Be@t: Sustainable chemical processes for developing regenerative materials and ingredients in the textile industry

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Extended Abstract

Introduction:

The reuse and valorization of waste and by-products generated by other industrial sectors in the textile sector currently represents a strategy of 'sustainable waste minimization,' leading to the achievement of economic development and environmental sustainability goals. In recent years, waste and by-products from industrial processing, e.g., agro-industry, agroforestry, marine, canning, mining, leather, cork industries, among others, have been a source of bioactive compounds with potential application in the textile industry, as it is possible to extract a wide variety of compounds with a broad range of functionalities. A good example is agro-food waste and by-products, which are excellent sources of biological compounds that can be explored as raw materials to replace fossil fuels, complementing the use of forest biomass and adding value in obtaining new bio-based materials that are more versatile and sustainable. In the classification of bio-based materials, there are three major groups that can be valorized: protein-based, polysaccharides, and polyphenols. Among the most common protein-based materials derived from animal sources are keratin, collagen, and gelatin, which are often obtained from waste and by-products of industries like leather industry. These materials present valuable opportunities for sustainable reuse and resource efficiency. The extraction of these types of proteins is generally carried out through alkaline hydrolysis in combination with thermal processes, with or without the use of enzymes.

Wastes/by-products from the agrifood industry can also serve as a natural source of functional dyes rich in phenolic compounds. These extracted materials can promote various functionalities of interest when applied to the textile and clothing industry, such as repellency, easy cleaning, anti-odor, flame retardancy, fluorescence, antioxidant, antimicrobial properties, among others.

Although some methods for the extraction and valorization of waste and by-products are already described in the literature, one of the difficulties observed relates to scalability, the lack of interaction between industries, and the suitability of ingredients for textile industry processes.

Aim:

The main objective of this study is to identify the most effective technologies, utilizing diverse raw materials and processes, to develop active agents suitable for application in the textile industry. The goal is to contribute to the creation of

greener processes and products that support industrial symbiosis and promote a circular bioeconomy.

Materials and methods:

Two approaches were tested based on different industrial by-products. These included by-products from the leather and agro-food industries. For the leather by-products the work focused on exploring different enzymes and hydrolysis conditions for the repurposing of leather towards the creation of versatile functional coatings to be re-used within the leather industry. The characterization of the samples was done using different methodologies, including SE-HPLC analyses to determine MWs, hydrolysis percentage (TNBS), total protein (BCA and Kjeldahl) and antioxidant activity (ORAC). The second approach was to extract phenolic compounds from different by-products of the agro-food industry through green and sustainable extraction methodologies. The obtained extracts were then characterized regarding their sugar, total phenolic and flavonoid content, as well as their biological potential as antioxidants and antimicrobials. Their cytotoxicity was also evaluated.

Main results:

Regarding leather hydrolysis, the results showed that all the enzymes were effective in processing the leather by-product. It was also possible to conclude that Alcalase provided better hydrolysis performance than ProtaBate P and Bromelain. Alcalase showed the highest hydrolysis degree, leading to peptides mixtures with MWs between 10 and 50 kDa and a high antioxidant activity. These results outline the potential of re-using leather by-products to create versatile functional coatings through a circular and more sustainable process. Regarding the extraction of phenolic compounds from different by-products, the results revealed a high variability of results among the different studied parameters. The different extraction methods impacted the extraction of phenolic compounds and other components (aqueous vs hydroethanolic vs ultrasound extraction methods). Sugar content varied significantly among by-products and extraction methods with apple skin aqueous extract having the highest amount of sugar. Total phenolic content of the by-products ranged from 4,4 to 512,9 mg GAE/g and flavonoid content from 2,1 to 287,8 mg CAE/g of sample. Antioxidant activity of the by-products followed the same pattern observed for the total phenolic content. Gram-negative bacteria (*E. coli* and *P. aeruginosa*) were more resistance to the extracts than Gram-positive (*S. aureus* and *S. epidermidis*). The majority of the extracts showed cytotoxicity against HaCaT cell line at the tested concentrations.

Conclusion:

The conclusions of this study can be divided regarding the two different approaches. In relation to the leather by-products approach, this study outlines the potential of re-using leather by-products to create versatile functional coatings through a circular and more sustainable process. Regarding the agro-food by-products approach, while more studies are necessary, the results show that some by-products have great potential to be used as sources of functional compounds in the textile industry, especially lemongrass and peanut skin. Different extracts exhibit varying functionalities, with some showing superior antioxidant properties while others demonstrate enhanced antimicrobial activity. This variation underscores the need to select the appropriate extract based on the specific functional requirements of the application.Despite their cytotoxicity at the tested concentrations against the tested cell line, further studies should be conducted to

better understand the concentration limits to be applied when dyeing different textiles with these extracts. As a final remark, a sustainable approach within the leather and agro-food industries can be implemented by upcycling side streams through eco-friendly methods to create high-value products. This valorization concept represents a shift from traditional linear production and consumption patterns towards a circular economy. This strategy shift not only contributes to reducing overall waste but also aligns itself with the 12nd UN sustainability goal (Ensure sustainable consumption and production patterns) by the re-use of its own by-products.

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