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Multi-layered Microcapsules of Biopesticides to Support Sustainable Agriculture

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SUMMARY

The use of biopesticides is one way to overcome plant pests that are environmentally friendly and in line with the concept of sustainable agriculture. The disadvantages of vegetable pesticides are that vegetable materials decompose quickly and their working power is relatively slow so the application must be more frequent, less practical and not hold up for a long time. Furthermore smart method is needed to extend the shelf life and release process of plant materials slowly and in a controlled manner. One of the methods that can be applied is multi-layer microcapsules asembly by layer-by-layer adsorption method. The microcapsules made by this method can produce multilayer microcapsules which can be adjusted in size, thickness, permeability, stability, responsibility and encapsulated material. This method forms self-assembly based on physical-chemical phenomena that occur naturally, namely the arrangement of alternately positive and negative charged shell of microcapsule.

Introduction

Agriculture has had to face the destructive activities of numer ous pests like fungi, weeds and insects which have serious effect on feed production as global crop yield is reduced by 20 to 40% annually due to plant pest and diseases [1]. With the advent of chemical pesticides, this crisis was resolved to a great extent. But the over dependence on chemical pesticides and eventual uninhibited use of them has necessitated for alternatives mainly for environmental concerns. Though biopesticides cover about 1% of the total plant protection products globally, their number and the growth rate have been showing an increasing trend in the past two decades [2]; about 175 biopesticides active ingredients and 700 products have been registered worldwide.

Biopesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria and certain minerals. In commercial terms, biopesticides include microorganisms that control pests (microbial pesticides), naturally-occurring substances that control pests (biochemical pesticides), and pesticidal substances produced by plants containing added genetic material (plant-incorporated protectants). Biopesticides are employed in agricultural use for the purposes of insect control, disease control, weed control, nematode control and plant physiology and productivity. The EPA separates biopesticides into three major classes based on the type of active ingredient used, namely, biochemical, plant-incorporated protectants and microbial pesticides. Within each of these, there are various types of products, each with its own mode of action [3]. Pest management products from plants are also an important segment of the biopesticide market, including such products as pyrethrum and neem for insect control and many essential oil formulations for a range of pest management options [4].

Biopesticides have a range of attractive properties that make them good components of integrated pest management. Most are selective, produce little or no toxic residue, and development costs are significantly lower than those of conventional synthetic chemical pesticides [5]. The demand for biopesticides is rising steadily in all parts of the world. When used in Integrated Pest Management systems, biopesticides' efficacy can be equal to or better than conventional products, especially for crops like fruits, vegetables, nuts and flowers. By combining performance and safety, biopesticides perform efficaciously while providing the flexibility of minimum application restrictions, superior residue and resistance management potential, and human and environmental safety benefits. It is very likely that in future their role will be more significant in agriculture and forestry. Biopesticides clearly have a potential role to play in development of future integrated pest management strategies Hopefully, more rational approach will be gradually adopted towards biopesticides in the near future and short-term profits from chemical pesticides will not determine the fate of biopesticides [6].

The potential benefits to agriculture and public health programmes through the use of biopesticides are considerable. The interest in biopesticides is based on the advantages associated with such products which are inherently less harmful and less environmental load; designed to affect only one specific pest or, in somecases, a few target organisms; often effective in very small quantities and often decompose quickly, thereby resulting in lower exposures and largely avoiding the pollution problems and when used as a component of Integrated Pest Management (IPM) programs, biopesticides can contribute greatly [6]. The disadvantages of biopesticides are that plant materials decompose quickly and their working relatively slow; power is therefore the application of biopesticides must be more frequent, less practical and not hold up for a long time. Furthermore smart method is needed to extend the shelf life and release process of plant materials slowly and in a controlled manner. One of the methods that can be applied is multi-layer microcapsules asembly by layer-by-layer adsorption method.

Method of Multi-layered Microencapsulation

Microencapsulation is a process in which tiny particles or droplets are coated by certain material to give small capsules with many unique properties. Sobel et al. [7] define microencapsulation as the process of enclosing small particles, liquid, or gas within a layer of coating, or within a matrix for protection and/or slow/controlled release. There are various compounds that can be enclosed in the microcapsules, e.g., pigments, monomers, catalysts, drugs, antioxidants, polyphenols, amino acids, carotene, phytosterols, nanoparticles and oil soluble components [8] or other materials on a micro or nano metric scale. Any materials enclosed inside the microcapsule is referred to as the core, internal phase, or fill, whereas the wall is sometimes called a shell, coating, or membrane (Figure 1). Ghosh [9] indicated that compatibility of the enclosed materials with the shell are one of the determining factors for improving the microcapsule's performance; pre-treatment of the enclose materials might needed to achieve certain compatibility. There are two types of microcapsules, mono-layered and multi-layered microcapsules. The advantages of designing multi-layered microcapsules are control over the thickness of shell and therefore the release can be controlled. The microcapsules can carry different active

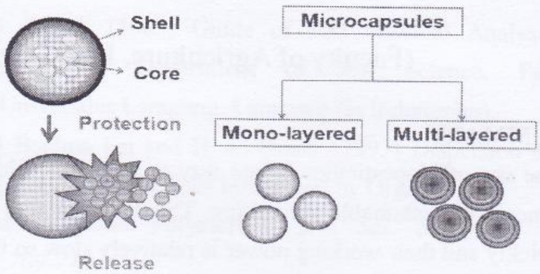

Fig.1 Two types of microcapsules

materials either in between the layers or in the core.

The essence in manufacturing microcapsules as controlled release devices is that the capsules must be able to protect and then release their contents in respone to spesific triggers at a controlled rate. The spesific property is influenced by mechanical, physical, and chemical exposures as well as their release properties are essential factors for microcapsules.

In addition, size monodispersity and core design are important to determine the microcapsules' behaviour at spesific release rate and sensory perception of capsules by consumers [10]. One of method to produce microcapsules with the mentioned properties is layer by layer (LbL) adsorption technique. This methods makes use of self-assembly at interface in which –physical-chemical phenomena by nature is utilized (Rossier-Miranda 2010). Oil droplets act as templates for the microcapsules and as reservoirs for the active material that will be carried out [10]. The schematic route to produce microcapsules by LbL adsorbtion technique is depicted in Figure 2.

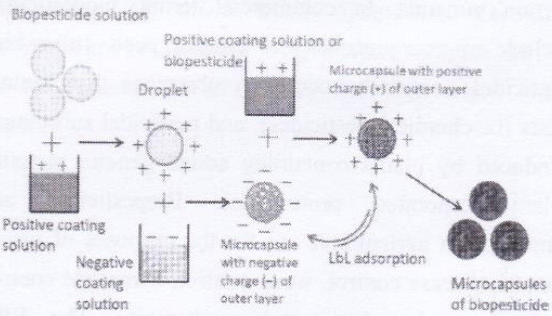

Fig. 2 Schematic route of LbL adsorpsion method (Adapted from Rossier-Miranda [10], Purwanti [11] and Warji et al. [12])

Microcapsules of Pesticides

Layer-by-layer adsorption method is one of the methods used to prepare multi-layered microcapsules. This method allows fine tuning the desired size of microcapsules by designing appropriate number of layers. In addition, different functional compounds can be stored among and within the layers which makes slow release possible, such as a biopesticide released in first day, second day, and thirth day. Therefore, the development of multi-layered microcapsules pesticides have a prospective, especially in sustainable agriculture. There are two way make slow release biopesticide microcapsule; the various layer of microcapsules (Figure 3A) and multi-layered microcapsule (Figure 3B).

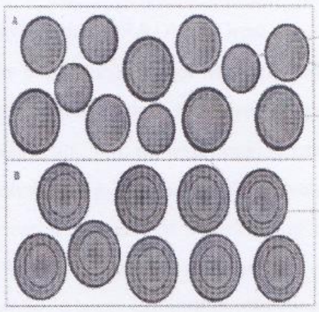

Fig. 3 Two types of slow release biopestiside. (A) The various layer of microcapsules and (B) Multi-layered microcapsules

Figure 3A shows that biopesticide microcapsules are designed to have various layers; for example biopesticide microcapsules one layer (mono layer), two layers and three layers are mixed together. The three different layers are applied to the same agricultural crop; It is expected that one layer of biopesticide is released on the first day, two layers break on the second day and three layers break on the third day so that so that the applied biopesticide lasts for 3 days. The release of the third different layer microcapsules is shown in Figure 4A. Furthermore Figure 3B shows a 5-layer multi-layered microcapsules of biopesticide. These biopesticides are designed to be in the core of the microcapsules, and placed between the shells of the microcapsules (in the second and fourth layers). Figure 4B illustrates the release of multi-layer microcapsules of biopesticide; the first day of biopesticide in the second layer of release after the first layer microcapsule shell broke, the second day of pesticide in the fourth layer of release after the third layer microcapsule shell broke, and on the third day biopesticide in the microcapsule nucleus release after the fifth layer microcapsule shell broke.

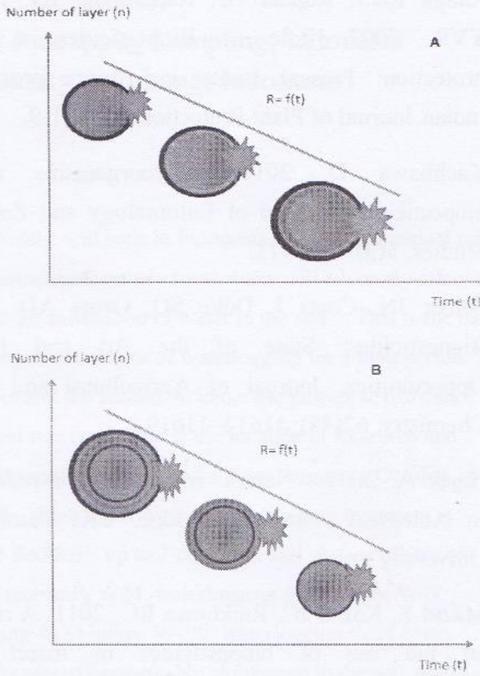

Fig. 4 Release of biopesticide microcapsules

The time-based release process of biopesticides greatly helps the process of applying biopesticides to plants. Once a biopesticide application can be regulated release for several days. Triger against biopesticide releases can be combined with other trigers, such as pressure, sun exposure and the presence of certain chemicals. Furthermore, the breakdown of biopesticide microcapsules can also be setup based on the presence of insect or fungal activity in cultivated plants. Based on the application of multilayer biopesticide microcapsules, it is expected that the use of biopesticides can be more developed. The use of biopesticides is expected to reduce chemical pesticides and create an environment that is environmentally friendly and sustainable agriculture.

Conclusion

Multilayer microcapsules made by layer-by-layer have the potential to be applied to biopesticides. Multilayer biopesticide microcapsules are expected to increase the life of biopesticide applications. Increasing the age of biopesticide applications is expected to increase the use of biopesticides in agriculture so that they can support sustainable agriculture.

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