Novel strategies to control mycotoxins

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Introduction

Mycotoxin contamination, specifically contamination with deoxynivalenol (DON), is a common issue in animal husbandry; in North America, up to 85% of grain samples and 90% of livestock feed samples are contaminated with DON. The CFIA has set a regulatory guidance limit of 1 part per million (ppm) of DON in swine diets, but current detoxification strategies are limited by binding efficiency, biosafety, and cost effectiveness.

Ingestion of contaminated feed can result in health issues and associated economic losses. DON can result in reduced feed intake, impaired growth performance, and if the concentration is high enough, it can interrupt intestinal barrier integrity, immune function, and the composition of the normal gut microbiome. The initial exposure to mycotoxins is of the greatest concern as it has the most pronounced effect. Over time, pigs will adapt to the presence of mycotoxins in feed, though they do not produce as well as they would if they were never exposed.

Our group has previously identified magnetic graphene (MGO) as a method of reducing DON contamination in feed, with MGO application reducing DON concentrations by up to 34% with no impact on animal health or growth performance. This study investigated the application of magnetic graphene oxide (MGO)-based nanocomposites for the photocatalytic degradation of DON in wheat grains. Photocatalysis is a type of chemical reaction that involves the absorption of light by one or more reactive species. It was hypothesized that the integration of photocatalytic degradation would accelerate reaction rates and enhance DON degradation efficiency.
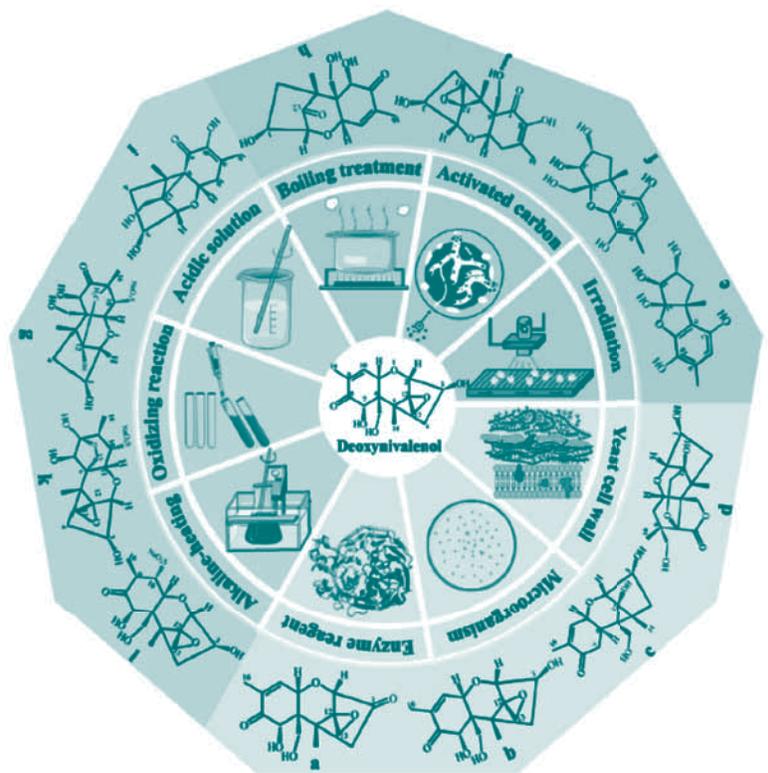

Figure 1. DON detoxification strategies. From Zhang et al., 2024. Deoxynivalenol: Occurrence, toxicity, and degradation. Food Control https://doi.org/10.1016/j.foodcont.2023.110027

Our Objectives

To assess and optimize the impact of magnetic graphene (MGO) nanocomposites on DON contamination, several objectives were formulated. First, we set out to synthesize MGO-based nanocomposites ourselves, then confirmed their ability to degrade the toxin. Second, we worked to characterize the surface morphology and composition of the synthesized
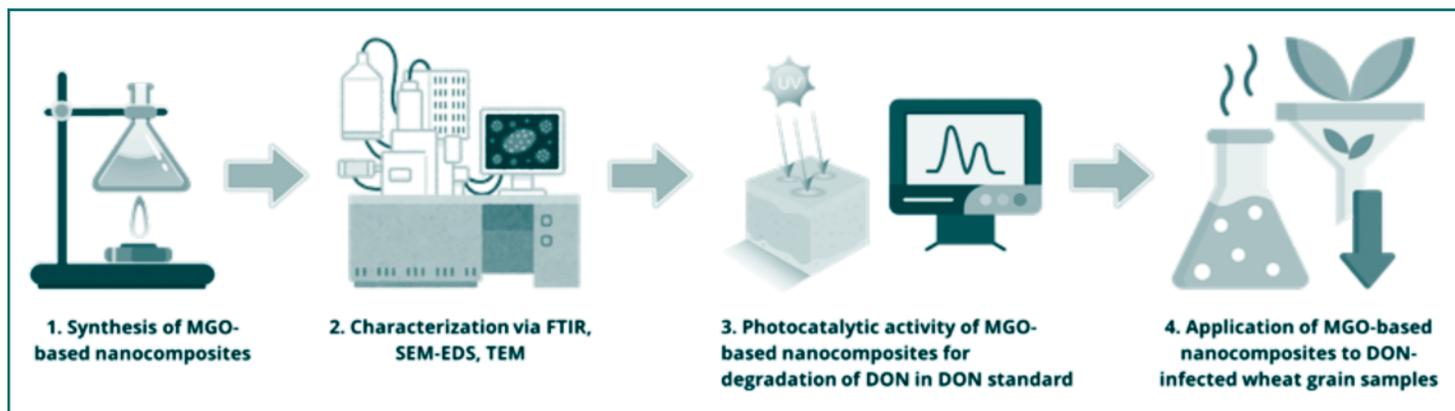
Figure 2. Workflow diagram to address project objectives.

nanocomposites using microscopy and spectroscopy techniques, furthering our understanding of the compounds. Our third objective was to evaluate the photocatalytic activity of the nanocomposites on standard and DON-contaminated samples in a controlled experiment, furthering our understanding of optimal exposure conditions. Fourth and finally, we are working to determine the resulting intermediate products of the degradation of DON and then assessing the impact of the photocatalytic reaction on wheat quality.

OR

To assess and optimize the impact of magnetic graphene (MGO) nanocomposites on DON contaminated grains, several objectives were developed;

1. Synthesize MGO-based nanocomposites for the degradation of DON

2. Characterize the surface morphology and composition of these nanocomposites using microscopy and spectroscopy

3. Evaluate the photocatalytic activity of the nanocomposites on standard and DON-contaminated feed samples

4. Determine the intermediate products of DON degradation and assess the impact of nanocomposite photocatalysis on wheat quality

What we did

Zinc oxide (ZnO) and titanium dioxide (TiO2) were selected as photocatalysts and integrated with MGO nanomaterials using a modified hydrothermal synthesis method. This may sound like a complicated procedure, but it actually utilizes a microwave to heat the solution! The liquid solution was then filtered and rinsed to collect the resulting residue, which was then dried in an oven to be used for further investigation.

Addressing our second objective, the resulting MGO-based nanocomposites were characterized using scanning electron microscopy, energy dispersive x-ray spectroscopy and Fourier transform infrared radiation. These methods allowed us to understand the characteristics of the compounds and visualize how they were bonded (Figure 3).

Following synthesis and characterization, photocatalytic experiments were conducted under visible light to determine the most promising nanocomposite and optimize key application
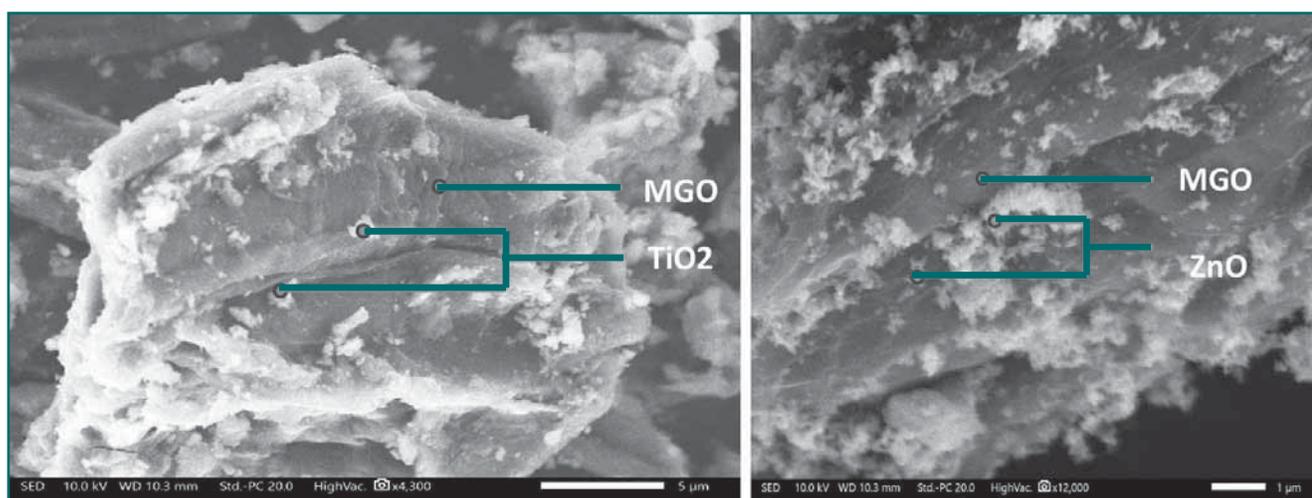

Figure 3. Resulting images from scanning electron microscopy on MGO-TiO2 (A) and MGO-ZnO (B) nanocomposite samples.

conditions such as dosage and irradiation time, for DON degradation in wheat grains. Six treatments were evaluated for two different time periods (2h or 6h); 1. MGO-TiO2, 2. MGO-ZnO, 3. Pure MGO, 4. Pure TiO2, 5. Pure ZnO, and 6. No treatment (Control). In glass vials, treatment materials were combined with a DON solution and ground wheat, then kept in a dark space for one hour. Samples were then placed under LED lamps for 2 hours or 6 hours. DON levels were then analyzed using high performance liquid chromatography (HPLC) and percent DON reduction was calculated.
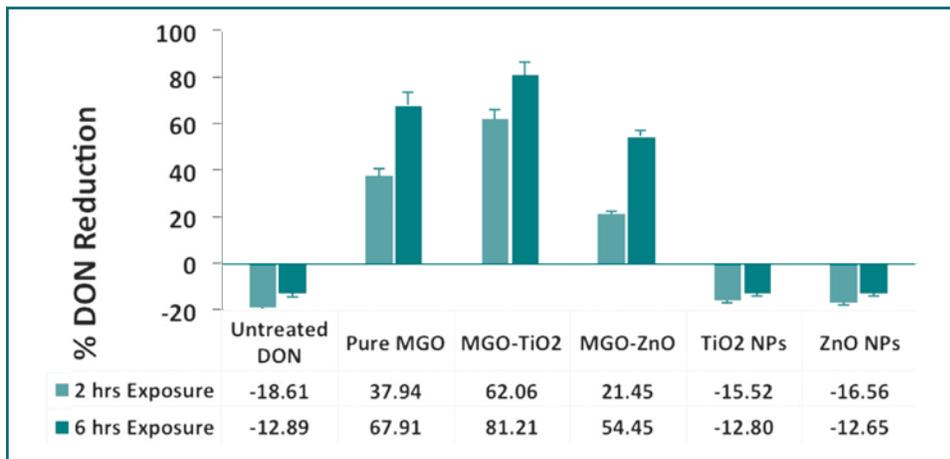

	Untreated DON	Pure MGO	MGO-TiO2	MGO-ZnO	TiO2 NPs	ZnO NPs
2 hrs Exposure	-18.61	37.94	62.06	21.45	-15.52	-16.56
6 hrs Exposure	-12.89	67.91	81.21	54.45	-12.80	-12.65

Figure 4. Resulting DON degradation (%) following 2 and 6h of exposure to six experimental treatments.

What we found

Results of the photocatalytic experiments revealed that MGO-TiO2 nanocomposite (30 mg/ml) reduced DON by 81% after 6 hours of exposure to visible light, while MGO-ZnO demonstrated a 54% reduction (Figure 4). With 2 hours of light exposure, MGO-TiO2 caused a 62% reduction of DON concentration, while MGO-ZnO caused a 21.45% reduction. The use of MGO alone reduced DON concentration by 37.94% at 2 hours of exposure and 67.91% at 6 hours of exposure. Treatment with TiO2 and ZnO alone did not reduce DON contamination, and no reduction was seen in the untreated control group.

"This study may provide opportunities to further utilize low-value grains."

MGO-TiO2 nanocomposites exhibited enhanced photocatalytic degradation of DON among all tested nanomaterials. Both dosage and irradiation time significantly influenced degradation performance. Further photocatalytic experiments using wheat grains will be conducted to determine the optimum operating conditions for subsequent practical applications and assess the impact of the technology on wheat quality.

Next steps

This project is ongoing – we are currently working on our fourth objective, understanding the by-products of DON catalysis and how wheat quality is impacted by the addition of our nanocomposite. We are also working on further optimization of the reaction, experimenting with the type of light used, dosage, and confirming which nanocomposite is the most effective. Once this stage is complete, we will move forward with scaling our methods, working with greater amounts of wheat and different exposure periods. Ultimately, these experiments and trials will allow us to develop further projects to move forward with feed testing and possible commercial applications.

Implications

The findings of this study may provide opportunities for the industry to remediate their low-value grains and utilize them more widely for feed or any other use, as well as mitigate the adverse impact of feeding contaminated grains to livestock. Further research on this topic must include the optimization of operational requirements, as large-scale exposure to visible light may be challenging in a commercial feed mill or grain processing plant. Economic feasibility of this process must also be assessed, as the synthesis of this nanoparticle is not currently commercialized.

Over all, this study has discovered an approach to mycotoxin decontamination with great potential. Reduction of a high concentration of DON by an average of 62% after only 2 hours of light exposure is undeniably promising, and the simplicity of the commercial approach is compelling. If mixing a powder into grain and then exposing it to light could reduce DON concentration by more than 50%, the way mycotoxin contamination is approached could be changed for good.