖維、奈米銀傷口敷料、抗菌力

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圖目錄

NaBH4:AgNO3 molar ratio against Escherichia coli or Bacillus sp169

表目錄

參考文獻

1.水野卓、川何正允 編著。1992。菇類的化學生化學。第260-263頁。國立編譯館版。台北。2.尤新 編著。2001。機能性發酵食品之研究。第119-1670頁。藝軒出版社。台北。3.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。國立中興大學食品暨應用生物技術學系碩士論文。台中。4.黃唯欣。2007a。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。國立中興大學食品生物應用甕技術學系碩士論文。台中。5.黃德為。2007b。細菌纖維素生產培養基配方改良暨規模放大之研究。國立中興大學食品暨應用生物技術學系碩士論文。台中。6.盧天惠主編。2002。X光繞射與應用。滄海書局:22-36。7.蕭淑娟。2004。利用醋酸菌Acetobacter xylinum發酵燒酒糟生產細菌纖維素之研究。私立東海大學食品科學系研究所碩士論文。台中。8. http://isch.skhsslmc.edu.hk/~boyscouts/imagedata/burnt.ppt 2008.9. http://www.nhi.gov.tw/ 2008.10.Adams, A. P., Santschi, E. M. and Mellencamp, M. A. 1999. Antibacterial properties of a silver chloride-coated nylon wound dressing. Veterinary Surgery 28: 219-225.11.Alaban, C. A. 1962. Studies on the optimum conditions for Nata de coco bacterium or Nata formation in coconut water. The Philippine Agriculturist 45: 490-515.12.Anderson, J. M. 2004. Inflammation, wound healing, and the foreign body response. In: Ratner, B. D., Hoffman, A. S., Shoen, F. J. and Lemons, J. E. (Eds.), Biomaterials Science. An Introduction to Materials in Medicine. San Diego, Elsevier. C.A.13.Aschner, M. and Hestrin, S. 1946. Fibrillar structure of cellulose of bacterial and animal origin. Nature 157: 659.14.Atalla, R. H. and VandelHart, D. L. 1986. Native cellulose: a composite of two crystalline forms. Science 223: 283-285.15.Bae, S. and Shoda, M. 2004. Bacterial cellulose production by fed-batch fermentation in molasses medium. Biotechnology Progress 20(5): 1366-1371.16.Bae, S., Sugano, Y. and Hoda, M. 2004. Improvement of bacterial cellulose production by addition of agar in a jar fermentor. Journal of Bioscience and bioengineering 97(1): 33-38.17.Bakos, D. Soldan, M. and Hernandez-Fuentes, I. 1999. Hydroxyapatite-collagen- hyaluronic acid composite. Biomaterials 20: 191-195.18.Barbucci, R. Lamponi, S. and Aloisi, A. M. 2002. Platelet adhesion to commercial and modified polymer materials in animals under psychological stress and in a no-stress condition. Biomaterials 23: 1967-1973.19.Bergey, D. H., Harrison, F. C., Breed, R. S., Hammer B. W., and Huntoon, F. M. 1925. Bergey's Manual of Determinative Bacteriology, 2nd ed. The Williams and Wilkins Co., Baltimore, p. 1-462.20.Blacjwell, J. 1982. The macromoleculear organization of cellulose and chitin. In Brown, R. M., Jr.(ed.) Cellulose and Other Natural Polymer Systems. Planum Publishing Corp. 327-339.21.Bowler, P. G. and Davies, B. 1999. The microbiology of infected and noninfected leg ulcers. International Journal of Dermatology 38: 573-578.22.Brown, A. J. 1886. On acetic ferment which forms cellulose. Journal of Chemical Society 49: 432-439.23.Brown, R. M. Jr. 1989. Cellulose structure and function aspects. Ellis Howoodide 144-151.24.Brown, R. M. Jr., Kudlicka, K., Cousins, S. K. and Nagy, R. 1992. Gravity effects on cellulose assembly. American Journal of Botany 79: 1247 – 1258.25.Cannon, R. E. and Anderson, S. M. 1991. Biogenesis of bacterial cellulose. Critical Reviews in Microbiology 17: 415-447.26.Chambers, C. W., Proctor, C. M. and Kabler, P. W. 1962. Bactericidal effect of low concentrations of silver. Journal of the American Water Works Association 54: 208-216.27.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:

345-352.28.Chao, Y., Mitarai, M., Sugann, Y. and Shoda, M. 2001. Effect of assition of water- soluble polysaccharides on bacterial cellulose production in a 50-L airlift reactor. Biotechnology progress 17 (4): 781-785.29.Chao, Y., Sugano, Y. and Shoda, M. 2001. Bacterial cellulose production under oxygen-enriched air at different fructose concentrations in a 50-liter internal-loop airlift reactor. Applied Microbiology and Biotechnology 55: 673-679.30.Charpentier, P. A., Maguire, A. and Wan, W. K. 2006. Surface modification of polyester to produce a bacterial cellulose-based vascular prosthetic device. Applied Surface Science 252: 6360-6367.31.Cho, K. H., Park, J. E., Osaka, T. and Park, S. G. 2005. The study of antimicrobial activity and preservative effects of nanosilver ingredient. Electrochimica Acta 51: 956-960.32.Coates, D. M. and Kaplan, S. L. 1996. Modification of polymeric surfaces with plasmas. MRS Bull 21:1.33.Czaja, W. K., Young, D. J., Kawecki, M. and Brown, R. M. 2007. The Future Prospects of Microbial Cellulose in Biomedical Applications. Biomacromolecules. 8: 1-12.34.De Faveri, D., Torre, P., Molinari, F., Perego, P. and Converti, A. 2003. Carbon material balances and bioenergetics of 2,3-butanediol bio-oxidation by Acetobacter hansenii. Enzyme and Microbial Technology 33: 708-719.35.Delmer, D. P. 1999. Cellulose biosynthesis: exciting times for a difficult field of study. Annual Review of Plant Physiology and Plant Molecular Biology 50: 245-276.36.Dudman, W. F. 1959. Cellulose production by Acetobacter acetigenum in defined medium. The Journal of General Microbiology 21: 327-337.37.Embuscado, M. E., Marks, J. S. and Bemiller, J. N. 1994. Bacterial cellulose Ⅱ. Optimization of cellulose production by Acetobacter xylinum through response surface methodology. Food hydrocoll 8: 419-430.38.Embuscado, M. E., Marks. J. S. and Bemiller, J. N. 1994a. Bacterial cellulose. I. Factors affecting the production of cellulose by Acetobacter xylinum. Food Hydrocoll 8: 407-418.39.Eming, S., Smola, H. and Kreig, T. 2002. Treatment of chronic wounds: state of the art and future concepts. Cells Tissues Organs 172: 105-117.40.Farina, J. I., Sineriz, F., Molina, O. E. and Perotti, N. I. 2001. Isolation and physico-chemical characterizeation of soluble scleraoglucan from scleraotiumrolfsii Rheological propertyes, molecular wight and conformational characteristics. Carbohydrate Research 44: 41-50.41.Fontana, J. D., de Souza, A. M., Fontana, C. K., Torriani, I. L., Moreschi, J. C., Gallotti, 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: 253-264.42.Godbey, W. T. and Atala, A. 2002. In vitro systems for tissue engineering. The New York Academy of Sciences 961: 10-26.43.Guhados, G., Wan, W. and Hutter, J. L. 2005. Measurement of the elastic modulus of single bacterial cellulose fibers using atomic force microscopy. Langmuir 21: 6642.44.Gupta, B., Hilborn, J., Hollenstein, C., Plummer, C. J., Houriet, R. and Xanthopoulos, N. 2000. Surface modification of polyester films by RF plasma. Journal of Applied Polymer Science. 78: 1083-1091.45.Ha, J. H., Shehzad, O., Khan, S., Lee, S. Y., Park, J. W., Khan, T. and Park, J. K. 2008. Production of bacterial cellulose by a static cultivation using the waste from beer culture broth. Korean Journal of Chemical Engineering 25(4): 812-815.46.Haigler, C. H. and Weimer, P. J. 1991. Biosynthesis and Biodegradation of Cellulose. Marcel Dekker, Inc p.5-23, p.71-98, p.219-243.47.Helenius, G., B?ckdahl, H., Bodin, A., Nannmark, U., Gatenholm, P. and Risberg, G. 2007. In vivo biocompatibility of bacterial cellulose. Journal of Biomedical Materials Research 76: 431-438.48.Henneberg, W. 1906. Zur Kenntniss der Schnellessig und Weinessigbakterien. Deutsche Essigindustrie 10:106-108.49.Hestrin, S. and Schramm, M. 1954. Synthesis of cellulose by Acetobacter xylinum: preparation of freeze-dried cells capable of polymerizing glucose to cellulose. The Biochemical Journal 58: 345-35250.Hestrin, S. Aschner, M. and Mager, J. 1947. Synthesis of cellulose by resting Cells of Acetobacter xylinum. Nature 159: 64-65.51.Humphries, A. W., Hawk, W. A. and Cuthbertson, A. M. 1961. Arterial prosthesis of collagen-impregnated dacron tulle. Surgery 50: 947-954.52.Hwang, J. W., Yang, Y. K., Hwang, 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(2): 183-188.53.Hwang, J. W., Yang, Y. K., Hwang, 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(2): 183-188.54.Iguchi, M., Yamanaka, S. and Budhiono, A. 2000. Bacterial cellulose – a masterpiece of nature ’ s arts. Journal of Materials Science 35: 261-270.55.Ishida, T., Sugano, Y. and Shoda, M. 2002. Novel glycosyltransferase genes involved in the acetan biosynthesis of Acetobacter xylinum. Biochemical and Biophysical Research Communications 295(2): 230-235.56.Ishida, T., Sugano, Y., Nakai, T., and Shoda, M. 2002. Effects of acetan on production of bacterial cellulose by Acetobacter xylinum. Journal of Bioscience and Bioengineering 66: 1677-1681.57.Ishihara, M., Matsunaga, M., Hayashi, N. and Ti?ler, V. 2002. Utilization of D-xylose as carbon source for production of bacterial cellulose. Enzyme and Microbial Technology 31(7): 986-991.58.Ishikawa, A., Matsuoka, M., Tsuchida, T. and Yoshinaga, F. 1995. Increasing of bacterial cellulose production by sulfoguanidine-resistant mutants derived from Acetobacter xylinum subsp. Sucrofermentans BPR2001. Bioscience Biotechnology and Biochemistry 59: 2259-2263.59.Ishikawa, A., Tsuchida, T. and Yoshinaga, F. 1996. Production of bacterial cellulose using microbial strain resistant to inhibitor of DHO-dehydrogenase. Japanese patent 08009965A.60.Ishikawa, A., Matsuoka, M., Tsuchida, T. and Yoshinaga, F. 1995. Increase in cellulose production by sulfaguanidine-resistant mutants derived from Acetobacter xylinum subsp. Sucrofermentans. Bioscience, Biotechnology, and Biochemistry. 59(12): 2259-2262.61.Jonas, R. and Farah, L. F. 1998. Production and application of microbial cellulose. Polymer Degradation and Stability 59(1): 101-106.62.Joo S. H., Goo, K. H., Ki, K. K., Soo, K. H., Gyun, K. Y. and Joon, L. S. 2003. Increased production of bacterial cellulose by Acetobacter sp. V6 in synthetic media under shaking culture conditions. Bioresource Technology 86(3): 215-219.63.Joseph, G., Rowe, G. E., Margaritis, A. and Wan, W. 2003. Effects of polyacrylamide on bacterial cellulose production. Journal of Chemical Technology and Biotechnology 78(7): 964-970.64.Ka?ur?kov?, M., Smith, A. C., Gidley, M. J. and Wilson, R. H. 2002. Molecular interactions in bacterial cellulose composites studied by 1D FT-IR and dynamic 2D FT-IR spectroscopy, Carbohydrate Research 337: 1145-1153.65.Kamide, K., Matsuda, Y., Iijima, H. and Okajima, K. 1990. Effect of culture condition of acetic acid bacteria on cellulose biosynthesis. British Polymer Journal 22: 167-171.66.Kawano, S., Tajima, K., Kono, H., Erata, T., Munekata, M. and Takai, M. 2002. Effect of endogenous endo-beta-1,4-glucanase on cellulose biosynthesis in Acetobacter xylinum ATCC23769. Journal of

Bioscience and Bioengineering 94: 275-281.67.Keshk, S. 2002. Gluconacetobacter xylinus : a new resource for cellulose. Egypt Journal of Biotechnology 11: 305-310.68.Keshk, S. and Sameshima, K. 2006. Influence of lignosulfonate on crystal structure and productivity of bacterial cellulose in a static culture. Enzyme and Microbial Technology 40(1): 4-8.69.Keshk, S. and Sameshima, K. 2006a. The utilization of sugar cane molasses with/without the presence of lignosulfonate for the production of bacterial cellulose. Applied Microbiology and Biotechnology 72: 291-296.70.Kim, S. Y., Kim, J. N., Wee, Y. J., Park, D. H. and Ryu, H. W. 2006. Production of bacterial cellulose by Gluconacetobacter sp. RKY5 isolated from persimmon vinegar. Applied Biochemistry and Biotechnology 131(1-3):705-715.71.Kitano, T. Ateshian, G. A. Mow, V. C. Kadoya, Y. and Yamano, Y. 2001. Constituents and pH changes in protein rich hyaluronan solution affect the biotribological properties of artificial articular joints. Journal of Biomechanics 34(8): 1031-1037.72.Klamm, D., Schumann, D., Udhardt, U. and Marsch, S. 2001. Bacterial synthesized cellulose - artificial blood vessels for microsurgery. Progress in Polymer Science 26: 1561-1603.73.Klemm, D., Heublein, B., Fink, H. P. and Bohn, A. 2005. Cellulose: fascinating biopolymer and sustainable raw material. Angewandte Chemie International Edition 44: 3358-3393.74.Kongrang, S. 2008. Bacterial cellulose production by Acetobacter xylinum strains from agricultural waste products. Applied Biochemistry and Biotechnology 148: 245-256.75.Kouda, T., Naritomi, T., Yano, H. and Yoshinaga, F. 1997. Effects of oxygen and carbon dioxide pressures on bacterial cellulose production by Acetobacter in aerated and agitated culture. Journal of Fermentation and Bioengineering 84: 124-127.76.Krystynowicz, A., Galas, E. and Paelak, E. 1997. Method of bacterial cellulose production. Polish patent P-299907.77.Laboureur, P. 1998. Process for production bacterial cellulose from material plant origin. WO 88/09381.78.Lala, N. P., Ramaseshan, R., Bojin, L., Sundarrajan, S., Barhate, R. S., Ying-Jun, L. and Ramakrishna, S. 2007. Fabrication of nanofibers with antimicrobial functionality used as filters: protection against bacterial contaminants. Biotechnology and Bioengineering 79(6): 1357-1365.79.Lapuz, M. M., Gallardo, E. G. and Dalo, M. A. 1967. The Nata organism - culltural requirement, characteristics and identify. The Philippine Journal of Science 96: 91-96.80.Lee, I. Y., Seo, W. T., Kim, G. J., Kim, M. K., Park, C. S. and Park, Y. H. 1997. Production of curdlan using sucrose and sugar cane molasses by two-step fed-batch cultivation of Agrobacterium species. Journal of Industrial Microbiology Biotechnology 18: 255-259.81.Lin, F. C., Brown, R. M. Jr., Drake, R. R. Jr. and Haley, B. E. 1990. Identidfication of the uridine 5 ’ -diphosphoglucose (UDP-glc) binding subunit of cellulose synthease in Acetobactor xylinum using the photoaffinity probe 5-azido-UDP-glc. Journal of Biological Chemistry. 265: 4782-4784.82.Linton, J. D., Ash, S. G. and Huybrechts, L. 1991. Microbial polysaccharides. In: Byron, D. (ed.). Biomaterials: Novel Materials from Biological Sources. Stockton Press. New York.83.Maneerungm, T., Tokura, S. and Rujiravanit, R. 2008. Impregnation of silver nanoparticles into bacterial cellulose for antimicrobial wound dressing. Carbohydrate Polymers 72: 43-51.84.Masahiro, K., Mikitomo, A., Akitomo, A., Tomonori, Y. 1998. Feed composition for fish kind cultivation. Japanese patent 10313794.85.Masaoka, S., Ohe, T. and Ameyama, M. 1993. Production of cellulose from glucose by Acetobacter xylinum. Journal of Fermentation and Bioengineering 75: 18-22.86.Masayuki, T. and Yukihiro, N. 1990. Noodle made of rice powder and producing method thereof. Japanese patent 02249466.87.Matsuoka, M., Tsuchida, T., Matsushita, K., Adachi, O. and Yoshinaga, F. 1996. A syntheic medium for bacterial cellulose production by Acetobacter xylinum snusp. sucrofermentans. Bioscience, Biotechnology, and Biochemistry 60(4): 575-579.88.Miyamoto, T., Takahashi, S., Ito, H., Inagaki, H. and Noishiki, Y. 1989. Tissue biocompatibility of cellulose and its derivatives. Journal of Biomedical Materials Research 23: 125-133.89.Nakai, T., Moriya, A., Tonouchi, N., Tsuchida, T., Yoshinaga, F., Horinouchi, S., Sone, Y., Mor, H., Sakai, F. and Hayashi, T. 1998. Control of expression by the cellulose synthase (bcsA) promoter region from Acetobacter xylinum BPR2001. Gene 213: 93-10090.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(1): 89-95.91.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(6): 598-603.92.Nasseri, B. A. and Vacanti, J. P. 2002. Tissue engineering in the 21st century. Surgical Technology International 10: 25-37.93.Nieduszynski, I. A. and Preston, R. D. 1970. Crystallite size in natural cellulose. Nature 225: 273-274.94.Nishi, Y., Uryu, M., Yamanaka, S., Watanabe, K., Kitamura, N., Iguchi, M. and Mitsuhashi, S. 1990. The structure and mechanical properties of sheets prepared from bacterial cellulose. Part 2: improvement of the mechanical properties of sheets and their applicability to diaphragms of electroacoustic transducers. Journal of Materials Science 25: 2997-3001.95.Nishinari, K. and Takahashi, R. 2003. Interaction in polysaccharide solutions and gels. Current Opinion in Colloid and Interface Science 8: 396-400.96.Noro, Y., Sugano, Y. and Shoda, M. 2004. Utilization of the buffering capacity of corn steep liquor in bacterial cellulose production by Acetobacter xylinum. Applied Microbiology and Biotechnology 64: 199-205.97.Oikawa, T., Morino, T. and Ameyama, M. 1995. Production of cellulose from D-cellulose from D-arabitol by Acetobacter xylinum KU-1. Bioscience, Biotechnology, and Biochemistry 59(8): 1564-1565.98.Okiyama A., Motoki M. and Yamanaka S. 1993. Bacterial cellulose IV. Application to processesd foods. Food Hydrocoll 6: 503-511.99.Okiyama, A., Motaki, M. and Yamanaka, S. 1992a. Bacterial cellulose II. Processing of the gelatinous cellilose for food materials. Food Hydrocoll. 6: 479-487.100.Okiyama, A., Shirae, H., Kano, H. and Yamanaka, K. 1992b. Two-stage fermentation process for cellulose production by Acetobacter aceti. Food Hydrocoll. 6: 471-477.101.Park, J. K., Jung, J. Y. and Park Y. H. 2003. Cellulose production by Gluconacetobacter hansenii in a medium containing ethanol. Biotechnology Letters 25: 2055-2059.102.Pollock, T. J. 1993. Gellan-related polysaccharide and the genus Sphingomonas. Journal of General Microbiology 13: 1939-1945.103.Qian, X. F., Yin, J., Huang, J. C., Yang, Y. F., Guo, X. X. and Zhu, Z. K. 2001. The preparation and characterization of PVA/Ag2S nanocomposite. Materials Chemistry and Physics 68: 95-97.104.Ramana, K. V., Tomar, A. and Singh, L. 2000. Effect of various carbon and nitrogen sources on cellulose synthesis by Acetobacter xylinum. World Journal of Microbiology & Biotechnology 16: 245-248.105.Rambo, C. R., Recouvreux, D. O. S., Carminatti, C. A., Pitlovanciv, A. K., Ant?nio, A. V. and Porto, L. M. 2008. Template assisted synthesis of porous nanofibrous cellulose membranes for tissue

engineering. Materials Science and Engineering C 28: 549-554.106.Ronen, M., Guterman, H. and Shabtai, Y. 2002. Monitoring and control of pullan peoduction using vision sensor. Journal of Biochemical and Biophysical Methods 51: 243-249.107.Rong, M. Z., Zhang, M. Q., Zheng, Y. X., Zeng, H. M. and Friedrich, K. 2001. Improvement of tensile properties of nano-SiO2/PP composites in relation to percolation mechanism. Polymer 42: 3301-3304.108.Ross, P., Mayer, R. and Benziman, M. 1991. Cellulose biosynthesis and function in bacteria. Microbiological Reviews 55: 35-58.109.Ross, P., Weinhouse, H., Aloni, Y., Michaeli, D., Weinbergerohana, P., Mayer, R., Braun, S., Devroom, E., Vandermarel, Ga., Vanboom, J. H. and Benziman, M, 1987. Regulation of cellulose synthesis in Acetobacter-xylinum by cyclic diguanylic acid. Nature 325 (6101): 279-281.110.Sangok, B. and Makoto, S. 2005. Production of bacterial cellulose by Acetobacter xylinum BPR2001 using molasses medium in a jar fermentor. Applied Microbiology and Biotechnology. 67: 45-51.111.Saxena, I. M., Kudlicka, K., Okuda, K. and Brown, R. M. Jr. 1994. Characterization of genes in the cellulose-synthesizing operon (acs Operon) of Acetobacter xylinum: implicaton for cellulose crystallization. The Journal of Bacteriology 176: 5735-5752.112.Saxena, I. M., Lin, I. F. C. and Brown, R. M. Jr. 1990. Cloning and sequencing of the cellulose synthase catalytic subunit gene of Acetobacter xylinum. Plant Molecular Biology 15: 673-683.113.Schramm, M. and Hestrin, S. 1954. Factors affecting production of cellulose at the air/liquid interface of a culture of Acetobacter xylinum. The Journal of General Microbiology 11: 123-129.114.Schramm, M., Gromet, Z. and Hestrin, S. 1957. Role of hexose phosphate in synthesis of cellulose by Acetobacter xylinum. Nature 179(5): 28-29.115.Serafica, G. C. 1997. Production of Bacterial Cellulose Using a Rotating Disk Film Bioreactor by Acetobacter xylinum. PhD Thesis, Rensselaer Polytechnic Institute.116.Serafica, G. Mormino, R. and Bungay, H. 2002. Inclusion of solid particles in bacterial cellulose. Applied Microbiology and Biotechnology 58(6): 756-760.117.Shamolina, I. I. 1997. Prospects for use of microbial raw material for fabrication of fibre and film materials. Review. Fibre Chemistry 29(1): 1-8.118.Siqueira, J. J. P. e Moreschi, J. C. 2000. Membranas de celulose porosas desidratadas para curativos em ?lceras, escoria??es e queimaduras. Cir Vasc Angiol 16: 179-180.119.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: 215-219.120.Standal, R., Iversen, T. G., Coucheron, D. H., Fjaervik, E., Blatny, J. M. and Valla, S. 1994. A new gene required for cellulose production and a gene encoding cellulolyt IC activity in Acetobacter xylinum are co-localized with The Bcs Operon. The Journal of Bacteriology 176: 665-672.121.Stredansky, M., Conti, E., Bertocchi, C., Matulova, M., and Zanetti, F. 1998. Succinoglycan production by Agrobacterium tumefaciens. Journal of Fermentation and Bioengineering 85: 398-403.122.Sugiyama, J., Vuong, R. and Chanzy, H. 1991. Electron diffraction study of two crystalline phases occurring in native cellulose from an algal cell wall. Macromolecules 24: 4168-4175.123.Sutherland, I. W. 1998. Novel and established application of microbial polysaccharides. Trends Biotechnol 16: 41-46.124.Sutherland, I. W. 2001. Microbial polysaccharides from Gram-negative bacteria. International Dairy Journal 11: 663-674.125.Tahara, N., Tabuchi, M., Watanabe, K., Yano, H., Morinaga, Y. and Yoshinaga, F. 1997. Degree of polymerization of cellulose from Acetobacter xylinum BPR2001 decreased by cellulase produced by the strain. Bioscience Biotechnology & Biochemistry 61: 1862-1865.126.Takayasu, T. and Fumihiro, Y. 1997. Production of bacterial cellulose by agitation culture systems. Pure and Applied Chemistry 69(11): 2453-2458.127.Takeda-Hirokawa, N., Neoh, L. P., Akimoto, H., Kaneko, H., Hishikawa, T., Sekigawa, I., Hashimoto, H., Hirose, S. I., Murakami, T., Yamamoto, N., Mimura, T. and Kaneko, K. 1997. Role of curdlen sulfate in the binding of HIV-1 gp120 to CD4 molecules and the production of gp120-mediated THF-a. Microbiology and Immuneology 41: 741-745.128.Tanaka, M., Murakami, S., Shinke, R. and Aoki, K. 2000. Genetic characteristics of cellulose-forming acetic acid bacteria identified phenotypically as Gluconacetobacter xylinus. Bioscience, Biotechnology and Biochemistry 64: 757-760.129.Tantratian. S., Tammarate, P., Krusong, W., Bhattarakosol, P. and Phunsri, A. 2005. Effect of dissolved oxygen on cellulose production by Acetobacter sp. Journal of Scientific Research, Chulalongkorn University 30(2): 179-186.130.Tarr, H. J. and Hibbert, H. 1931. Polysaccharide synthesis by the action of Acetobacter xylinum on carbohydrates and related compounds. The Canadian Journal of Research 4: 372-388.131.Tendero, C., Tixier, C., Tristant, P., Desmaison, J. and Leprince. P. 2006. Atmosperic pressure plasmas: A review. Spectrochimica Acta Part B. 61: 2-30.132.Timell, T. E. 1967. Recent progress in the chemistry of wood hemicelluloses. Wood Science and Technology 1: 45-70.133.Toda, K., Asakura, T., Fukaya, M., Entani, E. and Kawamura, Y. 1997. Cellulose production by acetic acid-resistant Acetobacter xylinum. Journal of Fermentation and Bioengineering 84(3): 228-231.134.Tokoh, C., Takabe, K., Fujita, M. and Saiki, H. 1998. Cellulose synthesized by Acetobacter xylinum in the presence of acetyl glucomannan. Cellulose. 5: 249-261.135.Toyosaki, H., Naritomi, T., Seto, A., Matsuoka, M., Tsuchida, T. and Yoshinaga, F. 1995. Screening of bacterial cellulose- producing Acetobacter strains suitable for agitated culture. Bioscience Biotechnology & Biochemistry 59: 1498-1502.136.Tripodo, M. M., Lanuzza, F., Micali, G., Coppolino, R. and Nucita, F. 2004. Citrus waste recovery: a new environmentally friendly procedure to obtain animal feed. Bioresource Technology. 91: 111-115.137.Umeda, Y., Hirano, A., Ishibashi, M., Akiyama, H,, Onizuka, T., Ikeuchi, M. And Inoue, Y. 1999. Cloning of cellulose synthase genes from Acetobacter xylinum JCM 7664: implication of a novel set of cellulose synthase genes. DNA Reviews 6: 109-115.138.Vacanti, J. P. and Langer, R. 1999. Tissue engineering: The design and fabrication of living replacement devices for surgical reconstruction and transplantation. Lancet;354 (Suppl 1): SI32-SI34.139.Vandamme, E. De-Bates, S., Vanbaelen, A., Joris, k. and De-wulf, P. 1998. Improved production of bacterial cellulose-production Acetobacter strains suitable for agitated culture. Biosecience Biotechnilogy and Biochemistry 59: 1498-1502.140.VanderHart, D. L., and Atalla, R. H. 1987. Further carbon-13 NMR evidence for the coexistence of two crystalline forms in native celluloses. In R. H. Atalla, The structures of celluloses. ACS Symposium Series (340) p.88 – 118. American Chemical Society. Washington, DC, USA.141.White, D. G. and Brown, Jr. R. M. 1989. Prospects for the commercialization of the biosynthesis of microbial cellulose. In: Schuerch C, editor. Celllulose and Wood – Chemistry and Technology. 573-590.142.Wong, H. C., Fear, A. L., Calhoon, R. D., Eichinger G. H, Mayer R, Amikam, D. Benziman, M., Gelfand, D. H.,

Meade, J. H. and Emerick, A. W. 1990. Genetic organization of the cellulose synthase operon in Acetobacter xylinum. Proceedings of the National Academy of Sciences 87: 8130-8134.143.Wright, J. B., Lam, K., Hansen, D. and Burrell, R. E. 1999. Efficacy of topical silver against fungal burn wound pathogens. American Journal of Infection Control 27(4): 344-350.144.Xiong, J., Ye, J., Liang, W. Z. and Fan, P. M. 2000. Influence of microwave on the ultrastructure of cellulose. Journal of South China University of Technology 28(3): 84-89.145.Yamamoto, H., Horii, F. and Hirai, A. 1996. In situ crystallization of bacterial cellulose. II. Influences of different polymeric additives on the formation of cellulose I α and I β at the early stage of incubation. Cellulose 3: 229-242.146.Yamanaka, K., Hasegawa, A., Sawamura, R. and Okada, S. 1989. Dimethylatedarsenics induce DNA strand breaks in lung via the production of active oxygen in mice. Biochemistry and Biophysical Research Communications 165: 43-50.147.Yoshida, M. 1998. Cosmetic material. Japanese patent 10203953A.148.Yoshida, M. 1999. Composition for acid hair dye. Japanese patent 11240824A.149.Yoshinaga, F., Tonouchi, N. and Watanabe, K. 1997. Research progress in production of bacterial cellulose by aeration and agitation culture and its application as a new industrial material. Bioscience, Biotechnology and Biochemistry 61(2): 219-24.150.Young, K. Y., Sang, H. P., Jung, W. H., Yu, R. P. and Yu, S. K. 1998. Cellulose production by Acetobacter xylinum BRC5 under agitated condition. Journal of Fermentation and Bioengineering 85: 312-317.151.Zevenhuizen, L. P. T. M. 1997. Succinoglycan and galactoglucan. Carbohydrate Polymers 33: 139-144.152.Zhou, L. L., Sun, D. P., Hu L. Y., Li, Y. W. and Yang, J. Z. 2007. Effect of addition of sodium alginate on bacterial cellulose production by Acetobacter xylinum. Journal of Industrial Microbiology & Biotechnology 34(7): 483-487.