OPEN ACCESS Freely available online

Journal of Nanomedicine & Nanotechnology

Review Article

Bionanocellulose: A Trending Natural Nanomaterial for Groundbreaking Applications in Regenerative Medicine

Dieter Klemm[*1], **Vanessa Raddatz**[1], **Katrin Petzold-Welcke**[1]

[1]*Vanessa Raddatz, aKKF-Gesellschaft, Hans-Knöll-Str. 6, 07745 Jena, Germany*

ABSTRACT

The concern of this mini review is to feature the natural nanomaterial bionanocellulose (BNC) and its potential as a novel type of biomaterial for applications in regenerative medicine. The hydrogel BNC is characterized by high purity, dimensional stability and good surgical handling. A fundamental current progress is the biotechnological design of shape, dimensions, nanofibernetwork and surface properties of the BNC materials. The corresponding template-based technology allows the tailoring of implants for quite different organs such as urgently needed small diameter blood vessel substitutes, bile duct and ureter implants. Further application fields are advanced wound dressings and controlled release scaffolds.

Keywords: bionanocellulose, regenerative medicine, visceral implants, cardiovascular implants, wound dressing, drug delivery.

CONCLUSION AND OUTLOOK

The high potential of bionanocellulose (BNC) as biotechnological designable implant materials open up new possibilities for regenerative medicine. By the process parameters of the currently established technology, the functional implant properties for replacement and repair of human organs can be tailored. The technology can supply the research market by corresponding products to advance implant development. In near future, the development of applicable BNC medical devices should be possible, especially in the background of “first in man” dura mater implants.

CONFLICT OF INTEREST

Figure 1: Overview of products made by MMR Tech, a) never-dried BNC tube on a red glass rod (99 % water content). Length >100 mm, inner diameter: 5 mm, wall thickness: 1 mm, b) photography of the cross-section of a multilayered BNC tube, scale bar: 1 mm, and c) lateral view of this BNC tube. The wall thickness of the shown tube is of extra-large size for better demonstrating the layers, scale bar: 1 mm, d) never-dried BNC membrane with dimensions up to 200 x 100 x 3 mm, scale bar: 10 mm, e) never-dried hollow BNC-Y-piece, scale bar: 10 mm, f) never-dried hollow BNC-X-piece for demonstration of 3D structures, scale bar: 10 mm (from Klemm D, Petzold-Welcke K, Kramer F, Richter T, Raddatz V, Fried W, et al. (2021) Biotech nanocellulose: A review on progress in product design and today's state of technical and medical applications. Carbohydr Polym 254:117313. [12]).

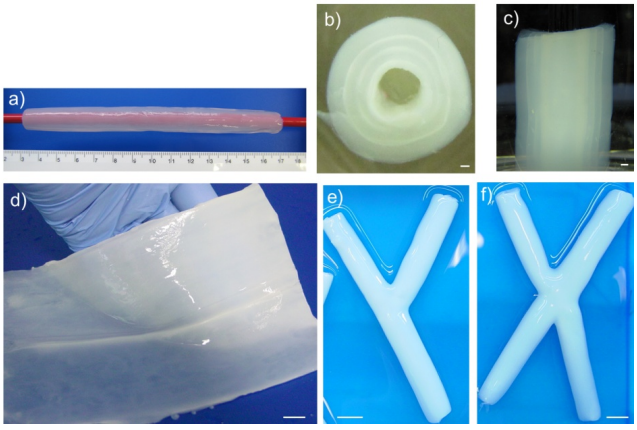


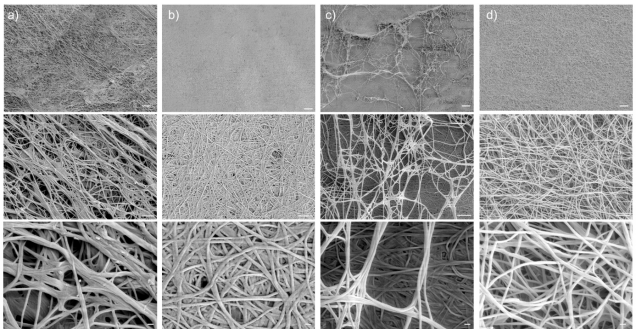
Figure 2: Scanning electron microscopic image of BNC tubes synthesized by MMR Tech from K. xylinus DSM 32384 (top line: 600x, scale bar: 10 µm, middle line: 5,000x, scale bar: 2 µm, lower line: 20,000x, scale bar: 200 nm), a) inner surface of BNC

***Corresponding author**: Dieter Klemm, KKF-Gesellschaft, Hans-Knöll-Str. 6, 07745 Jena, Germany, Tel: +49/3641 548281; E-Mail: d.klemm@kkfpolymers.de.

Received date: Apr 03, 2021; **Accepted date**:september6, 2021; **Published date**: September 16, 2021.

Citation:, (2020) Klemm D : Bionanocellulose: a trending natural nanomaterial for groundbreaking applications in regenerative medicine; J Nanomed Nanotechno :12:9P658

tube directed to bamboo template, b) outer surface of BNC tube, synthesized on a bamboo template, directed to the air space, c) inner surface of a manually inverted BNC tube, synthesized on a bamboo template, d) inner surface of BNC tube directed to air space, synthesized inside a hollow cylinder (form Klemm D, Petzold-Welcke K, Kramer F, Richter T, Raddatz V, Fried W, et al. (2021) Biotech nanocellulose: A review on progress in product design and today's state of technical and medical applications. Carbohydr Polym 254:117313. [12]).



REFERENCES

1. Klemm D, Lindström T, Abitbol T, Kralisch D (2021) The nanocellulose family. In: Thomas S, Pottathara YB. Nanocellulose based composites for electronics. Amsterdam, Netherlands: Elsevier. p. 1–14.
2. Gama M, Gatenholm P, Klemm D (2013) Bacterial nanocellulose: A sophisticated multifunctional material. Boca Raton: CRC Press.
3. Klemm D, Kramer F, Moritz S, Lindström T, Ankerfors M, Gray D, et al. (2011) Nanocelluloses: A new family of nature-based materials. Angew Chem Int Ed Engl 24:5438–66.
4. Klemm D, Cranston ED, Fischer D, Gama M, Kedzior SA, Kralisch D, et al. (2018) Nanocellulose as a natural source for groundbreaking applications in materials science: Today's state. Materials Today 7:720–48.
5. Nishi Y, Uryu M, Yamanaka S, Watanabe K, Kitamura N, Iguchi M, et al. (1990) The structure and mechanical properties of sheets prepared from bacterial cellulose. J Mater Sci 6:2997–3001.
6. Schramm M, Hestrin S (1954) Factors affecting production of cellulose at the air/liquid interface of a culture of Acetobacter xylinum. J Gen Microbiol 1:123–9.
7. Hornung M, Ludwig M, Gerrard AM, Schmauder H-P (2006) Optimizing the Production of Bacterial Cellulose in Surface Culture: Evaluation of substrate mass transfer influences on the bioreaction (part 1). Eng. Life Sci. 6:537–45.
8. Hornung M, Ludwig M, Schmauder HP (2007) Optimizing the production of bacterial cellulose in surface culture: A novel aerosol bioreactor working on a fed batch principle (part 3). Eng. Life Sci. 1:35–41.
9. Luo H, Dong J, Yao F, Yang Z, Li W, Wang J, et al. (2018) Layer-by-Layer assembled bacterial cellulose/graphene oxide hydrogels with extremely enhanced mechanical properties. Nanomicro Lett 3:42.
10. Fried W, Klemm D, Kopsch V, Koth D, Kramer F, Moritz S, et al. (2013) Process for producing hollow bodies from microbial cellulose, WO2013113675A1.
11. Klemm D, Kopsch V, Koth D, Kramer F, Moritz S, Richter T, et al. (2013) Vorrichtung zur Herstellung von Hohlkörpern aus mikrobiellem Polymer. Germany, DE102012201272B4.
12. Klemm D, Petzold-Welcke K, Kramer F, Richter T, Raddatz V, Fried W, et al. (2021) Biotech nanocellulose: A review on progress in product design and today's state of technical and medical applications. Carbohydr Polym 254:117313.
13. Rosen CL, Steinberg GK, DeMonte F, Delashaw JB, Lewis SB, Shaffrey ME, et al. (2011) Results of the prospective, randomized, multicenter clinical trial evaluating a biosynthesized cellulose graft for repair of dural defects. Neurosurgery 5:1093-103; discussion 1103-4.
14. Klemm D, Rauchfuss F, Kramer F, Petzold-Welcke K, Richter T, Ruhe C, et al. (2016) Design of biocellulose implants for first successful bile duct regeneration. 251st ACS National Meeting & Exposition. San Diego, United States.
15. Rauchfuss F (2018) Biocellulosis as scaffold for tissue regeneration in modern surgery. 225th ACS National Meeting & Exposition. New Orleans, United States.
16. Rauchfuss F, Settmacher U, Klemm D, Fried W, Richter T, Petzold-Welcke K, et al. (2017) Medical implant based on nanocellulose, WO2017021468A1.
17. World Health Organization (2020) The top 10 causes of death [cited 2021 Mar 25]. Available from: https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death
18. Scherner M, Reutter S, Klemm D, Sterner-Kock A, Guschlbauer M, Richter T, et al. (2014) In vivo application of tissue-engineered blood vessels of bacterial cellulose as small arterial substitutes: Proof of concept? J Surg Res 2:340–7.
19. Schumann DA, Wippermann J, Klemm DO, Kramer F, Koth D, Kosmehl H, et al. (2009) Artificial vascular implants from bacterial cellulose: Preliminary results of small arterial substitutes. Cellulose 5:877–85.
20. Wippermann J, Schumann D, Klemm D, Kosmehl H, Salehi-Gelani S, Wahlers T (2009) Preliminary results of small arterial substitute performed with a new cylindrical biomaterial composed of bacterial cellulose. Eur J Vasc Endovasc Surg 5:592–6.
21. Wacker M, Kießwetter V, Slottosch I, Awad G, Paunel-Görgülü A, Varghese S, et al. (2020) In vitro hemo- and cytocompatibility of bacterial nanocelluose small diameter vascular grafts: Impact of fabrication and surface characteristics. PLoS One 6:e0235168.
22. Weber C, Reinhardt S, Eghbalzadeh K, Wacker M, Guschlbauer M, Maul A, et al. (2018) Patency and in vivo compatibility of bacterial nanocellulose grafts as small-diameter vascular substitute. J Vasc Surg 6S:177S–187S.e1.
23. Sulaeva I, Hettegger H, Bergen A, Rohrer C, Kostic M, Konnerth J, et al. (2020) Fabrication of bacterial cellulose-based wound dressings with improved performance by impregnation with alginate. Mater Sci Eng C Mater Biol Appl 110619.
24. Mori R, Nakai T, Enomoto K, Uchio Y, Yoshino K (2011) Increased antibiotic release from a bone cement containing bacterial cellulose. Clin Orthop Relat Res 2:600–6.
25. Shao W, Liu H, Wang S, Wu J, Huang M, Min H, et al. (2016) Controlled release and antibacterial activity of tetracycline hydrochloride-loaded bacterial cellulose composite membranes. Carbohydr Polym 114–20.
26. Ye S, Jiang L, Wu J, Su C, Huang C, Liu X, et al. (2018) Flexible amoxicillin-grafted bacterial cellulose sponges for wound dressing: In vitro and in vivo evaluation. ACS Appl Mater Interfaces 6:5862–70.
27. Adepu S, Khandelwal M (2020) Bacterial cellulose with microencapsulated antifungal essential oils: A novel double barrier release system. Materialia 6:100585.
28. Marquele-Oliveira F, da Silva Barud H, Torres EC, Machado RTA, Caetano GF, Leite MN, et al. (2019) Development, characterization and pre-clinical trials of an innovative wound

healing dressing based on propolis (EPP-AF®)-containing self-microemulsifying formulation incorporated in biocellulose membranes. Int J Biol Macromol 570–8.

29. Trovatti E, Freire CSR, Pinto PC, Almeida IF, Costa P, Silvestre AJD, et al. (2012) Bacterial cellulose membranes applied in topical and transdermal delivery of lidocaine hydrochloride and ibuprofen: In vitro diffusion studies. Int J Pharm 1:83–7.

30. Gupta A, Keddie DJ, Kannappan V, Gibson H, Khalil IR, Kowalczuk M, et al. (2019) Production and characterisation of bacterial cellulose hydrogels loaded with curcumin encapsulated in cyclodextrins as wound dressings. European Polymer Journal 437–50.

31. Karl B, Alkhatib Y, Beekmann U, Bellmann T, Blume G, Steiniger F, et al. (2020) Development and characterization of bacterial nanocellulose loaded with Boswellia serrata extract containing nanoemulsions as natural dressing for skin diseases. Int J Pharm 119635.

32. Numata Y, Mazzarino L, Borsali R (2015) A slow-release system of bacterial cellulose gel and nanoparticles for hydrophobic active ingredients. Int J Pharm 1-2:217–25.

33. Beekmann U, Karl B, Zahel P, Käfer D, Schmölz L, Lorkowski S, et al. (2019) Manufacturing of modified bacterial cellulose as tailor-made anti-inflammatory wound dressing. 4th International Symposium on Bacterial Nanocellulose. Porto, Portugal.