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There is “something” in the air: an overview of allicin-based antibacterial materials

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The rising prevalence of multidrug-resistant (MDR) bacterial strains constitutes a significant threat to modern global society. Unfortunately, the practical and financial challenges associated with developing new antibiotics have already led many pharmaceutical companies to shift their focus toward different, more cost-effective and profitable products. On the other hand, garlic (*Allium sativum*) has been used in various forms and cherished worldwide as a universal natural remedy. Allicin, produced in garlic enzymatically from its stable precursor (alliin) due to mechanical damage, has gained significant scientific attention for its exceptionally broad range of therapeutic effects. A combination of the short half-life, high reactivity and non-specificity to particular proteins is a reason most pathogens cannot cope with allicin's mode of action and develop effective defence mechanisms. Furthermore, it has been demonstrated that allicin can induce transient pore formation in biological membranes, which renders pathogens more vulnerable. The synergistic use of antibiotics and allicin proved to be more effective than monotherapy, enhancing antibacterial action, lowering biofilm levels, and reducing dosage and associated negative toxic effects. Thus, using a combination of allicin with common antibiotics may serve as a viable solution to address drug resistance in infectious diseases.

Drawing inspiration from the antibacterial properties of allicin and its efficacy against multidrug-resistant (MDR) bacterial strains in both liquid and gas phases, we implemented a variety of strategies to replicate the natural concept of substrate-enzyme compartmentalisation. We developed materials for the on-demand synthesis of allicin in several forms, including flexible casted films, 3D bioprinted structures of various geometries, core-shell beads with diameters in the hundreds of microns achieved through encapsulation, and spray-dried microparticles with diverse internal structures, suitable for topical application or deep lung inhalation. We assessed the cytotoxicity of these materials against relevant cell cultures that reflect the intended application site and confirmed their antibacterial effectiveness using both standard and non-contact testing methods explicitly developed for this purpose in our laboratory. We aim to show that different techniques can be used to encapsulate both enzyme and substrate in various forms, enabling the synthesis of antibacterial allicin for a specific application.