Bigstock/budabar

Reducing fungal toxins in maize:
Biological approaches

By Dr Hanneke Alberts (PhD Microbiology): Research Leader of the Mycotoxicology Research Group, Institute of Biomedical and Microbial Biotechnology, Cape Peninsula University of Technology

Hanneke's research interests are in biological methods for reduction/detoxification of Fusarium mycotoxins in maize, with special emphasis on enzymatic detoxification.

Introduction

Fusarium ear rot in maize is one of the main diseases affecting maize production worldwide, and poses a huge threat to the international trade of foods and feeds, with harmful effects on human and animal health. Fungal species *Fusarium verticillioides*, *Fusarium proliferatum* and *Fusarium subglutinans* are some of the most important causative fungal agents, with the fumonisin mycotoxins as the main toxigenic and carcinogenic secondary metabolites contaminating South African maize, a major dietary staple. Reduction of fungal toxins in maize via physical and chemical control methods has stimulated an increased interest in biologically based approaches. These methods most likely will have a reduced effect on the nutritional value, quality, safety, or sensory attributes of foods and feed, and impact on the environment.

Biological control methods for post-harvest mycotoxin decontamination

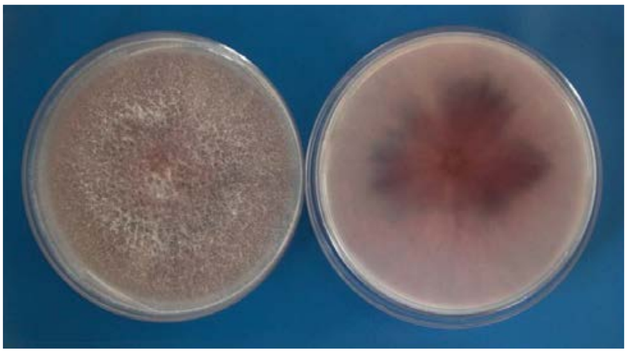
- **Antioxidants, phenolic compounds and essential oils**

Several natural phenolic compounds derived from plants and microorganisms exhibit strong antioxidant and antimicrobial activity by inhibiting key enzymes associated with fungal growth. The phenolic compound butylated hydroxyanisole (BHA) and the phenolic acid propylparaben (PP) have shown potential for reducing *Fusarium* growth and fumonisin production *in vitro*. BHA and PP are generally regarded as safe (GRAS) by the United States Food and Drug Administration (U.S. FDA) and are frequently employed as preservatives in the food industry.

Other effective plant-derived phenolic compounds include: tetrahydrocurcuminoids, extracted from the roots of *Curcoma longa* L. (turmeric); vanillic and caffeic acid, chlorophorin, iroko, maakianin and ferulic acid; flavonoids, phenolic acid and terpine extracts of the non-toxic food-grade plants *Equisetum arvense* (horsetail) and *Stevia rebaudiana* (candyleaf); extracts of *Gynostemma pentaphyllum* (southern ginseng); and a wide range of essential oils and oleoresins extracted from *Zingiber officinale* (ginger), cinnamon, clove, oregano and palmarosa. The bioactivity of antioxidants, essential oils, phenolic compounds and combinations thereof in the vapour phase makes it promising as fumigant for protection of grains on the field immediately after harvest or during storage.

- **Detoxification of fumonisins via enzyme breakdown**

Recent studies on enzymatic detoxification focus on modification of the chemical structures of mycotoxins by enzymatic cleavage or conversion of chemical bonds/groups that play a key role during cytotoxic/carcinogenic effects. Complete detoxification of fumonisin B1 (FB1) is achieved through de-esterification by carboxylesterase enzymes and subsequent deamination by aminotransferase enzymes.



Credit: Dr John Rheeder (CPUT)

Fusarium cultures

A knowledge base on reduction of fumonisin levels by bacterial and fungal cultures has been established over the years. This information was further developed by identifying microbial carboxylesterase and aminotransferase enzymes responsible for detoxification; characterisation of the genes; expression of the genes in food-grade microorganisms; and development of recombinant culture and enzyme preparations for commercial application.

Technologically advanced methods are devised in mass production of relevant enzymes in bioreactors, which find multiple applications during storage and food processing in the form of a wash, additive or spray. Other sophisticated techniques entail genetic engineering of ruminal organisms and supplementation to feed in the form of a probiotic inoculant. Effective enzyme technologies for fumonisin detoxification have been commercialised and are considered safe for humans, animals and the environment by the European Food Safety Authority (EFSA); however, application is presently mainly directed towards the animal feed industry.

- **Natural clay adsorbents**

Incorporation of natural clay adsorbents during food processing involves detoxification of contaminated food through adsorption of mycotoxins. The bioavailability of mycotoxins in animal feed is also reduced in this manner, thereby preventing toxic interactions and absorption across the gastrointestinal tract. Montmorillonite clay minerals including hydratable aluminium silicates effectively reduce FB1 in aqueous solutions (e.g. malt extract) and in human and animal models, and are considered GRAS by the U.S. FDA.

Montmorillonite clay

Bigstock/budabar

Practical and culturally acceptable methods

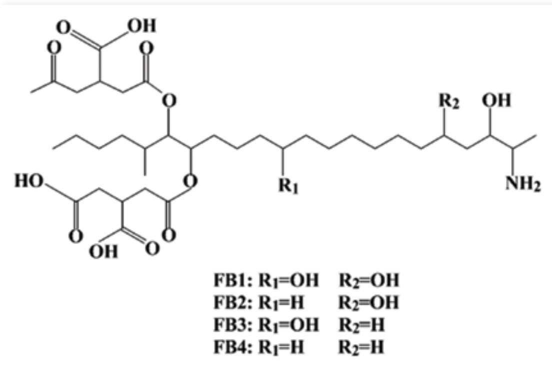
In many developing countries, mycotoxin regulations are either lacking or poorly enforced, which creates scenarios where mycotoxin exposures occur above safe levels set by international health regulatory bodies. In low-income countries, resources are limited and sophisticated technologies for mycotoxin reduction are lacking, hence the importance of cost-effective and simple intervention methods. Effective reduction of the fumonisins has been demonstrated with hand sorting, flotation, washing, dehulling of maize kernels, and combinations thereof *in vitro* and in field studies. The efficacy of these methods could be further enhanced by incorporating clay minerals or fumonisin detoxifying enzymes. Interventions should, however, be culturally acceptable and implemented through educational campaigns; and must be feasible and sustainable in remote rural areas where they are most needed.

Conclusion

Although several commercial products for biological control of *Fusarium* diseases and the fumonisins have been developed for application alone, in combination or as part of an integrated control strategy, much effort is put into *in vitro* studies. The growing knowledge base on this subject should be further developed for application during storage and food processing. Biological control methods for other mycotoxins contaminating maize, i.e. aflatoxins and deoxynivalenol, are also being investigated, and are in certain cases commercialised and successfully applied.

An integrated approach involving good agricultural management practices, HACCP models and storage management, together with appropriately selected biologically based microbial treatments, and mild chemical and physical treatments, could reduce fumonisins in maize effectively. Biologically based methods could have potential commercial application, while simple and practical intervention strategies could also impact positively on food safety and security, especially in rural populations reliant on maize as a dietary staple.

Maize kernels



Chemical structures of the fumonisin mycotoxins produced by Fusarium *species in maize*

References

Alberts, J.F., Lilly, M., Rheeder, J.P., Burger, H.M., Shephard, G.S. & Gelderblom, W.C.A. (2017). Technological and community-based methods to reduce mycotoxin exposure. *Food Control*. DOI: 10.1016/j.foodcont.2016.05.029.

Alberts, J.F., Van Zyl, W.H. & Gelderblom, W.C.A. (2016). Biologically based methods for control of fumonisin-producing *Fusarium* species and reduction of the fumonisins. *Frontiers in Microbiology*. DOI: 10.3389/fmicb.2016.00548.

Credit: Dr Hester Burger (CPUT)