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Biopesticides and their Encapsulation Techniques: Current Updates and Future Prospective

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ABSTRACT: Exploitation of chemical fertilizers and synthetic pesticides are serious problems for today's agriculture. Use of these chemical substances destabilize the natural soil microbial content and kills natural enemies of the targeted pest. Moreover, their contributions towards environmental pollutions are also significant. On the contrary, as an alternative source, the usage of biopesticides for pest control is emerging as a promising strategy for pest management in agriculture. However, the traditional use methods of biopesticides may result in the sub-optimal outputs. To provide solutions, the encapsulation of biopesticides is done that effectively improve the biopesticide performance and decreases the environmental contamination concerns. In this review, we have provided a brief idea about the current status and the future prospects of biopesticide usages and the different encapsulation methods employed to improve the biopesticide efficacy.

Keywords: Biopesticides, active ingredient, encapsulation, environmental pollution.

I. INTRODUCTION

Pesticides originating through natural elements including microbes, plants, animals, and minerals are known as biopesticides. Biopesticides play very important character in sustainable agriculture, however they are usually used in conjunction with some other pest's management activities, such as synthetic chemicals, as element of integrated pest management using a bio-intensive approach. These are biological pesticides based on microbial pathogens that are unique to a particular pest and provide environmentally friendly and efficient pest management. These are less harmful to the ecosystem and people's health because they are biodegradable and leave no residues. Microbes that possess a negative impact on the pest of concern are typically utilised as microbial pesticides. Biofungicides (*Trichoderma* sp.) bioherbicides (*Phytophthora* sp.) and bioinsecticides (*Bacillus sphaericus*, *B. thuringiensis*) are among them. The advantages of using biopesticides in farming are significant [1-4].

Antimicrobial and antioxidant activity of extract from *Ipomoea carnea* a wild plant also reported [5]. Leaf powder from certain plants also found effective against pulse beetle during laboratory experiment [6]. Several organic amendments have been reported to have a considerable impact on late blight occurrence and intensity in potato and tomato plants [7].

Biopesticides have sparked a lot of attention throughout the scientific society and they've been suggested as possible replacement for chemical pesticides. Although here are concerns about performance and research of product, particularly in terms of nanomaterials, is a booming field in which biopesticide formulations were being improved. As a result, they've gotten a lot of attention in the last ten years [8]. Biopesticides provide a coordinated plant protection approach, and upcoming formulation products must have a better balance of development inputs and effectiveness. Although it shall be simple to supply sole organism-based to consortium-based products, particularly suitable to insecticidal and microbiological types of biopesticides. Newer unique insecticidal and microbiological formulations with improved performance, including nanoemulsions, nanocapsule and nanosuspensions, have also been discovered for commercial development as technological advances [9].

II. BIOPESTICIDES IN AGRICULTURE

Pests attack crop plants on a regular basis, affecting its development and subsequent condition. Growers typically depend on rapid pest management strategies, primarily synthetic pesticides, to safeguard their crops against pest damage [10]. While chemical pesticides' efficacy, long-term use poses problems, such as the emergence of pesticide-resistant pests [11]. Chemical pesticides can have detrimental implications on individuals and society, as well as toxic effects to non-target creatures, which has an adverse effect on ecosystems [12]. Several risks connected mostly with mishandling and excess use of chemical pesticides had prompted the development of alternate solution for pest management [13].

Because biopesticides have no toxic effect in the managing of plant pathogens, these are as secure and efficient solutions for both the applicator and the user [14, 15]. These are environmentally safe, easily biodegradable, target specialised and do not develop resistance among pests [16-18]. Whereas biopesticides offer benefits such as a secure ecosystem and good produce for public intake, there are still some barriers that obstruct its use as pest and disease management tools. At field conditions higher dosages of such component substances are required for better activity [17]. The habitat wherein crops develop represents the frequency of bioactive component in biopesticides [19]. The range of crops and its cultivars also affect the component active ingredients resulting in variations of disease reactions [20]. The process of production utilised has an impact on the efficacy of plant extracts [21]. It might be difficult to achieve the proper quantities of functional and inert components throughout the formulation process. In addition, there are still no standardized processing techniques or recommendations besides efficiency evaluation, especially in the field conditions [22]. Whereas most in vitro studies give great outcomes, variations are usually present in the field condition due to low storage period or occasionally bad quality of sources or processes of production.

III. ENCAPSULATION TECHNIQUES FOR BIOPESTICIDE PRODUCTION

Encapsulation refers to a process, where an active ingredient, such as chemicals, drugs, and even tissues is caged inside an encapsulating or gelling agent to form a stable complex [23]. Encapsulation is a widely-used technique in pharmaceuticals and food industries [24, 25]. In agriculture, development and use of biopesticides often encounter with problems, like human exposure related issues, chemical residual issues, and environmental contamination issues. However, encapsulation of the developed biopesticides can help in minimizing all these issue in practice [26]. The method of encapsulation can vary depending on the active ingredient of the biopesticide. In addition, the encapsulating chemical can also be of many choices, ranging from solids to liquids, at times even gases. Similarly, shape of the encapsulation can be different, including spherical, bead-structural, capsules, and multi-core/shell [27]. Thus, to finalize an encapsulation method, various factors, such as biopesticide particle size, physical and chemical nature, biocompatibility, release mechanism, and encapsulating material play vital roles [23].

A number of encapsulation techniques are there which are employed in the agricultural sector on the basis of their physical or chemical natures. For instance, some of the most widely used physical encapsulation processes are gelation, fluidize coating, and spray drying [28]. Similarly, some of the popular chemical processes include polymerization, melt-dispersion, and coacervation [29, 30]. At many occasions, the choice of encapsulation technique can actually alter the efficacy of the biopesticide. For example, the antimicrobial activity essential oils from oregano and thyme were amplified by the use of encapsulated carvacrol [31]. Likewise, the toxic effects of carvacrol on the non-target organisms were evaluated [32].

Encapsulations also helped in overcoming other short-comings of the crude biopesticides. For instance, water solubility of carvacrol was improved by encapsulation. Apart from that, key improvements have been made to enhance the efficacy and stability of the biopesticides by encapsulation and addition of surfactants [33]. For instance, encapsulation of D-limonene, which is the active compound in citrus fruit oils, via emulsion polymerization enhanced its activity. D-limonene acts as a potent fungicide by possibly causing fungal cytoplasmic disintegration. Without encapsulation the activity of D-limonene is lost rapidly due to volatilization and oxidative degradation [33].

Biopesticide encapsulations can improve their efficacy in the environment. For instance, use of encapsulated plant oils from tea, pomegranate, and grape reduced the feeding of rice weevil [34]. In addition, the encapsulation improved the stability and water solubility of the plant oils. Another technique of biopesticide encapsulation, in-situ polymerization, provided improved efficacy of neem oil by mixing phenol aldehyde microparticles with it [35]. Similarly, the coacervation-mediated encapsulation of the insecticidal fungus *Metarhizium anisopliae* showed significant improvements against fire ants [36]. Recently, use of fluid-bed coating technique successfully produced entrapped biopesticides from the fungal spores of *Beauveria bassiana*, *Cordyceps fumosorosea* and *M. brunneum*, which were employed in integrated pest management [37].

In a separate study, nematodes were entrapped in alginate beads that protected the maize plants from *Diabrotica balteata* [38]. Algination of the biopesticides increased their chances of bioactivity and survival and ensured a longer shelf life. Encapsulation of biopesticide provide numerous advantages over the traditional *Diabrotica balteata* use of biopesticides, including improvement of biopesticide activity, enhanced stability and bioavailability, lower toxicity, and environmentally friendly [39].

IV. CONCLUSION AND FUTURE PROSPECTIVE

Presently, the use of biopesticides is gaining recognition and farmers are showing interests to adopt it as an alternative to the chemical pesticides. As the biopesticides cost a fraction of the cost of the chemical pesticides, use of the biopesticides seems to be a pocket-friendly option. Their advantages and less toxicity natures are gaining the biopesticides a good marketplace in India. On the other hand, various encapsulation techniques are improving the biopesticide stability, bioavailability, and release mechanism. These collectively reflect on the success of various encapsulated biopesticide formulations. Having said that, advances in the encapsulation techniques are essential to achieve even more stability and effectiveness of the biopesticides. For example, the supercritical fluid technology, such as use of CO_2 is gaining popularity as a promising encapsulation method. This not only decreases the production cost, but also reduces the effects of other chemical solvents used for encapsulation. Moreover, further researches must be conducted to study the new encapsulation techniques, their effects on the biopesticide activity, and the compatibility in between these two.

REFERENCES

[1]. Gupta, S., & Dikshit, A.K. (2010). Biopesticides: An ecofriendly approach for pest control. *Journal of Biopesticides*, **3**(1), 186–188.

[2]. Kumar G., & Kumar A. (2018). Biopesticides: Environment-friendly Approach Toward Plant Disease Management. *Int. J. Res. Anal. Rev.,* **5**(4), 245-253.

[3]. Kumar, G., Maharshi, A., Patel, J., Mukherjee, A., Singh, H.B., & Sarma, B.K. (2017). Trichoderma: a potential fungal antagonist to control plant diseases. *SATSA Mukhapatra-Annual Technical Issue*, **21**, 206-218.

[4]. Srivastava, M.P. (2017). A Novel Strain for the Managements of Plant Diseases: *Trichoderma* Spp. *International Journal of Theoretical & Applied Sciences,* **9**(2), 1-10.

[5]. Srivastava, D., & Shukla, K. (2015). Pharmaceutical efficacy of *Ipomoea carnea*. *Biological Forum – An International Journal,* **7**(1), 225-235.

[6]. Yankanchi, S.R., & Lendi G.S. (2009). Bioefficacy of certain plant leaf powders against pulse beetle, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae). *Biological Forum – An International Journal*, **1**(2), 48-51.

[7]. Islam, M.R., Mondal, C., Hossain, I., & Meah M.B. (2013). Organic Management: An Alternative to Control Late Blight of Potato and Tomato Caused by *Phytophthora infestans*. *International Journal of Theoretical & Applied Sciences,* **5**(2), 32-42.

[8]. Nuruzzaman, M., Liu, Y., Rahman, M. M., Dharmarajan, R., Duan, L., Uddin, A.F.M.J., & Naidu, R. (2019). Nanobiopesticides: composition and preparation methods. In *Nano-biopesticides today and future perspectives* (pp. 69-131). Academic Press.

[9]. Mandal, B.K. (2019). Silver nanoparticles: Potential as insecticidal and microbial biopesticides. In *Nano-biopesticides today and future perspectives* (pp. 281-302). Academic Press.

[10]. Nkechi, E.F., Ejike, O. G., Ihuoma, N. J., Maria-goretti, O.C., Francis, U., Godwin, N., & Njokuocha, R. (2018). Effects of aqueous and oil leaf extracts of Pterocarpus santalinoides on the maize weevil, Sitophilus zeamais pest of stored maize grains. *African Journal of Agricultural Research*, **13**(13), 617-626.

[11]. Shabana, Y.M., Abdalla, M.E., Shahin, A.A., El-Sawy, M.M., Draz, I. S., & Youssif, A.W. (2017). Efficacy of plant extracts in controlling wheat leaf rust disease caused by Puccinia triticina. *Egyptian Journal of Basic and Applied Sciences*, **4**(1), 67-73.

[12]. Sande, D., Mullen, J., Wetzstein, M., & Houston, J. (2011). Environmental impacts from pesticide use: a case study of soil fumigation in Florida tomato production. *International journal of environmental research and public health*, **8**(12), 4649-4661.

[13]. Mahmood, I., Imadi, S.R., Shazadi, K., Gul, A., & Hakeem, K.R. (2016). Effects of pesticides on environment. In *Plant, soil and microbes* (pp. 253-269). Springer, Cham.

[14]. Rhoda, B., Fryer, B., & Macharia, J. (2006). Towards reducing synthetic pesticide imports in favour of locally available botanicals in. In *Kenya. Conference on International Agricultural Research for Development, Bonn, Germany,* 1-4.

[15]. Damalas, C.A., & Koutroubas, S.D. (2016). Farmers' exposure to pesticides: toxicity types and ways of prevention.

[16]. Leng, P., Zhang, Z., Pan, G., & Zhao, M. (2011). Applications and development trends in biopesticides. *African Journal of Biotechnology*, **10**(86), 19864-19873.

[17]. Shiberu, T., & Getu, E. (2016). Assessment of Selected Botanical Extracts against Liriomyza Species (*Diptera: Agromyzidae*) on Tomato under Glasshouse Condition. *International Journal of Fauna and Biological Studies,* **3**(1): 87-90

[18]. Ganate, M.A., & Khan, T.A. (2010). Biological Potential of *Paecilomyces lilacinus* on Pathogenesis of *Meloidodynejavanica* Infecting Tomato Plant. *Eur. J. Appl. Physiol.,* **2**: 80-84.

[19]. Ghorbani, R., Wilcockson, S., & Leifert, C. (2005). Alternative Treatments for Late Blight Control in Organic Potato: Antagonistic Micro-Organisms and Compost Extracts for Activity against *Phytophthora infestans*. *Potato Res.,* **48**, 181-189.

[20]. Sales, M.D.C., Costa, H.B., Fernandes, P.M.B., Ventura, J.A., & Meira, D.D. (2016). Antifungal

Activity of Plant Extracts with Potential to Control Plant Pathogens in Pineapple. *Asian Pac. J. Trop Biomed*., **1**, 26-31.
[21]. Sesan, T.E., Enache, E., Iacomi, M., Oprea, M., Oancea, F., & Iacomi, C. (2015). Antifungal Activity of some Plant Extract against *Botrytis cinerea* Pers. in the Blackcurrant Crop (*Ribes nigrum* L). *Acta Sci. Pol. Technol. Aliment*., **1**, 29-43.
[22]. Okunlola, A.I., & Akinrinnola, O. (2014). Effectiveness of Botanical Formulations in Vegetable Production and Bio-Diversity Preservation in Ondo State. *Nigeria J. Hortic. For*., **1**, 6-13.
[23]. Silva, K.E., Angela, A., & Meireles, M. (2014). Encapsulation of food compounds using supercritical technologies: Applications of supercritical carbon dioxide as an antisolvent. *Food Public Health*, **4**, 247–258.
[24]. Couto, R., Alvarez, V., & Temelli, F. (2017). Encapsulation of Vitamin B2 in solid lipid nanoparticles using supercritical CO_2. *J. Supercrit Fluids*, 1**20**, 432–442.
[25]. McClements, D.J. (2018). Recent developments in encapsulation and release of functional food ingredients: Delivery by design. *Curr. Opin. Food Sci.,* **23**. 80–84.
[26]. Singh, A., Dhiman, N., Kar, A.K., Singh, D., Purohit, M.P., Ghosh, D., & Patnaik, S. (2020). Advances in controlled release pesticide formulations: Prospects to safer integrated pest management and sustainable agriculture. *J. Haz. Mat.,* **385**, 121525.
[27]. Sonawane, S.H., Bhanvase, B.A., Sivakumar, M., & Potdar, S.B. (2020). Current Overview of Encapsulation. In Encapsulation of Active Molecules and Their Delivery System; Elsevier: Amsterdam, The Netherlands.
[28]. Klettenhammer, S., Ferrentino, G., Morozova, K., & Scampicchio, M. (2020). Novel Technologies Based on Supercritical Fluids for the Encapsulation of Food Grade Bioactive Compounds. *Foods* (Basel, Switzerland), **9**(10), 1395.
[29]. Gharieh, A., Khoee, S., & Mahdavian, A.R. (2019). Emulsion and miniemulsion techniques in preparation of polymer nanoparticles with versatile characteristics. *Adv Colloid Interface Sci.,* **269,** 152–186.
[30]. Huang, B., Chen, F., Shen, Y., Qian, K., Wang, Y., Sun, C., Zhao, X., Cui, B., Gao, F., Zeng, Z., & Cui, H. (2018). Advances in Targeted Pesticides with Environmentally Responsive Controlled Release by Nanotechnology. Nanomaterials (Basel, Switzerland), **8**(2), 102.
[31]. Chang, Y., McLandsborough, L., & McClements, D.J. (2013). Physicochemical properties and antimicrobial efficacy of carvacrolnanoemulsions formed by spontaneous emulsification. *J. Agric. Food Chem.,* **61**(37), 8906–8913.
[32]. Campos, E., Proença, P., Oliveira, J.L., Pereira, A., de Morais Ribeiro, L.N., Fernandes, F.O., Gonçalves, K.C., Polanczyk, R.A., Pasquoto-Stigliani, T., Lima, R., Melville, C.C., Della Vechia, J.F., Andrade, D.J., & Fraceto, L.F. (2018). Carvacrol and linalool co-loaded in β-cyclodextrin-grafted chitosan nanoparticles as sustainable biopesticide aiming pest control. *Sci. Rep.,* **8**(1), 7623.
[33]. Feng, J., Wang, R., Chen, Z., Zhang, S., Yuan, S., Cao, H., Jafari, S.M., & Yang, W. (2020). Formulation optimization of D-limonene-loaded nanoemulsions as a natural and efficient biopesticide. Colloids Surf. *A Physicochem. Eng. Asp*., **596**, 124746.
[34]. Wahba, T.F. (2020). Antifeedant activity of three essential oils and their nanoemulsions against antifeedant activity of three essential oils and their nanoemulsions against the rice weevil *Sitophilus oryzae* (L.). *Egypt Sci J Pestic*., **2**, 19–31.
[35]. Bagle, A.V., Jadhav, R.S., Gite, V.V., Hundiwale, D.G., & Mahulikar, P.P. (2013). Controlled release study of phenol formaldehyde microcapsules containing neem oil as an insecticide. *Int. J. Polym. Mater Polym. Biomater* **62**, 421–425.
[36]. Qiu, H.L., Fox, E.G.P., Qin, C.S., Zhao, D.Y., Yang, H., & Xu, J.Z. (2019). Microcapsul edentomopathogenic fungus against fire ants, *Solenopsisinvicta*. *Biol. Control*, **134**,141–149.
[37]. Stephan, D., Bernhardt, T., Buranjadze, M., Seib, C., Schäfer, J., Maguire, N., & Pelz, J. (2021). Development of a fluid-bed coating process for soil-granule-based formulations of *Metarhizium brunneum*, *Cordyceps fumosorosea* or *Beauveria bassiana*. *J. Appl. Microbiol.,* **131**(1), 307–320.
[38]. Jaffuel, G., Sbaiti, I., & Turlings, T. (2019). Encapsulated Entomopathogenic Nematodes Can Protect Maize Plants from *Diabroticabalteata* Larvae. *Insects,* **11**(1), 27.
[39]. Rad, H.B., Sabet, J.K., & Varaminian, F. (2019). Study of solubility in supercritical fluids: Thermodynamic concepts and measurement methods - A review. *Braz. J. Chem. Eng*., **36**, 1367–1392.