Novel Chitosans for Plant Protection

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Abstract

Chitin is one of the most abundant natural polymers, and its partially de-*N*-acetylated counterpart chitosan is one of the most promising and most versatile renewable resources. However, in spite of superior material properties and diverse biological functionalities, chitosan-based products were slow to enter the market due to poor reproducibility in production processes and product performances. More than a decade ago, we hypothesised that this failure to achieve reproducible bioactivities was at least partly due to the rather poor characterisation and the resulting batch-to-batch differences in what we now call 'first generation' chitosans.

We therefore explored in molecular or nano-scale detail structure/function relationships of partially acetylated chitosans. We analysed the influence of the degree of polymerisation (DP) and acetylation (DA) of chitosans on their antimicrobial and plant strengthening activities. We showed that chitosans with low DA and intermediate DP exhibited the highest antimicrobial activities, independent of the bacteria or fungi studied, while chitosans with intermediate DA and high DP were best for plant strengthening, but the optimal chitosan differed between plant species and disease.

When previously, 40 kg of raw chitosan was required per hectare to achieve reliable crop protection – a value too high to be manageable and too costly to be affordable to farmers – we reduced this amount to 160 g/ha and achieved reliable efficacies of ca 50% with this low dosage of specifically optimised chitosans. We have since further optimised the performance of these 'second generation' chitosans and have developed two chitosan-based plant strengtheners now successfully applied in India. A simple seed treatment with the appropriate, very low amount (4-40 g/ha) of one selected chitosan prior to sowing, followed by two-weekly foliar sprays with a different chitosan will protect the crop for a full growth cycle from severe disease, and will reliably increase the yield by typically 25% even in the absence of pathogens. The recent classification of chitosan as a 'basic substance' by the EC will hopefully allow us to introduce these consumer-safe and environment-friendly products on the European market, too.

We currently aim to increase the efficacy of our chitosan-based bio-stimulators using different approaches. Firstly, we are developing biotechnological production ways for 'third generation' bio-engineered chitosans with controlled, non-random patterns of acetylation (PA) using recombinant chitin and chitosan synthesising and modifying enzymes in a cell factory approach. Secondly, we combine copper-loaded chitosan nano- or microparticles with bio-control agents, concomitantly reducing the copper load required for efficient plant disease protection. The results achieved so far nourish our confidence that this approach will finally yield a solution to maintain copper as a fungicide suitable for organic crop production even in the face of changing European legislation which, in the near future, will further limit the copper load accepted in plant protection. In anticipation of a need to establish pilot and then industry scale production processes for such nano- or micro-formulated chitosans, we have developed an interest in electro-spraying and electro-spinning technologies.

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