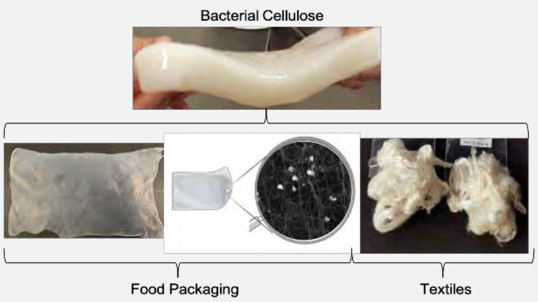
Development of bacterial cellulose composites for food packaging and textiles

F.A.G.S. Silva[1]*, F. Dourado[1], M. Hummel[2], F. Poças[3], M. Gama[1]

[1]Centre of Biological Engineering, University of Minho, Campus de Gualtar 4710-057 Braga, Portugal; [2]LABBELS - Associate Laboratory, 4710-057 Braga, Portugal; [3]Department of Bioproducts and Biosystems, Aalto University, P.O Box 16300, 00076 Aalto Espoo, Finland; [4]Universidade Católica Portuguesa, CBQF-Centro de Biotecnologia e Química Fina – Laboratório Associado, Escola Superior de Biotecnologia, Rua Diogo Botelho 1327, 4169-005 Porto, Portugal.

*francisco.agss@gmail.com



Most of all petroleum-based materials are used for a short period of time but then take centuries to degrade. Food packaging and textile are examples of industries that are truly dependent of synthetic materials. Therefore, there is an increasing interest on seeking alternatives to these materials. Plant nanocellulose (PNC) has been actively studied, yet the high demand may arise environmental issues such deforestation and wood processing. An alternative source is bacterial cellulose (BC), produced by bacteria of the genus *Komagataeibacter*, through fermentation. BC has a great potential due to great mechanical performance, despite some drawbacks such high water affinity (for food packaging) and high molecular weight (for textiles). Different approaches were used with the attempt to reduce water vapor permeability and functionalize BC based composite for Food packaging. For textiles, highly performing fibres were developed after using adapted Lyocell and Ioncell technologies.

Challenges of Food Packaging and Textiles

Most of all petroleum-based materials are used for a short period of time but then take centuries to degrade. About 21% of global production are accumulated in landfills and waterways [1]. These may release microplastics that have harmful effects to both terrestrial and marine ecosystems [2].

Food packaging and textile are examples of industries that are truly dependent of synthetic materials. The plastic packaging market has been expanding with a growth rate of 20–25% per year [3]. Regarding the textile industry, synthetic fibres have dominated the market representing up to 60 % of the global fibre production [4]. The most used synthetic fibre is polyester, with a market share of around 50 % of total global fibre production, followed by Cotton with 25 % of total global fibre production [4]. Cotton also raised environmental concerns due to a measureless water consumption [5]. The development of sustainable or renewable polymeric materials is an active research area, yet the overall performance of renewable polymers is often inferior when compared to traditional petroleum-based polymers [6]. Plant nanocellulose (PNC) is seen as an alternative for the production of high-performance bio-based materials. Yet the high demand for bio-based materials (such PNC), may lead to intensive deforestation for PNC extraction, as well as wood (chemical based) processing.

An alternative is bacterial cellulose (BC), a cellulose produced by bacteria of the genus *Komagataeibacter*, through fermentation. BC offers interesting properties such as high porosity, biocompatibility, non-toxicity and biodegradability [7]. Either for food packaging and textile industries, BC has a great potential due to the great mechanical performance. Yet some limitations need to be surpassed, such the high-water affinity (for food packaging) as well as the high degree of polymerization (for textiles) [8,9].

BC application on Food Packaging

The first task was to develop a layered biodegradable composite based on a plasticized BC (either with glycerol or polyethylene glycol) and poly (3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV), as an attempt to improve the water vapour permeability. The PHBV coating on plasticized BC reduced significantly the water vapour permeability (from 0.990 to 0.032 $g.\mu m.m^{-2}.day^{-1}.Pa^{-1}$) and increased the hydrophobicity (contact angle from 10-40° to 80-90°). The mechanical and barrier properties of the obtained layered composite met the requirements for food packaging.

Although the results obtained being important for food packaging, its commercial use is still far off due to production costs and low production capacity, especially when compared to PNC [6]. Nevertheless, BC is a proven material to support substances that play an active/intelligent role in food packaging, with ability to carry and release active substances [10,11].

BC application on Active Food Packaging

A functionalized BC film was developed, by *in situ* incorporating zinc oxide nanoparticles (ZnO). BC_{ZnO} composites were developed and characterized, and the Zn migration assessed using food simulants (ethanol 10, 20 and 50%v/v) and chicken skin as a food model. Finally, the antimicrobial properties of BC_{ZnO} on chicken skin were also investigated. Small ZnO nanoparticles (≈144 nm) with low polydispersity index (≈0.139) were successfully produced, with high ZnO incorporation (27% m_{ZnO}/mBC_{ZnO}) and homogeneous distribution inside BC, by the dropwise addition of NaOH, to a $Zn(CH_3COO)_2$-PVOH solution with an immersed BC membrane, followed by drying. Low Zn migration levels were observed using both food simulants and chicken skin at 4 °C (being temperature and pH dependent). Using chicken skin as a food model, the BC_{ZnO} film was effective against Escherichia coli, Salmonella spp. (0.5-1.0 log reduction) and Campylobacter spp. (2.0 log reduction), showing promising results as an alternative film for active packaging.

BC application on Textiles

In order to seek an alternative sources of textile fibres, the development of man-made cellulosic fibers (MMCF) using BC was considered. Lyocell and Ioncell technologies (with collaboration of Thuringian Institute for Textile and Plastics Research and the Department of Bioproducts and Biosystems, Aalto University) were adopted to assess cellulose dissolution (using *N*-methylmorpholine-*N*-oxide (NMMO) and 1,5-diazabicyclo [4.3.0] non-5-enium acetate ([DBNH][OAc]) as well as the spinnability of the obtained dopes. Successful spinning trials were achieved after BC dissolution on the aforementioned solvents. The resulting filaments offered competitive mechanical performance, with improved stiffness (breaking tenacities: 56 $cN.tex^{-1}$ $BC_{Lyocell}$ and 60 $cN.tex^{-1}$ for BC_{Ioncel}) and competitive elasticity (Elongation: 8.29 % $BC_{Lyocell}$ and 12 % for BC_{Ioncel}). These results showed that BC is a promising bio-based material that textile industry may benefit from.

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