Integrated biorefinery development: Valorisation of orange waste for the production of bacterial cellulose and various value-added products

E. Tsouko[1], S. Maina[1], A. Koutinas

Department of Food Science and Human Nutrition, Agricultural University of Athens, Iera Odos 75, 11855 Athens, Greece

[1]*equally contributed authors*

Citrus fruits including oranges, lemons, limes, grapefruits and tangerines represent an important sector of fruit production and processing. In 2016/17, the global citrus production amounted to 63.3 million t, with oranges dominating market share at 80% (Andritsou, 2018). The orange processing industry creates large amounts of side streams in the form of peels, seeds, rag and pulp, being around 60% of the fruit weight. These side streams have great valorisation potential in a biorefinery context for the recovery of value-added products, such as essential oil and antioxidants, and the production of fermentation products, such as bacterial cellulose (Andritsou, 2018).

Under this concept, this study initially focused on the recovery of D-limonene, antioxidants and pectins from orange peels discarded after juice extraction. Soluble sugars were extracted using aqueous solution, while D-limonene (up to 3.5%) was recovered by steam distillation. The remaining solid residues were used for the extraction of various antioxidants via aqueous ethanol extraction. The liquid to solid ratio and extraction time were evaluated in order to maximise the extraction efficiency. Subsequently, pectins were recovered via dilute HCl pre-treatment. Citric acid was also assessed for pectin extraction. High pectins yields were achieved with galacturonic acid content up to 54% and degree of esterification up to 72%. The cellulose and hemicellulose rich remaining solids were hydrolysed to their monomers via dilute acid pretreatment and/or enzymatic hydrolysis.

Aqueous extracts rich in free sugars as well as cellulose and hemicellulose hydrolysates were used as carbon sources for bacterial cellulose production in shake flask fermentations with the bacterial strain *Komagataeibacter sucrofermentans* DSM 15973. Bacterial cultures grown on hydrolysate deriving after enzymatic hydrolysis of acid pre-treated orange waste biomass lead to the highest bacterial cellulose production (4.4 g/L). The physiochemical properties of bacterial cellulose produced under the different regimes were determined and evaluated.

The results of this study demonstrated the effective utilization of renewable orange waste for the development of an integrated biorefinery. Further study should focus on the potential value-added applications of the derived products, while techno-economic and life cycle assessment is required in order to demonstrate the sustainability of the proposed biorefinery concept.

Keywords
D-limonene, pectin, antioxidants, bacterial cellulose, citrus waste, biorefinery

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