Heavy metal reinforcement in biomaterials: the influence of zinc on the mechanical properties of leafcutter ants mandibles

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Faculté : Faculté des Sciences appliquées
Diplôme : Cours supplémentaires destinés aux étudiants d'échange (Erasmus, ...)
Année académique : 2023-2024
URI/URL : http://hdl.handle.net/2268.2/20910

Heavy metal reinforcement in biomaterials: the influence of zinc on the mechanical properties of the mandibles of the leafcutter ants *Acromyrmex octospinosus* workers.

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A.A. 2023/2024

Master thesis to obtain a degree in Materials Engineering at Università degli studi di Padova

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The presence of zinc and other transition metals, such as bromine, manganese, and copper, is common in a variety of arthropods tools such as legs, claws, jaws and teeth. These elements provide an alternative form of reinforcement for biomaterials compared to the well-studied biomineralization typical of mammalian bones. This type of reinforcement, in particular zinc, has been found in the mandibles of various species of leafcutter ants. Leafcutter ants are fungus farming ants, meaning that they feed on a fungus cultivated in their nest on a substrate of fresh plant material. To sustain the fungus, they must cut fresh plant material daily. Consequently, their mandibles evolved to be very sharp and wear resistant to minimize the energy required for cutting an impressive amount of plant material throughout their lifetime. In this work, various characterization techniques were used on the mandibles of *Acromyrmex octospinosus*, one of the known species of leafcutter ants, two of the worker castes of this species were studied: "majors" and "minors", which have a different morphology and a different role in the ant colony. Imaging techniques such as X-ray micro-computed tomography and digital microscopy were employed to acquire morphological information, scanning electron microscopy was used to obtain images of the mandible's internal part, and energy dispersive X-ray spectroscopy allowed us to acquire informations about zinc distribution in the mandibles. Different types of nanoindentation experiments such as quasi-static nanoindentation and wear resistance tests were performed both on *Acromyrmex octospinosus* and *Formica rufa* workers to characterize their mechanical properties. Stress-strain nanoindentation was used on the mandibles of an *Acromyrmex octospinosus* major worker to investigate its deformation behavior at the nanoscale. The aim of this thesis is to make use of different characterization techniques, correlating them to expand knowledge on a biological material that is not extensively studied in the materials engineering field and that could inspire new engineered materials. For both worker castes, indentation hardness and reduced elastic modulus of the zinc-reinforced areas of *Acromyrmex octospinosus* were found to be higher than in the non-reinforced areas. Wear tests, which have never been performed before on leafcutter ants, showed that the zinc-reinforced area of *Acromyrmex octospinosus* majors has an incredibly high wear resistance compared to the other tested areas of different samples. This work serves as a preliminary study on a relatively unexplored topic and aims to be a starting point for deeper and more extensive research.