MYCOTOXIN CONTAMINATION OF FOOD AND ITS POSSIBLE IMPLICATIONS ON SUSTAINABLE DEVELOPMENT IN RUNGWE DISTRICT, TANZANIA

Rose Mboya [a], Ayalneh Bogale [b]
[a, b] African Centre for Food Security, College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Pietermaritzburg, South Africa.
[a] Corresponding author: mujilarose@yahoo.com

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Abstract: The potential for mycotoxin contamination of maize to have negative implications on sustainable development was explored using secondary data, with special attention to a report on mycotoxin contamination of maize in Katumba ward, which revealed the existence of extremely high quantities of aflatoxins (0.4 mg/kg), fumonisins (87.7 mg/kg), ochratoxins (0.7 mg/kg) and T-2 toxins (6.2 mg/kg) in stored maize (Mboya *et al.*, 2012).

To investigate the heads of farm households' capacity to understand literature and issues around mycotoxin contamination of food, the same 260 heads of farm households whose maize had been studied for mycotoxin contamination were studied with respect to the number of years that each one of them had spent on obtaining formal education. In addition, the means that the farm households used to control fungi in stored maize were investigated. It was found that 10 % of the farm household heads had no formal education at all, 68.5 % had 1 - 7 years of primary education and 18.8 % had secondary education and only 2.3 % had college education. The mean for the heads of farm households' years of formal education was 6.57 and standard deviation was 3.08.

It was also found that 73 % of the farm households did not use any means of controlling moulds in stored maize, 26.2 % removed the infected maize kernels from the lot and disposed it in the fields. 0.8 % dehulled the maize whenever they noticed that it was being infected by fungi. It was concluded that such high levels of mycotoxins as those found in maize in Katumba ward have capacity to incapacitate people. In turn this would not only thwart the economic growth, but it would also negate the efforts made on sustainable development in the relevant communities. It was also concluded that the low level of formal education of the heads of farm households could possibly lead to the vulnerability of the farm households as a result of the farm households being insufficiently informed concerning issues around food security, particularly concerning mycotoxin contamination of food. Lastly, it was further concluded that the farm householders did not know how to control the development of fungi in stored maize, and that the practice of dumping fungal infected maize kernels in the fields was detrimental to the environment because it created possibilities for the multiplication of pathogenic fungal species in the fields. It was recommended that simple literature, which is compatible with the level of education of farm householders be made available to them, and that educating ordinary people concerning mycotoxins be prioritized.

Keywords: Education, Food, Health, Mycotoxins, Sustainable development

INTRODUCTION

Epidemics caused by toxins that are produced by toxigenic fungi were acknowledged as early as in the 1880's in Europe, where 100,000 people died due to the latter (Smith and

Moss, as cited by Pitt, 2000, p.184)[2]. In 1930's thousands of horses died in USSR and other types of animals also became ill due to the epidemics. (Moreau, as cited by Pitt, 2000)[3], currently known as mycotoxins (Pitt, 2000 p. 184)[4]. Likewise, in 1942 - 1948 mycotoxins were responsible for a disease known as stachybotryotoxicosis, that killed 100,000 people (Joffe, as cited by Pitt, 2000, p.184)[5], whereas in 1960 100,000 young turkeys died due to aflatoxicosis (Rodricks, as cited by Pitt, 2000 p. 184)[6]. By then, it was not clear that mycotoxins could be produced in foods and feeds by common fungi that grow in food and feeds. This fact became clear only in the last 30 years (Pitt, 2000 p. 184)[7].

Currently, mycotoxin contamination of food has been reported worldwide, and the fact that the consumption of foods that are contaminated with mycotoxins can lead to ill health or even death of the consumers (Wu, 2004, p.4049)[8] has been acknowledged. Their deadly nature and their capacity contaminate the air and the soil (Klich, 2009, p.658, 660)[9] suggest that pathogenic fungi that produce mycotoxins should be placed in the same category of elements such as industrial pollutants and contaminants that are known to have negative implications on Sustainable Development (Maser, 1997, p. 30, 31)[10].

Maize, one of the most important food crops in the world and a staple food crop in Africa (International Institute of Tropical Agriculture (IITA), 2009, p.1}[11] has been shown to be susceptible to fungal infection, especially by *Fusarium*, *Penicillium* and *Aspergillus* species, which are also known to be the most important pathogenic moulds in the world (Klich, 2009, p. 658)[12]. This suggests that maize consumers especially the rural poor may be at risk of consuming maize which is contaminated by mycotoxins that are produced by the indicated fungal species. It further raise concern regarding the extent to which ordinary people are aware of the health risks associated with the consumption of mycotoxin contaminated maize among other types of food.

In Katumba ward, Rungwe district, Tanzania, people may consume three maize meals per day in six days per week (Mboya *et al.*, 2011 b, p. 2620)[13], and normally, farm households would make the maize meals using 0.5 - 3 kg of maize flour depending on the households' size (Mboya *et al.*, 2011 b p. 2619)[14]. Extremely high levels of mycotoxins which are associated with the indicated fungal species were found in stored maize in Katumba ward (Mboya *et al.*, 2011 a, 189, 197)[15]. They include fumonisins, which are mainly produced by *Fusarium* species, aflatoxins which are produced by *Aspergillus* species and ochratoxins, which mainly produced by *Penicillium* and some *Aspergillus* species such as *A. niger*, *A. carboinarius,* and *A. ochraceous* (Pitt, 200, pp. 186 - 189)[16] and T-2 toxins, which are also mainly produced by *Fusarium* species. Higher quantities of up to 212000 µg/kg (or 212 mg/kg) of aflatoxins have been reported before in maize in Kenya (Probst *et al*., 2007, p. 2763)[17] and up to 300 mg/kg (or 300000 µg/kg) were reported in Italy (Rittieni *et al*., 1997, p. 4011)[18]. The existence of such high levels of mycotoxins in stored maize raised questions regarding their possible implications on sustainable development in places such as Katumba ward where maize is the staple food crop.

In addition, there is ample information on mycotoxins in the form of scientific literature, which is available in books, Journals and on the internet. However, no such literature exists in Nyakyusa, the language of the people in Rungwe district, or in Swahili, the official language in Tanzania (Mboya, 2011, p. 64)[19]. These facts raised questions regarding the farm householders' capacity to read and understand literature on mycotoxins, the manner in which they deal with mycotoxin contaminated maize, and the implications on sustainable development.

Main objective

This study was conducted in order to explore the potential for mycotoxin contamination of food to have negative implications on sustainable development.

Specific objectives

(a) To investigate the means that farm households in Katumba ward, Rungwe district, Tanzania used to control moulds in stored maize and determine their implications on the environment (b) To investigate the number of years that heads of farm household in Katumba ward spent in obtaining their formal education, so as to determine their capacity to understand literature and issues around mycotoxin contamination of food, and explore its implications on Sustainable Development. (c) To explore the implications of mycotoxin contamination of food on health and determine their possible inferences on Sustainable Development

Materials and Methods

A survey was conducted on 260 randomly sampled heads of farm households in Katumba ward, Rungwe district, Tanzania in order to investigate the methods that they use to control moulds in stored maize. The farm households' capacity to understand literature on mycotoxins was explored through investigating the number of years that they had spent on acquiring formal education. Available data was used as a source of secondary data.

Data collection tools

Face to face semi-structured interviews were administered to the heads of farm households using a guiding questionnaire at their own homes to encourage participation. The questionnaire was tested on 10 farm households, which were then excluded from the study.

Sampling of heads of farm households

260 farm households were randomly selected in Katumba ward using the systematic random sampling technique explained by Dattalo (2008, p. 4)[20]. The sample size was calculated using a sample size calculator, an internet computer programme used for easy and fast calculation of sample size (Al-Subaihi, 2003, p. 327)[21]. The calculation was done at 95 % confidence level, 6 % precision and 100 % response rate to obtain an affordable sample size. The procedure for the calculation involves feeding into the programme the population size to determine the required sample size. In 2009 the recorded number of households in Katumba ward was 2649, and 10 farm households were exluded from the study, therefore, the population size from which the number of farm households that should participate in this study was calculated was 2639 households. The total number of households in Katumba ward was divided by the required number of sample households to get the interval at which a sample household should be selected. Since 10 farm households on which the questionnaire was tested were excluded from the study, 2639 farm households were divided by 260 equals, which equals about 10 after rounding off. Therefore, a sample household was selected by walking through the population and selecting every tenth household from the randomly selected starting point.

Statistical analyses

Data analysis was conducted using the SPSS programme. The means that farm households used to control the infection of maize by fungi and the heads of farm households' years of formal education were correlated to explore the association between them.

A REVIEW OF LITERATURE

Sustainable Development is that which enables people to meet their needs without compromising future generations from meeting their own needs [World Commission on Environment and Development (WCED), 1987, as cited by Soubbotina, 2004, p. 9)[22]. This is the most widely used definition of Sustainable Development (Parry-Davies, 2012, p.1)[23]. The World Summit which took place in 2002 established that Sustainable Development has three dimensions, namely: the social, the environmental and the economic dimensions (Parry-Davies, 2012 p.1)[24]. Currently, out of the three dimensions of Sustainable Development, the environmental aspect is regarded as most important based on the understanding that the social and the economic activities cannot take place unless a healthy environment exists (Parry-Davies, 2012, p. 1)[25]. Therefore ensuring that the environment is free from pollution and contaminants is as important as ensuring that the environment is not depleted of its natural resources. Industrial pollutants and contaminants have been shown to have adverse effects on the environment and on health, and ultimately on Sustainable Development. However, the implications of naturally occurring contaminants such as mycotoxins on the latter have been hardly studied or discussed.

Poverty has been identified as the most important factor that cause the poor people in developing countries to engage in activities that lead to the depletion of natural resources (Rogers *et al.*, 2008, P. 52)[26], which ultimately renders the environment unsustainable. With respect to mycotoxin contamination of stored food crops, poverty has been shown to play a major role in influencing the former. The fact that the poor status of farm households influences their use of cheap to construct storage methods is well known. Often such storage methods fail to protect stored crops from infestations. Consequently, the infestation and the infection of stored grain by pests such as fungi, as well as the subsequent contaminations occur. Therefore the general understanding is that exposure to mycotoxins is most likely to occur in place where poor storage methods and malnutrition are common (Bennet and Klich, 2003, p. 549)[27], which is the case in poor communities. The link between poverty and the consumption of mycotoxin contaminated food imply that exposure to mycotoxin contamination is both a scientific and a socio-economic issue.

The most important fungal species that produce most of the major mycotoxins, namely: *Penicillium*, *Fusarium* and *Aspergillus*, may occur in the air, in the soil and on the vegetation {Klich, 2009, p.658[27]; Asan, 2011, p. 2 [28]; Mold and Bacterial Consulting Laboratories (MBL), 2007, p. 1}[29]. The inhalation of spores of the indicated fungi species can cause mild to serious chest problems such as the obstruction of the pulmonary airway, which is often associated with the inhalation of Aspergillus spores (Klich, 2009, p. 660)[30]. Under favourable conditions, toxigenic fungal species may infect food crops and produce mycotoxins in them (Bennet and Klich, 2003, p. 500)[31]. Thus the indicated pathogenic fungal species are dangerous environment pollutants. In this paper attention is paid to mycotoxins that were found in stored maize in Katumba ward in 2009 in a study which was conducted by Mboya *et al*., 2011), namely: ochratoxins (0.7 mg/kg), fumonisins fumonisins (87.7 mg/kg), T-2 toxins (6.2 mg/kg) and aflatoxins (0.4 mg/kg).

It has been noted that aflatoxins may cause cancer of the liver in human beings, decreased eggs production in chickens, decreased milk production and interference with reproductive efficiency in animals (Oliveira *et al*., 2006, p 355)[32]. Suppression of the immune system in both human beings (Pitt,2000 p.185)[33] and animals can also occur (Oliveira et al., 2006, p. 355 - 356)[34]. The internationally acceptable standard limit for aflatoxins in maize in 20 µg/kg (Iowa State University, 2009, p. 9)[35].

Ochratoxins may cause kidney problems in animals and human beings (Bayman and Baker, 2006, p. 219)[36]. Ochratoxins may also cause retarded growth to chickens that are raised for slaughter, decreased egg production to laying hens (Jewers, 2012, p. 198)[37] and may cause cancer in humans (Bennet and Klich, 2003, p. 504)[38]. Levels of up to 50 µg of ochratoxins per kilogram of maize (µg/kg) are acceptable for a number of countries (FAO, 2004, p. 24)[39]. Thus, quantities higher than 50 µg/kg for in maize may be detrimental to the consumers.

Fumonisins are specifically associated with cancer of the esophagus (Pitt, 2000, p. 188)[40], but they may also cause kidney, pancreas, gastrointestinal tract and blood cells problems and they may interfere with brain, liver, and lungs function (Vincelli and Parker, 2002, p. 3)[41]. Currently, up to 3mg/kg (FAO, 2004, P. 26) [42] is the accepted standard limit for fumonisins in maize for many countries, thus, commodities that have more than three mg/kg of fumonisins may cause health problems.

The consumption of high levels of T-2 toxins are said to cause aleukia, a disease of the alimentary canal, and digestive disorders (Bennet and Klich, 2003, p. 506)[43] and immunosuppression (Tai and Pestka, 1990, p. 149)[44]. In chickens T-2 toxins can cause lesions, low egg production, reduced weight and other diseases similar to those caused by ochratoxins (Sokolović *et al*., 2008, p. 43)[45]. Currently, there are no set acceptable standards for T-2 toxins in maize. In general, mycotoxins. Thus such high quantities of mycotoxins as those found in maize in Katumba ward have capacity to incapacitate people. With such high levels of mycotoxins, the reduction in the nutritive value of the contaminated maize may be possible. This is of much concern too as it could lead to the undernourishment of the individuals in the affected communities.

The reviewed literature shows that mycotoxins may interfere with health through three main ways: firstly, directly by causing or promoting diseases to individuals and secondly by suppressing the immune system of the individuals who have been exposed to them, thus, rendering them susceptible to attack by several diseases such as tuberculosis, HIV and malaria. In turn, the escalation of the indicated diseases is likely to occur in the affected communities. Most of the deaths caused by these diseases occur in the developing countries, especially among the poor in sub-Saharan Africa (Todaro and Smith, 2011, p. 392, 396)[47].

In sub-Saharan Africa, thousands of people die each year due to tuberculosis and HIV/AIDS, whereas malaria kills an estimate of one million people each year (Todaro and Smith, 2011, p. 392)[46]. Whether these diseases are being promoted by the occurrence of mycotoxins in foods is not clear. It is necessary that this be researched. However, in general, due to ill health the capacity of the affected individuals and communities at large to participate in economic activities is most likely to be reduced. This would have negative implications on economic growth. A sustained economic growth at individual and societal level is regarded necessary for the realization of human potential to take place. Thus by promoting diseases, mycotoxins play a direct role in hindering well being and economic growth, both of which are necessary for Sustainable Development to occur. Therefore it can be argued that mycotoxins promote poverty and are also promoted by poverty among other factors.

Poverty has been found to play a major role in encouraging the depletion and degradation of the environment. It has been noted that in their struggle to survive the poor may overuse natural resources (Rogers *et al*., 2008, p. 50)[48] without considering the effects that the latter may have on the future generations ability to meet their needs. In the light of this, ensuring that mycotoxin contamination of food does not occur at all or minimizing its occurrence would help to promote health and to encourage participation in economic activities, thus helping to eradicate poverty and to reduce the exploitation of natural resources.

On the other hand, while education has been shown to be important for enabling individuals to acquire the necessary skills, attitudes, values and knowledge that can help in achieving Sustainable Development (UNESCO, 2007, p. 5)[49], it also influences the capacity of individuals to develop self sustaining growth (Todaro and Smith, 2011, p. 359)[50]. However, the quality of education may influence the individuals' capacity to deliver the necessary output (Soubbotina, 2004, p. 44)[51]. In view of this, the quality of education may influence the individuals' understanding regarding issues around mycotoxin contamination of food and ways in which they respond to it.

FINDINGS AND DISCUSSION

Findings from the reviewed literature

Fungi that produce mycotoxins may affect Sustainable Development by directly polluting the three important components of the environment, namely: the soil, the air and the vegetation (Figure 2). The ingestion of the subsequent mycotoxins may cause diseases, which may ultimately lead to death or the incapacitation of the affected individuals. The incapacitation of people may further lead to less productivity and poverty, which may encourage the degradation of the environment.

Moreover, poverty and mycotoxin contamination of food crops are interrelated. While poor farm households may use poor technologies such as storage methods that allow the development of toxigenic fungi in stored food crops, due to being uninformed about the poisonous fungi the poor farm households may also engage in practices that are harmful to the environment, such as disposing fungal infected grains in the fields, thus promoting the pollution of the environment. In general, the toxigenic fungi together with the mycotoxins associated with them may affect all of the three important dimensions of Sustainable Development, namely, the socio, the environmental and the economic.

Means that farm households in Katumba ward used to control moulds in stored maize

Seventy three percent of the farm households did not apply any means to control moulds in stored maize, 26.2 % separated the infected maize kernels from the lot and 0.8 % dehulled the maize as soon as they noticed that it was infected. Furthermore, a total of 59.6 % of the farm households engaged in disposing the infected maize off in the fields. The farm households' ignorance regarding moulds is further revealed through the fact that at least 50 % of the farm households simply threw away mouldy maize if they felt that it was very badly damaged.

The practice of simply throwing away fungal infected maize would accelerate the infection of maize and other crops as the moulds would continue to grow where conditions are favorable. Katumba ward is known to be characterized by wetness throughout the year and cool temperatures ranging from 10 - 25 ^{0}C (Anon, 2008, p. 1)[52], which naturally leads to high humidity. High humidity (Golob, 2009, p. 29)[53] and temperatures ranging from 10 - 45 ^{0}C allow growth of fungi (MBL, 2005, P. 1)[54]. Thus, the temperatures in Katumba ward are within the range of temperatures which in combination with high humidity favours the growth of moulds. Thus, the practice of throwing fungal infected maize away in the fields would pave the way for the soil, the air and the vegetation to be infected by the fungi, rendering the soils unsafe for growing crops and the air unsafe for inhalation.

The implications of the level of formal education of heads of farm household

More than half of the heads of farm households that took part in this study had up to seven years of formal education (Figure 1). The mean for the heads of farm households' years of formal education was 6.57 and standard deviation was 3.1. When grouped into four categories of years of formal education, it was found that only 2.3 % of the heads of farm households had college education (Table 1). Furthermore, a negative association (-0.268) was observed between the tendency for the farm households to dispose off infected maize in the fields and the heads of farm households' years of formal education (Table 2). The association was significant at α = 0.001, implying that the tendency for farm households to dispose off infected maize in the fields decreased as the number of years that the heads of households spent on acquiring formal education increased. This indicates that householders whose heads of households had lower level education were most likely to dispose off infected maize in the fields than those whose heads of households had a higher level of education.

The low level of education of the majority of the farm households in Katumba ward raises concern regarding the degree to which the heads of farm households understand scientific issues involving food security and ecological factors that influence maize storage. This concern is based on the understanding that most of the available literature on mycotoxins may is available in scientific books or on the internet, the facilities which ordinary rural people do not have access to. Secondly, due to the language often used, literature on mycotoxins may be easily understood by academics, whereas ordinary people especially those who have had primary education only, may not be able to understand it. The understanding of scientific issues around food security and ecological factors that influence food storage is crucially important for understanding ways in which food should be handled for maximum safety and quality. Thus, it is important that extension literature on mycotoxin contamination of food be made available, and that it should be compatible with the low level of farm households. In addition, the role of the extension officers as educators is critical for ensuring that the farm households are informed concerning health problems associated with pathogenic moulds and for preventing fungal infection of maize among other crops.

CONCLUSION

This paper has shown that toxigenic fungi have capacity to pollute the environment through their existence in the soil, the air and the vegetation. It has also shown that mycotoxins have the capacity to contaminate food and animal feeds, thus causing serious health problems, whereas the existence of toxigenic fungi in the air and the soil render them unsafe for inhalation and cultivation, respectively. Therefore efforts to achieve Sustainable development should include educating ordinary people about mycotoxins using simple literature in their official languages. This is a challenge that still remains.

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Table 1: Categories of heads of farm households' years of formal education

Number of years of formal education in categorical order	**Percent of farm households**
0 (No formal education)	10.4
1 – 7 (Primary education)	68.5
8 – 12 (Secondary education)	18.8
> 13 (College education)	2.3

Table 2: The association between farm households' tendency to dispose fungal infected maize in the fields and heads of farm households' years of formal education

		Household head's years of formal education	Farm households' tendency to dispose infected maize in the fields
Household head's years of formal education	Pearson Correlation	1	-.268**
	Sig. (2-tailed)		.000
Involved in simply throwing away infected maize	Pearson Correlation	-.268**	1
	Sig. (2-tailed)	.000	

n= 260

**. Correlation is significant at the 0.01 level (2-tailed).

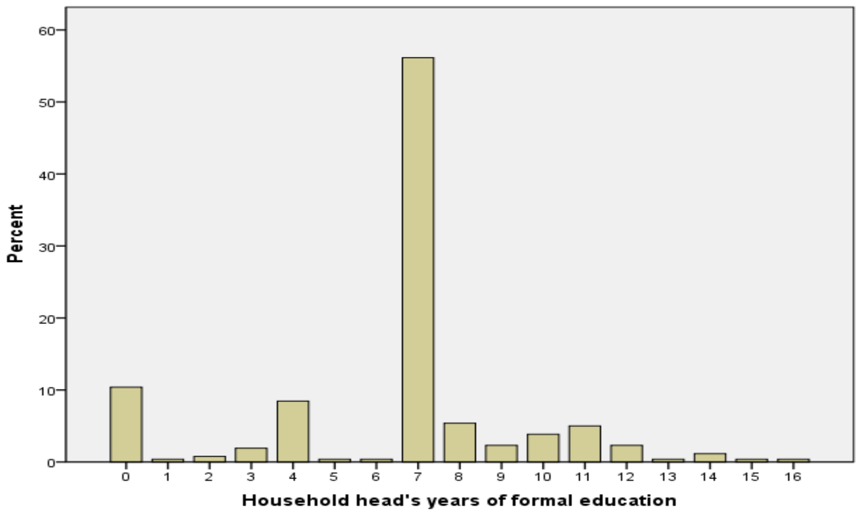

Figure 1: Household heads' years of formal education in Katumba ward

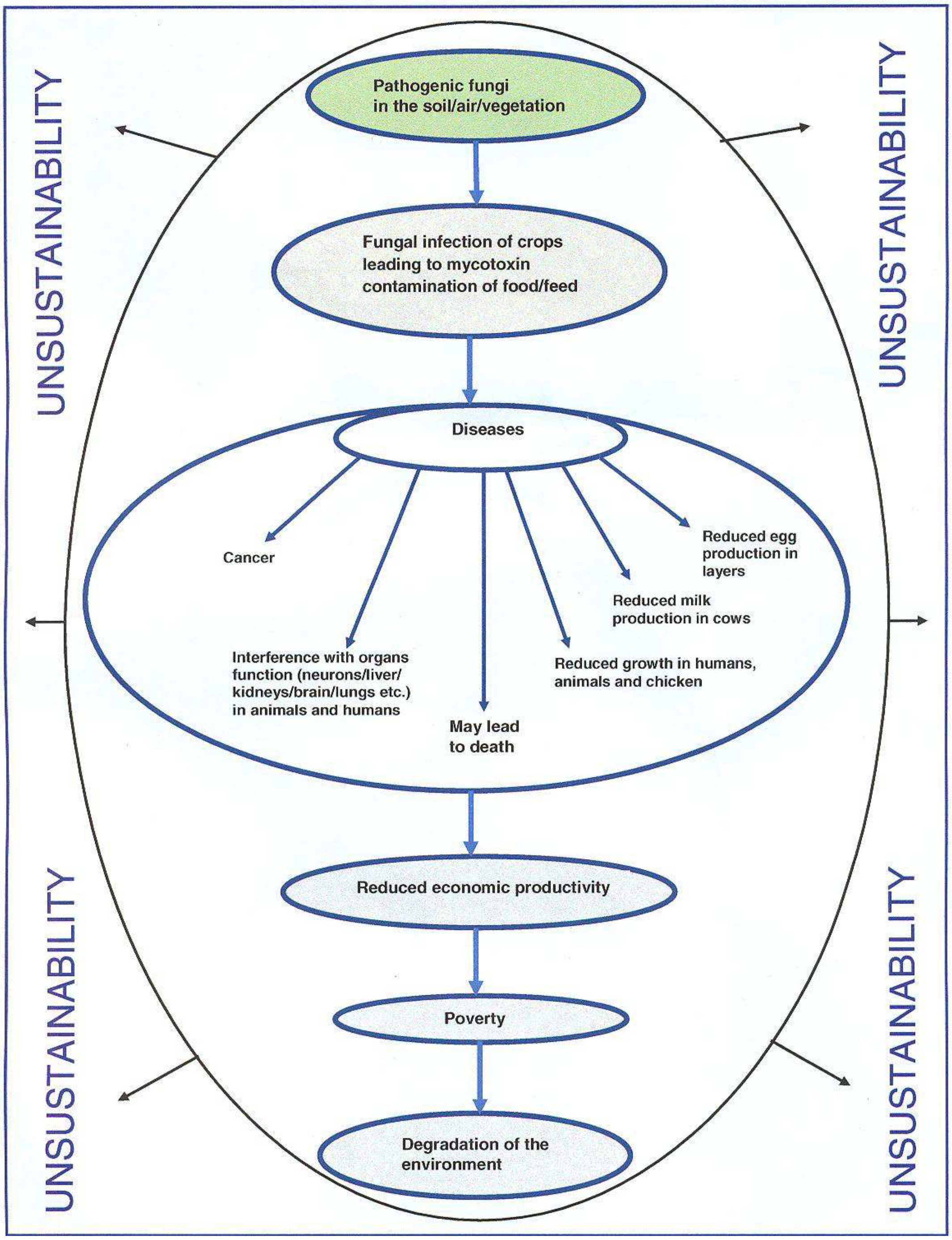

Figure 2: A summary of the implications of mycotoxins on Sustainable Development