RUFORUM Working Document Series (ISSN 1607-9345), 2021, No. 19 (1):768-771.
Available from http://repository.ruforum.org

Research Application Summary

Towards an AI-powered IoT approach for automated control and monitoring of Mycotoxins infections in cereals

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Abstract

Mycotoxins are poisonous substances mainly produced by fungi that attack field crops and contaminate agricultural commodities during postharvest under favourable conditions. They negatively affect the agriculture sector, cause serious health problems and affect the economy. To appropriately respond to these threats, advanced techniques need to be employed. This study aimed at exploring the literature and building a baseline framework that integrates both AI (Artifical Intelligence) and IoT (Internet of Things) for effective mycotoxin control and monitoring. A systematic review on Mycotoxins, AI and IoT was conducted using various articles from reputed publishers. The study found out that in addition to the main factors that cause mycotoxins, namely temperature and moisture, there is also oxidation. The study showed various favourable conditions and proposed a baseline framework for an efficient automated mycotoxins' handling system.

Keywords: Artificial Intelligence, IoT in agriculture, Mycotoxins, precision agriculture

Résumé

Les mycotoxines sont des substances toxiques principalement produites par des champignons qui attaquent les grandes cultures et contaminent les denrées agricoles après la récolte dans des conditions favorables. Ils affectent négativement le secteur agricole, causent de graves problèmes de santé et affectent l'économie. Pour répondre de manière appropriée à ces menaces, des techniques avancées doivent être utilisées. Cette étude visait à explorer la littérature et à créer un cadre de référence qui intègre à la fois l'IA (intelligence artificielle) et l'IoT (Internet des objets) pour un contrôle et une surveillance efficaces des mycotoxines. Une revue systématique sur les mycotoxines, l'IA et l'IoT ont été effectuées à l'aide de divers articles d'éditeurs réputés. L'étude a révélé qu'en plus des principaux facteurs à l'origine des mycotoxines, à savoir la température et l'humidité, il existe également une oxydation. L'étude a montré diverses conditions favorables et a proposé un cadre de référence pour un système automatisé efficace pour la manipulation des mycotoxines.

Mots clés: Intelligence Artificielle, IoT en agriculture, Mycotoxines, agriculture de précision

Introduction

Mycotoxin refers to the toxic chemical products that are produced by fungi (moulds) grown on numerous foodstuffs such as cereals, direct fruits, nuts and spices, often under warm and humid conditions. This means that it is a toxic secondary metabolite produced by organisms of the fungus kingdom (Peng *et al*., 2018). Mycotoxins are silent killers and their effects can be submerged over a long period especially during intermittent exposures. On human health, some major concerns are, but not limited to childhood impairment, acute toxicosis, fumonisins, and are also linked with esophageal cancer and neural tube defects (NTDS), Immunotoxic deoxynivalenol (DON) and other kidney diseases (Yvv *et al*., 2016). Parameters that influence the occurrence of mycotoxins include 1) Pre-harvest factors such as weather conditions associated with periods of drought, Heat stress, Excessive water, Nutrient deficiency, Insect damage; and 2) Post-harvest factors such as Temperature, Moisture, Oxygen which causes oxidation of compounds in foods and deterioration.

The traditional detection and control of Mycotoxins methodologies mainly focus on how to reduce mycotoxins in feed ingredients during food processing. Preventive strategies include lowering the moisture content of plant seeds, store commodities at low temperatures whenever possible, using fungicides and preservatives against fungal growth, control insect infestation in stored bulk grains, and removal of contaminated seeds (Peng *et al*., 2018). However, the above strategies to mitigate mycotoxins only work to some extent while not satisfactorily being able to address the problem.

In this context, various researchers have proposed alternatives solutions. Muga *et al*. (2019) researched on the effect of temperature, relative humidity and moisture on aflatoxin contamination of stored maize kernels (Muga *et al*., 2019). The results showed that the aflatoxin contamination significantly occurred at a temperature ranging from 20^0C to 30^0C and relative humidity ranging from 60% to 90%. Bertani *et al*. (2020) implemented Optical detection of aflatoxins B in grained almonds using fluorescence spectroscopy and machine learning algorithms. Likewise Soares *et al*. (2020) demonstrated that the quality of stored agriculture products is lost by some biological contamination (fungi, mycotoxin, and insects) and chemical contamination (pesticide residuals). Gaspar *et al*. (2021) on the other hand tried to monitor physical and biological conditions with the help of intelligent systems (with IoT Technology) in grain storage environments such as with varied temperature and humidity.

The gap in the previous works is that most of them carried out their experiments based mainly on temperature and moisture. Some other works adopted deep learning and computer vision techniques. This study aims at providing a framework grounded on the literature towards the integration of the Internet of Things and Artificial Intelligence technologies in an attempt to provide a better-automated solution for controlling and monitoring mycotoxins. This study will add an additional layer to the existing knowledge by integrating an electronic nose as well.

Materials and Methods

This study focussed on literature exploration. A deep search was done from various databases (Scopus, IEEE, Google scholar, MDPI, Hindawi, Elsevier, etc.). Various keywords were used such as mycotoxins, aflatoxins, IoT for agriculture, AI in agriculture, precision farming, crop quality monitoring, crop post-harvest monitoring, mycotoxin detection and control, cereals quality control and monitoring, etc. Various articles were retrieved, and the most appropriate to the research context were retained based on key filtering parameters such as year of publication,

content closeness to the topic, reported results analysis. In addition to the above information was obtained from various stakeholder institutions such as Rwanda Agriculture Board (RAB), STES (Seed Technology Engineering and Science) Group, Food Drug Authority (FDA) Rwanda, and Minimex, the largest producer of fine maize products in Rwanda.

A systematic survey analysis was then conducted to extract useful knowledge from the literature, identify the gap or area of reinforcement needs and subsequently produce a requirement analysis framework that will guide the implementation of the new solution.

Results

The findings indicate that mycotoxins remain a big challenge that needs further treatment. Although various researchers proposed some solutions, more is to be done. The findings highlighted a correlation between multiple factors which contribute to the development of this threat. The main ones being temperature and moisture. In addition to this, the results showed that oxygen can play an important role as well due to the effects of oxidation. The study found that the common mycotoxin observed in Rwanda is aflatoxin. This work found that the traditional aflatoxin testing kit is the one commonly used method in Rwanda. Also, it was found that the acceptable aflatoxin level of aflatoxin accepted by local factories should be less than or equal to 20ppb (particle per billions).

Based on the findings, this work proposed an approach (See Figure 1) that will help to automatically monitor and control mycotoxin's infections. Sensor nodes will be put at various selected locations (See Figure 2) to monitor and control mycotoxins infections in cereals.

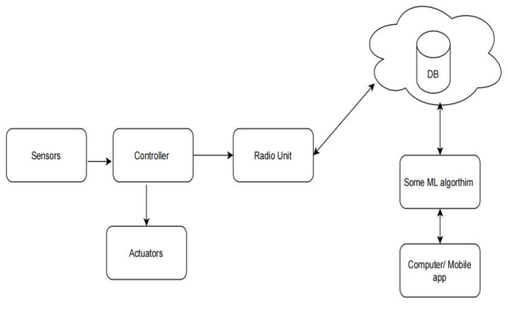

Figure 1. Proposed overall system architecture

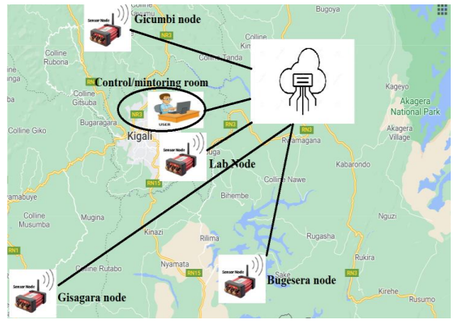

Figure 2. Sensor node architecture

Discussion

The main objective of this work was to explore and examine the literature in order to find strong foundations that will help in building an integrated AI-IoT mycotoxin control and monitoring system. The findings showed that although temperature and moisture highly contribute to the development of mycotoxins (Soares *et al*., 2020), also oxidation plays an important role in the process. Therefore, the study proposed a unique approach of collecting environmental factors data using IoT sensors including an electronic nose, then process and dynamically analyze them using AI techniques, especially machine learning and thus automate the control and monitoring process of the storage conditions of cereals.

Conclusions

This study aimed at exploring the literature purposely for assessing existing works and build on them to propose new ways of an improved solution. In addition to the literature, more information was obtained from the other stakeholders and private companies. The findings led to the proposed baseline framework that will integrate the Internet of Things and Artificial Intelligence technologies towards an automated solution for controlling and monitoring mycotoxins. Apart from the commonly used mycotoxins underlying parameters; this study will add an additional layer to the existing work by integrating the electronic nose in the overall automation process.

Although the research is still ongoing, based on the preliminary findings, it is recommended to the farmers and other relevant entities to find more advanced solutions apart from using traditional mycotoxins handling techniques.

Acknowledgement

The authors acknowledge and thank the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for the financial and technical support. This paper is a contribution to the Seventh Africa Higher Education Week and RUFORUM Triennial Conference held 6-10 December 2021 in Cotonou, Benin.

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