Application of nanotechnology for mitigation of DON in wheat grains

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SUMMARY

A series of laboratory-scale experiments were conducted to determine the most promising nanomaterials and to optimize its operational requirements for appropriate application in mitigating mycotoxin contamination in feed grains and formulated swine diets. Three candidate nanomaterials were selected for testing based on a comprehensive literature review conducted previously: chitosan polymeric nanoparticles (CS), montmorillonite nanocomposites (MN), and magnetic graphene oxide (MGO). Based on the preliminary test results, MGO showed the greatest potential in mitigating the risk of DON contamination in wheat grains among the three nanomaterials. Additional experiments are underway to further investigate the efficacy of each nanomaterial in counter-acting DON contamination in wheat grains as affected by various influencing parameters, and to establish the optimum application conditions for the most promising nanomaterial.

INTRODUCTION

Mycotoxins are secondary toxic chemicals produced by organisms of fungal origin found in contaminated grains. Mycotoxin-contaminated grains when fed to livestock result in feed refusal, affect immune and health status, and may even cause death. Nanotechnology has been used to treat contaminants in air, soil and water media. Nanomaterials are also known to have antifungal properties; several studies have shown the effective use of nanomaterials in mitigating mycotoxin contamination due to their high surface area and high reactivity and also on the fact that nanomaterials can be modified to enhance their physical and chemical properties.

Based on a set of assessment criteria which include previous similar applications, cost effectiveness, safety, and availability, three nanomaterials were selected: chitosan (CS) polymeric nanoparticles, montmorillonite nanomaterials (MN), and magnetic graphene oxide (MGO) nanostructures. While the nano-adsorbent efficiency of CS, MN and MGO against the elimination of specific mycotoxins have been demonstrated, their effectiveness against the synergistic effects of multiple mycotoxins has not been studied well.

In general, research on the potential application of nanomaterials for mycotoxin elimination in grains and in livestock feed is very limited, thus, its operational requirements such as effective dosage, binding capacity, optimum treatment application conditions, among others, are still unknown. Hence, this proposed work has been conceptualized to fill these gaps by conducting a comprehensive evaluation of the application of nanotechnology for mitigating mycotoxin risk in grain and livestock industries.

EXPERIMENTAL PROCEDURES

Some Laboratory-scale experiments of selected nanomaterials, particularly chitosan polymeric nanoparticles (CS), montmorillonite nanocomposites (MN), and magnetic graphene oxide (MGO), were conducted at a chemistry laboratory of a collaborating partner institution with previous experience in this area (Xavier University in the Philippines). Grain and feed samples from Canada and other necessary materials for the experiment (e.g., Deoxynivalenol (DON) reference standards, mycotoxin rapid test kit (Vertu reader), test nanomaterials, among others) were shipped to the partner laboratory. Each nanomaterial was subjected to a series of adsorption tests involving different ground samples of raw grains (i.e., wheat, barley, corn) and formulated swine diet (i.e., mixture of different grains and other feed ingredients).

In Activity 1, the selected nanomaterials were tested at 5 different concentrations and varying operational conditions (pH, controlled temperatures, equilibrium times, and shaking speed) to establish their efficacy in reducing the levels of DON in wheat grain. The objective of the tests was to investigate the efficacy of each commercially-available nanomaterial (adsorbent) and to determine the most effective adsorbent that will be used in subsequent tests. Additional experiments were carried out to investigate the efficacy of the selected nanomaterials at higher DON levels by spiking the naturally contaminated wheat grain with 10 ppm DON.

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In Activity 2, the most effective nanomaterials identified in the previous tests were investigated to establish the optimum application rate and operating conditions (i.e., pH, equilibrium time and temperature) for mitigating the contamination of mycotoxins in raw grains (i.e., wheat, barley and corn) and formulated swine diet. The second set of tests aimed to establish the optimum operating conditions for the most effective nanomaterial. Using the most effective nanomaterial and the corresponding application rate, the mixture of the test nanomaterial and one spiked raw grain or formulated swine diet was subjected to varying pH values, controlled temperatures, equilibrium times, and shaking speeds.

RESULTS AND DISCUSSION

Laboratory-scale experiments on the efficacy of mycotoxin nano-mitigation strategies involving raw grains and formulated swine diet are still underway. Figure 1 shows the preliminary results of the adsorption efficiencies of CS, MGO and MN nanomaterials at different application rates on DON at pH 3.1 and 8.3. Among the three nanomaterials, MGO nanoparticles showed the greatest potential in reducing DON contamination in wheat grains. Adsorption efficiencies tended to increase as application rate increased but no considerable increase was observed beyond 200 mg MGO per 5 g of wheat application rate. At this rate, adsorption efficiency of MGO on DON was about 50%.

For CS nanoparticles, adsorption efficiencies were below 50% regardless of pH and application rate. The maximum adsorption efficiency was achieved at pH 3.1 for 2 mg CS per mL solution (37%). Similar to CS nanoparticles, the adsorption efficiencies of MN nanocomposites on DON were below 50% regardless of pH and application rate. However, higher adsorption efficiencies were observed for pH 3.1 than pH 8.3. The maximum adsorption efficiency was 48% and was achieved at pH 3.1 for 10 mg MN per mL solution. Overall, adsorption efficiencies of nanomaterials were significantly influenced by application rate and pH.

IMPLICATIONS

Based on the raw results from the completed trials, the application of MGO nanoparticles was the most promising strategy in counter-acting the impact of DON in contaminated wheat grains. Additional experiments are currently underway to collect more data on the performance of the three nanomaterials for mitigating the contamination of DON in wheat grains. In addition, the effect of pH, temperature and contact time on the adsorption performance of the most promising nanomaterials will be assessed further in subsequent tests. Furthermore, in-barn tests are planned to test the application of the selected nanoparticles at the best application rates under real-life barn settings.

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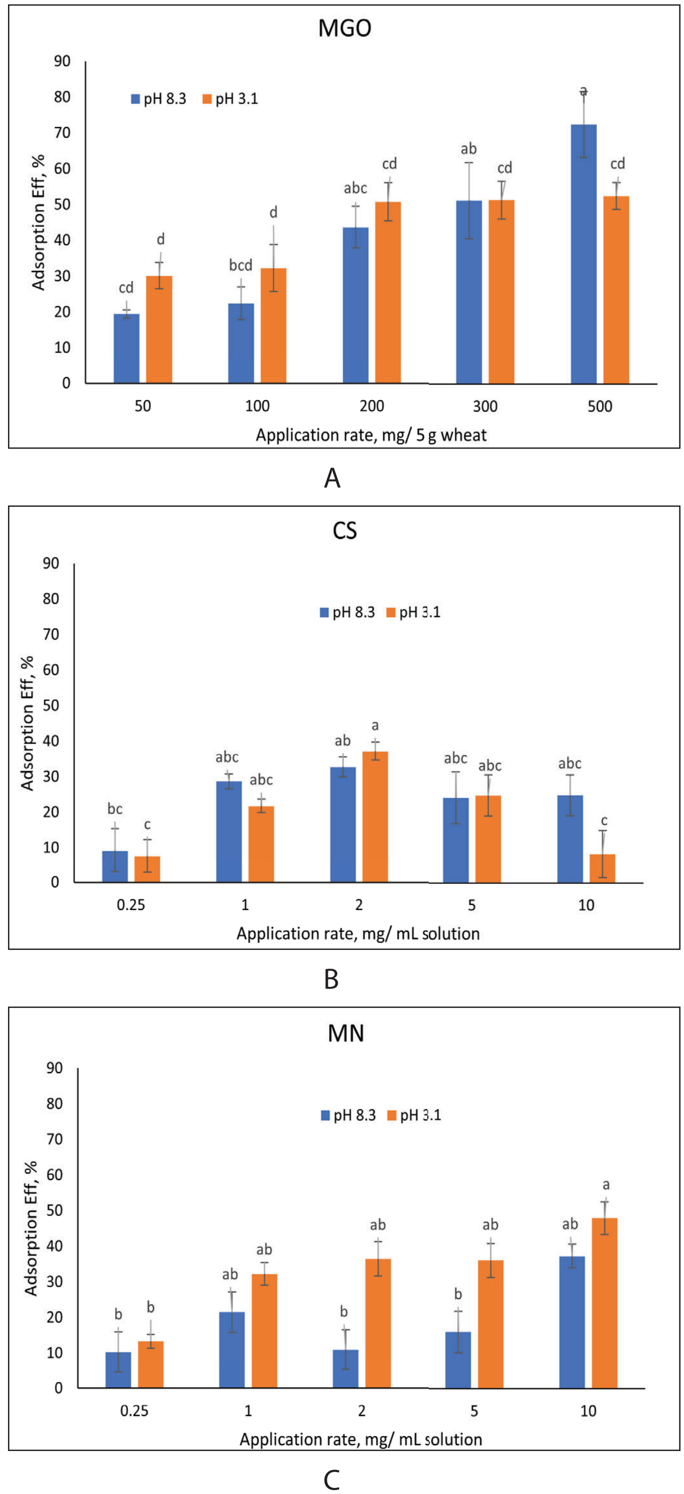

Figure 1. Adsorption efficiencies (%) of magnetic graphene oxide (A), chitosan (B) and montmorillonite (C) nanomaterials at different application rates on DON at pH 3.1 and 8.3.