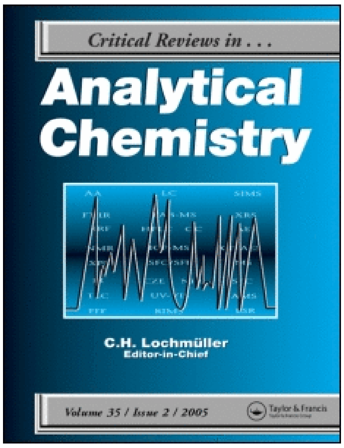

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Reducing the Toxicity of Pesticides

Bojana Boh and Aleksandra Kornhauser

University of Ljubljana, Faculty of Natural Sciences and Engineering, International Centre for Chemical Studies (ICCS), Vegova 4, P.O.B. 18/1, 1001 Ljubljana, Slovenia

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The project teams consisted of the following researchers: (1) *Microencapsulated animal repellents:* University of Ljubljana—ICCS: B. Boh, A. Kornhauser, D. Dolnicar, D. Hodžar, D. Kardoš, T. Požek Novak, N. Zupančič Brouwer, K. Voda; University of Nairobi: J.O. Midiwo; Agricultural Institute of Slovenia: V. Škerlavaj, G. Urek; Institute for Hop Research and Brewing: I. Košir, M. Kovačevič; Aero Chemical, Graphic and Paper Industry: E. Knez, M. Kukovič, V. Pipal; Agroruše: A. Škvarc; (2) *Non-toxic pesticide*: University of Ljubljana—ICCS: A. Kornhauser, B. Boh, A. Krumpak, A. Musar; Agricultural Institute of Slovenia: V. Škerlavaj; Helios Chemical Company: J. Perkavac, C. Colnar, Krka Pharmaceutical Industries: M. Pokorny, F. Novosel; Rast Horticulture: B. Kaiser.

INTRODUCTION

Environmental pollution with toxic substances is one of the major drawbacks of the extensive use of agrochemicals in modern agricultural practices, resulting in contamination of agricultural products, soil, surface and ground waters, and in endangered biodiversity. Several countries have already introduced serious measures for environmental protection, such as 1) stricter legislation; pesticides and other toxic agrochemicals are included in most of the legislative documents on environmental protection, 2) restrictions in the use of highly toxic and slowly degradable chemical pesticides, and 3) incentives for the development of environmentally safer methods and technologies for combating pests, weeds, and plant diseases.

The development of new pesticides is aimed towards achieving 1) a higher effectiveness on target pests, resulting in a smaller quantity of the pesticide needed, 2) an improved selectivity to target pests and reduced toxicity to non-target organisms, 3) a higher biodegradability, contributing to less environmental pollution and shorter preharvest periods, 4) controlled-release formulations for targeted and sustained release of active components, and 5) derivatives of natural products (Boh, 1996).

To support university-industry-agriculture, cooperation in research, and development for sustainable development, the University of Ljubljana-ICCS has developed an information-based research strategy for the recognition of opportunities for research and development, e.g., in efforts to achieve pollution minimization through the introduction of non-toxic starch-based pesticides with physical action, and through controlled release formulations and technologies, such as microencapsulation.

CASE STUDY 1: CONTROLLED-RELEASE MICROENCAPSULATED ANIMAL REPELLENTS FOR AGRICULTURAL USE

Microencapsulation, a technology of coating small nuclei with protective spherical membranes, is characterized by a strong basic research, leading to rapid development of applications and constant improvements of industrial technologies. This is accompanied by a rapid growth of publications, the especially patents (Figures 1–2). To be able to cope with large amounts of publications, the University of Ljubljana-ICCS built a specialized in-house information system on microencapsulation, containing

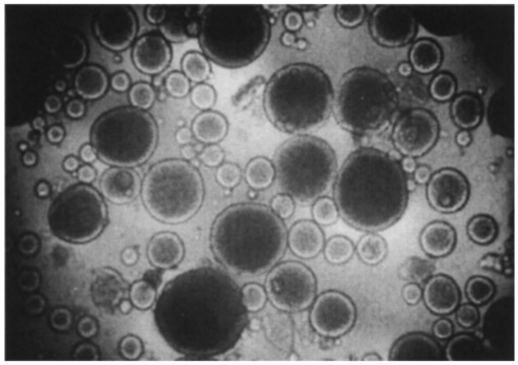


FIGURE 1. Dispersion of microcapsules produced by interfacial polymerization (100×, photographic enlargement 10×).

more than nine thousand records with scientific and technical information on microencapsulation technology and its wide range of applications. The system integrates a bibliographic database with specialized factual modules, including a module on agricultural formulations based on microencapsulated ingredients, and has been used in several projects for in-depth information searches, as well as for the identification of technological trends and free market niches.

In the University of Ljubljana-ICCS, cooperation with local industries and agricultural research institutes, a microencapsulated animal repellent for agriculture and forestry has been developed. Microencapsulation of agrochemicals results in locally limited activity, controlled release of active ingredients, and smaller quantities of agrochemicals needed for the same effect. Therefore, resulting in smaller environmental pollution.

In the first project phase, a smell-based animal repellent Daphne (a mixture of essential oils and synthetic volatile compounds) was microencapsulated by *in situ* polymerization method to reduce the volatility and prolong the activity of the active compound (Boh, 1999a). Three types of formulations were prepared: 1) aqueous suspension concentrates to be diluted for spraying, 2) thickened pastes with microcapsules for coating tree bark, and 3) textile, paper, and metal strips, coated or impregnated with microcapsules. In field testing (Figure 3) on roe deer (*Capreolus capreolus*) and rabbits (*Lepus europaeus*), all formulations with microcapsules showed a prolonged effect, in comparison with a non-encapsulated repellent Daphne (Boh et al., 1999b).

In the second project phase, a taste-based natural repellent from *Psiadia punctulata* leaf exudate (a plant species from Eastern Africa, known to be avoided by browsing herbivores) was microencapsulated and tested alone or in combination with Daphne. The results of testing showed that the microencapsulated repellent formulations were more effective than non-encapsulated standard in all trials. Microencapsulated *Psiadia punctulata* exudate exhibited better activity and efficacy than the commercial repellent mixture Daphne. The research in this field is still in progress.

CASE STUDY 2: DEVELOPMENT OF A COMPLETELY NON-TOXIC PESTICIDE WITH PHYSICAL ACTION, BASED ON MODIFIED STARCH

University of Ljubljana-ICCS, local industries and agricultural research institutes have developed

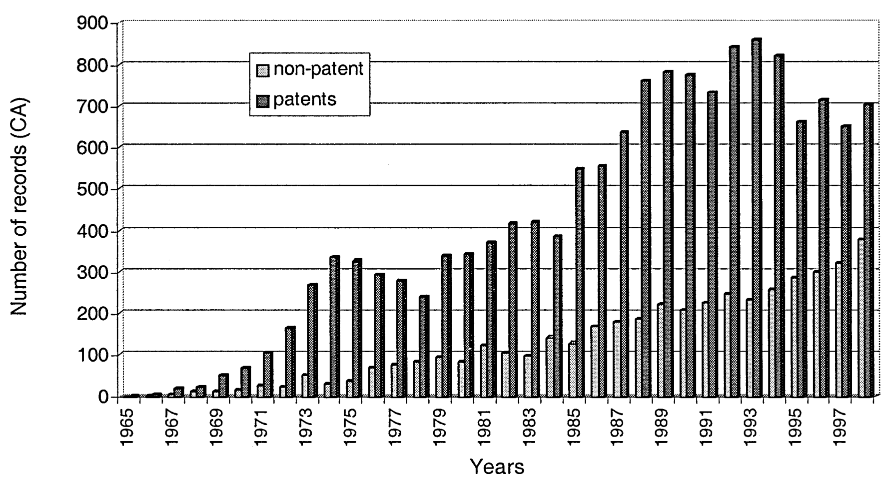


FIGURE 2. The ratio and trends in patent *vs.* non-patent literature on microencapsulation technology and its applications (Chemical Abstracts database).

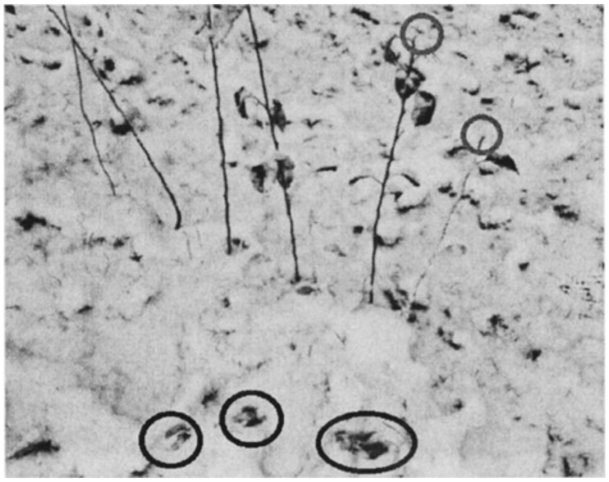
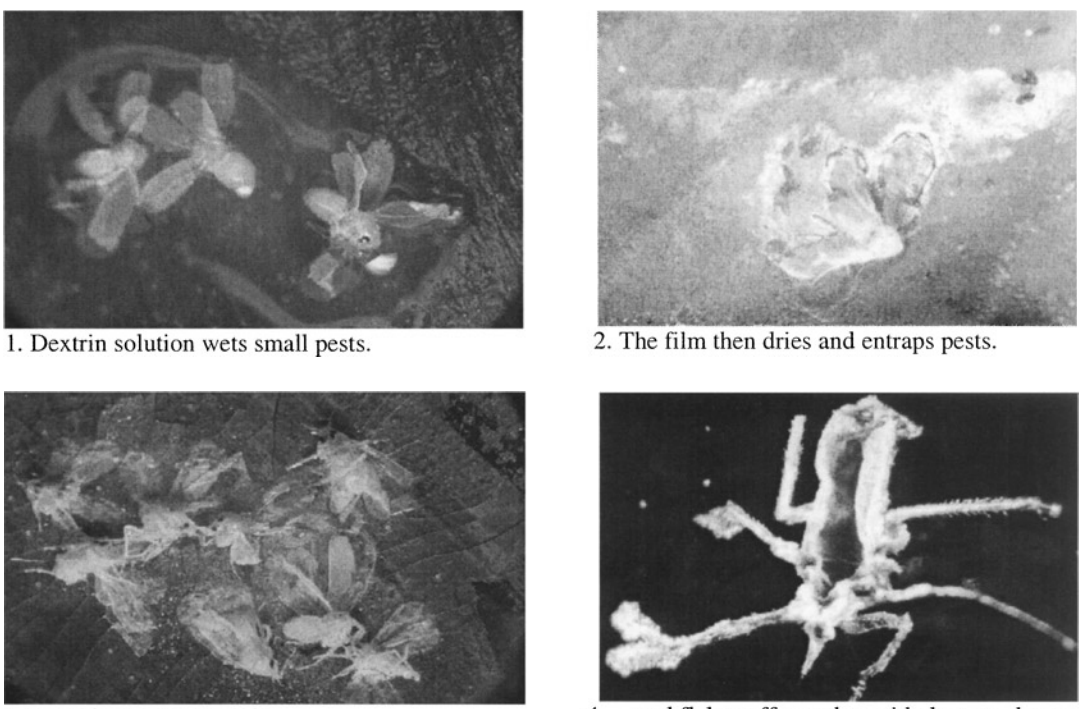


FIGURE 3. Testing of microencapsulated deer repellents was performed with baits (apple branches sprayed with microencapsulated repellents). The damage was evaluated as the number of damaged branches per bait and as the extent of damage. The presence of deer was evident from the footprints in snow.

a completely non-toxic pesticide with physical action (Boh and Škerlavaj, 1996; Boh and Kornhauser, 2000). The active component is a water-soluble specially modified starch. After the plant has been sprayed, a thin film is formed on its surface that entraps, immobilizes and destroys small insects and spider mites (Figure 4). There is no effect on large insects or either harmful pests or predators. The dry film flakes off, and the film remains can be washed off from the plant or fruits by rain or washing with water. The physical action prevents the development of insect resistance.

The biological effectiveness of the new pesticide was tested and proven on several different pests



1. Dextrin solution wets small pests.
2. The film then dries and entraps pests.
3. Dry film starts to crack ...
4. ... and flakes off together with destroyed pests

FIGURE 4. Physical activity of a potato starch dextrin pesticide.

in the laboratory, in green houses, and in open area plantations, especially orchards and vineyards. The preparations have shown the best effects on mites (e.g., *Tetranychus urticae, Panonychus ulmi, Aculus schlecthendalii, Eriophyes vitis, Calipitrimerus vitis*), thrips (*Thrips sp*.), greenhouse whitefly (*Trialeurodes vaporariorum*), and aphids (*Aphidiae*). Tests have also shown a significant decrease of infections with mealy bugs (*Pseudococcus sp*.), scale insects (*Coccus hesperidum, Quadraspidiotus perniciosus*), the apple codling moth (*Cydia pommonella*), and grape berry moths (*Lobesia botrana, Eupoecillia ambiguella*). The protective coating has an additional effect in decreasing infections with fungi, e.g., powdery mildew—oidiomycosis (*Uncinula necator*), downy grape mildew (*Plasmopara viticola*), and gray mould (*Botrytis cinerea*). Testing in vineyards has shown no negative effects, either on the grape yield or on the process of vinification. Repeated applications of the pesticide on tomato and cucumber plants did not result in any phytotoxic or other negative effects on plants. The photosynthetic activity measurements showed no essential differences in evapo-transpiration and photosynthesis between potato plants sprayed with the dextrin pesticide and the control non-sprayed group of plants.

The product has shown the best results in dry and warm climatic conditions, when the rapid drying of the film, optimal pesticidal effectivity, and increased peeling of the film can be achieved. Being completely non-toxic, the pesticide is most suitable for use indoors, in water-protected areas, on ripening fruits and vegetables, and for all kinds of organic farming. However, due to its higher production cost in comparison to chemical pesticides, the product was not introduced to the market yet. With stricter environmental legislation and with an increasing demand for organic farming products, it is expected that environmentally friendly pesticides of a higher price range will finally find their place on the market.

CONCLUSIONS

In the introduction of environmentally safe technologies and products, priority should be given to such innovations that do not require large capital investments, but are knowledge intensive and environmentally effective. The microencapsulation of agrochemicals to achieve controlled release and the development of a non-toxic pesticide, based on modified starch, can be taken as examples of such approaches.

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