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Multifunctional hybrid materials from biowaste valorization

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Sintesi della Tesi

According to a Circular Bioeconomy approach, humic acids (HA) are biowastes that can be viewed as a promising and cost-effective source for high-value products and novel materials, because of their chemical and biological richness. Indeed, HA are rich in phenolic and carboxylic groups, which enhance plant growth, flame retardancy and antiviral properties. The amphiphilic nature of HA allows them to self-assemble in water, act as metal chelating agents, and interact with organic contaminants. Quinone moieties in HA provide antioxidant and pro-oxidant properties by scavenging reactive oxygen species (ROS). However, their technological use is limited by their instability in water, leading to their classification as waste nowadays, while their presence in water environment raises big issues to decontamination processes. The present PhD work defined different synthetic approaches to turn HA environmental issues into technological opportunities through the design and the development of multifunctional hybrid materials based on HA biomolecules. The PhD thesis has been focused on two main parts: I) Design of hybrid nanostructured HA-based materials; II) Design of HA-based polymeric materials.

In the former, the molecular combination of these heterogeneous moieties with an inorganic matrix (e.g., SiO_2, TiO_2, ZnO) through a ceramic templated approach proved to be an effective method for limiting HA aqueous degradation phenomena, thus improving physicochemical stability, mechanical properties, and even enhancing intrinsic organic moieties features in the final hybrid nanostructured HA based materials [1]. This approach was also combined with the electrospinning technology to produce bioactive and sustainable nanocomposite films for active packaging applications made of electrospun biodegradable and bioderived polymers and hybrid nanoparticles (**Figure 1**) [2]. In the latter, HA were explored as functional additives for polymer materials. Indeed, proper synthesis strategies were designed to use these biomolecules as functional biowaste flame retardant for epoxy-based systems or as an additive for gelatine hydrogels to obtain hybrid HA-3D network with tunable rheological features and significant biological activity, including antimicrobial and antioxidant efficacy, for a broader range of biotechnological applications [3]. From a scientific point of view, this thesis has contributed to clarify the chemistry of HA with a special focus on their interaction with either organic or inorganic components as well as on the physico-chemical features of HA-based hybrid nanomaterials. From a technological point of view, it has provided viable routes for HA valorization by developing different materials of interest in diverse areas, especially environmental ones. Furthermore, developed synthesis strategies could be easily extended to biowaste valorisation other than HA, thus significantly contributing to the challenging mission of giving waste a new value.

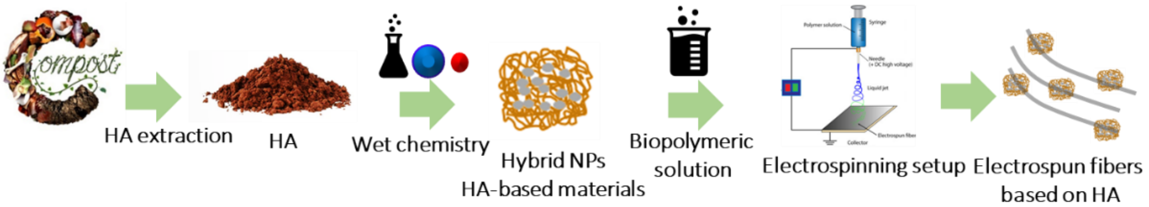

Figure 1: HA-based nanomaterials integrated with electrospinning approach.

Riferimenti

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3. Venezia, V., Avallone, P. R., Vitiello, G., Silvestri, B., Grizzuti, N., Pasquino, R., & Luciani, G. Adding humic acids to gelatin hydrogels: A way to tune gelation. *Biomacromolecules*, **2021**, *23*(1), 443-453.