Bacterial Cellulose Nanocomposites Developed by in-situ Fermentation

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ABSTRACT

In this research, a new methodology was developed to produce nanostructured composites of thermoplastic starch polymers/bacterial cellulose, throughout biosynthesis of cellulose by *Gluconacetobacter medellinensis sp. nov* bacteria. Due to the hydrophilic nature of starch, it was plasticizer with glycerol and cross-linked with citric acid to improve the mechanical and physical properties of nanocomposite films. Results indicate that the incorporation of cellulose nanofibrils and crosslinking process can improve mechanical and thermal properties, and suggest that these materials are promising candidates in food packing industry.

Keywords: bacterial cellulose nanocomposites, in-situ fermentation, crosslinking, mechanical properties

1. INTRODUCTION

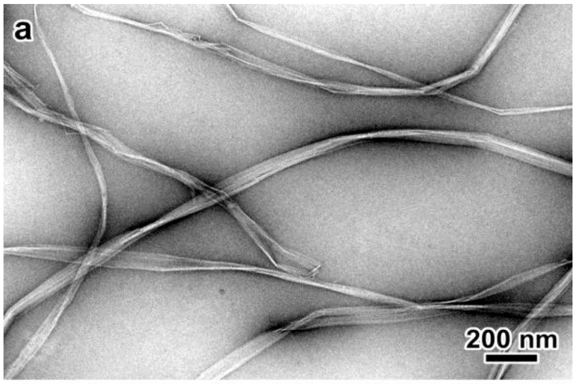
In recent years has increased the interest in the use and development of cellulose-based composites from plants, marine animals and obtained by microbial activity [1]. Some microorganisms such as *Gluconacetobacter* synthesize cellulose nanofibrils (BC) through the polymerization of glucose molecules and subsequent extrusion outside the cell (see Figure 1a). In static conditions, the bacteria produce a three-dimensional network that can be used as reinforcing material in polymer matrices (see see Figure 1b). Currently, nanocomposites can be developed by mixing bacterial cellulose nanofibrils in the wet state or dry state and polymer matrices and as a result a significant improvement in mechanical properties of the matrix is obtained [2]. However, other alternatives could be useful is the bioengineering provided by the bacteria of the genus *Gluconacetobacter* to develop new materials by incorporation of water soluble polymer during cellulose nanofibrils synthesis. In this project we produce by in-situ fermentation novel starch nanocomposites reinforced with bacterial cellulose nanofibrils. This method reduces the processing steps and energy consumption.

2. METHODOLOGY

The recently discovered *Gluconacetobacter medellinensis sp. nov.*, was used in this study. The purified bacterium was incubated in a static Hestrin-Schramm culture medium (HS) [3] modified with water-soluble polymers such as starch. To avoid the loss of the matrix during the purification steps of the material, strach/BC nanocomposites were chemical linked using citric acid. Curing temperature was 50 °C for 48 h. Mechanical properties were evaluated using an Instron 5582 universal testing instrument, equipped with a 50N load cell. Samples were tested according with ASTM D882-09, using a cross head speed of 25 mm/min. Thermal behavior was evaluated using a Mettler Toledo TGA/SDTA 851e. A nitrogen atmosphere at 40 ml/min was employed. The heating rate was 10 °C/min.

3. RESULTS AND DISCUSSION

Nanocomposite films produced, after the assembly of the components in static conditions, were obtained after chemical crosslinking, and a good distribution of nanofibrils is obtained (see Figure 2a-b). However, variation in BC production was affected by starch presence, thus the addition of different concentrations of thermoplastic matrix to the culture medium could be produced nanocomposites with different reinforcement and matrix weight concentration. Slight variation on films transparence could be observed in some of nanocomposites samples, this behavior could be associated with fiber/matrix concentrations.

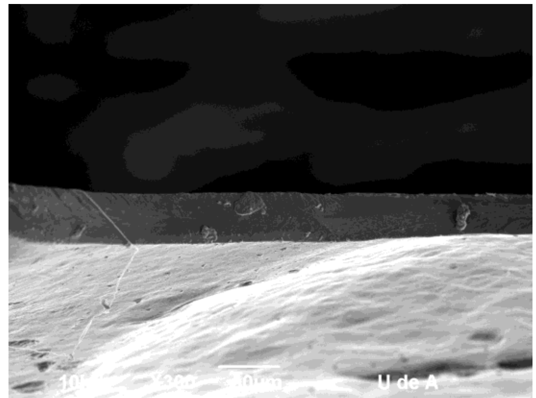


a)

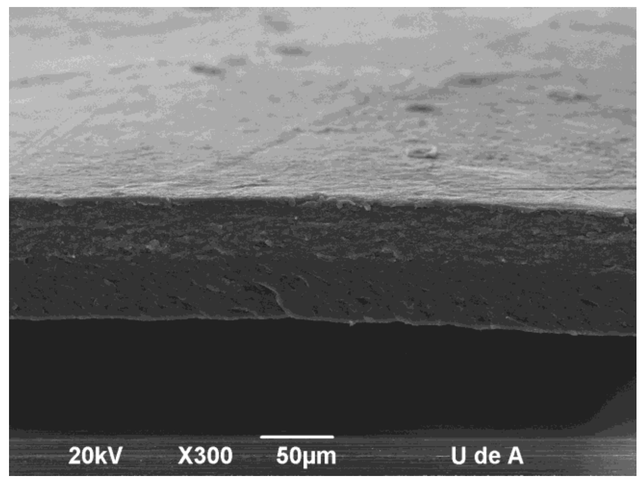
b)

Figure 1. TEM image of cellulose nanofibrils a), and cellulose pellicule b)

Mechanical and thermal results (see Figure 3a-b) indicate that the incorporation of cellulose nanofibrils and crosslinking process can improve nanocomposites behavior respect to neat matrix, and obtained values suggest that these materials are promising candidates in food packing industry, especially for edible films.



a)



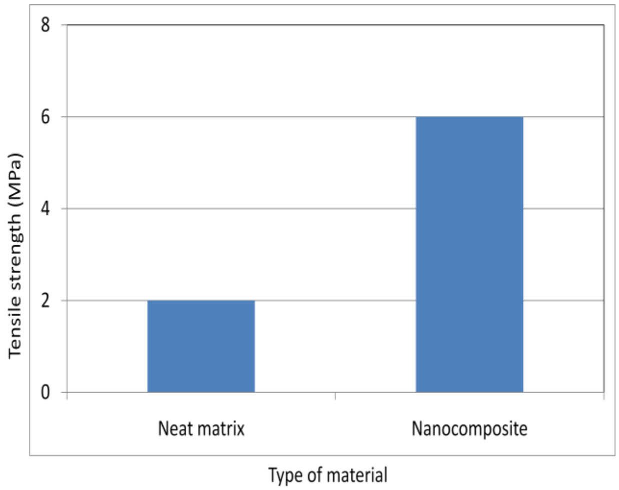
b)

Figure 2. SEM image of starch matrix a), and cellulose nanocomposites b)

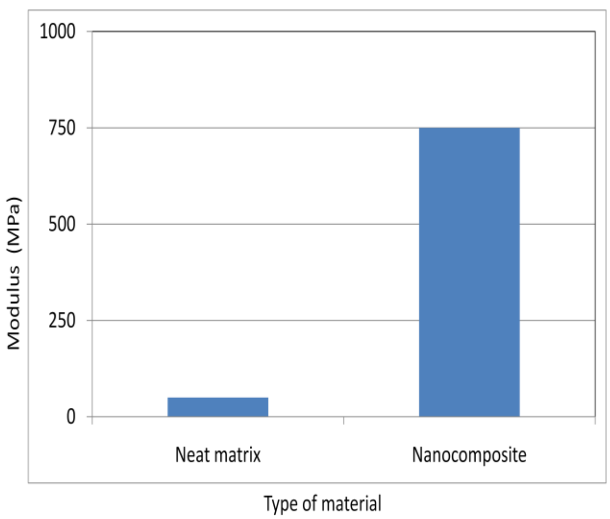
4. CONCLUSIONS

In this work, nanocomposites based on high content of bacterial cellulose nanofibrils synthesized from *Gluconacetobacter medellinensis sp. nov* bacteria and starch matrix were produced. Nanocomposites show good mechanical properties regarding tensile strength and elastic modulus. This behavior is related to the three-dimensional network-like structure formed by uniformly distributed cellulose nanofibrils that promoted interfibrillar bonding during in-situ fermentation.

Additionally, the effect of crosslinking conditions improve the mechanical and thermal behavior of nanocomposites. These new type of nanocomposites could be a promising candidates in food packing industry.



a)



b)

Figure 3. Tensile properties of starch matrix and cellulose nanocomposites

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