Ochratoxins - A review

S.O Fapohunda1*, Negedu, A2, Okeke, O.F.I3, Fapohunda, T4, Wahab M.K.A5 and Okeke, F1

1Department of Biosciences and Biotechnology, Babcock University, Ilishan remo, Ogun state, Nigeria.
2Raw Materials Research and Development Council, Abuja.
3Department of Medical Microbiology, Faculty of Medical Sciences, University of Jos, Plateau State, Nigeria.
4Department of Animal Science, University of Ibadan, Ibadan, Nigeria.
5Department of Wildlife, Osun state University, Ejigbo campus, Nigeria.

*Corresponding author: oystak@yahoo.co.uk
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ABSTRACT

The economic and health implications of ochratoxin contamination are discussed together with efforts by various bodies to set standards and ensure compliance. Occurrence on African crops, detection techniques and management systems are highlighted. This mycotoxin produces diverse morbidities in animals and man. It also compromises export value of crops. Good agricultural and manufacturing practices still hold the promise for an effective ochratoxin control in store, home and industry. The need to set and ensure compliance with standard on OTA in crops and livestock is highlighted. This could also come only after a credible country wide assessment on ochratoxin is carried out and an Africa Union attention centred on it

Keywords: Ochratoxin, food, man, livestock, morbidities

INTRODUCTION

Ochratoxins are toxic secondary metabolites produced by some fungi. They are mycotoxins the production of which is aided by high temperatures and moisture, unseasonal rains during harvest and flash floods (Bhat and Vasanthi, 2005). Contamination of various agricultural commodities by ochratoxins could occur either before harvest or under post-harvest conditions (FAO, 1991). Ochratoxins are a group of isocumarin derivatives, of which OTA (C20H18O6NCl) is the most abundantly produced and most toxic compound (Abramson, 1997). Ochratoxins comprise the first major group of mycotoxins identified after the discovery of aflatoxins. There are 3 structural members of ochratoxins: A, B and C which differ slightly from in the type of analogues (Fig 1). These differences, however, have marked effects on their respective characteristic potentials. (Risk Assessment Studies, Hong Kong, 2006). Ochratoxin A is the most abundant and relevant ochratoxin (Vedani, 2012). Concerns regarding exposure to ochratoxins have primarily centred on exposure to food contaminated with Ochratoxin A (OTA) such as wine, beer, coffee, dried vine fruit, grape juices, pork, poultry, dairy, spices, and chocolate. (Hope and Hope, 2011). Ochratoxin A is a mycotoxin mainly produced by mould species of the genera Aspergillus and Penicillium which grow on a variety of agricultural products. (Manda et al., 2009). Its original source is Aspergillus westerdijkiae (Frisvad et al., 2004). Record also showed that ochratoxins had a root in South Africa as far back as 1965 (Bayman and Baker, 2006), and constitutes one of the known mycotoxins with greatest public health and agro-economic significance (Duarte, 2011). Despite being described in a myriad of foodstuffs, cereal and its derivatives (i.e cereal products) remain the major contributions to OTA exposure (Duarte et al., 2010).
Using a preparation of monoclonal antibodies against OTA, Varga et al. (1996) found that OTA can be produced by atypical strains of A. ochraceus, A. alliiaceus, A. sclerotiorum, A. sulphureus, A. albertensis, A. auricomus, and A. wentii. Poor harvesting practices, improper storage and less than optimal conditions during transportation, marketing and processing can also contribute to fungal growth and increase the risk of mycotoxin production. Generally, the threat of OTA contamination of foods and feeds resulting in human and livestock poisoning is real and of major concern.

The largest mycotoxin-poisoning epidemic in a decade was reported in Africa during the last 13 years with a particular reference, however, to aflatoxin. Some mycotoxins such as aflatoxins are considered by the US Food and Drug Administration (FDA) to be unavoidable contaminants of food. The goal of any public health institution therefore, has been to minimize contamination. However, mycotoxin management methods used in developed countries cannot realistically be used in developing countries because of the characteristics of the food systems and the technological infrastructure in those countries resulting in uncontrolled mycotoxin levels in these situations. The threat is made even more palpable by the fact that, staple diets in many African households are more susceptible to contamination than those in developed countries resulting in uncontrolled mycotoxin levels in these situations. The threat is made even more palpable by the fact that, staple diets in many African households are more susceptible to contamination than those in developed countries resulting in uncontrolled mycotoxin levels in these situations. The threat is made even more palpable by the fact that, staple diets in many African households are more susceptible to contamination than those in developed countries resulting in uncontrolled mycotoxin levels in these situations.

Mycotoxins attract worldwide attention because of the significant economic losses associated with their impact on human health, animal productivity and trade (WHO, 2001; Wu, 2006). This review examines the extent of the ochratoxin problem in Africa, its implications to food/feed safety, health as well as economic implications of their contamination and poisoning. It also examines the scale and levels of human and animal exposure to different food crops in different parts of Africa; highlights the impacts and explores possible management interventions.

The term mycotoxin literally means poison from fungi. Among the thousands of species of fungi, only about 100 belonging to genera Aspergillus, Penicillium and Fusarium are known to produce mycotoxins. Out of the 300–400 mycotoxins known, the most important are aflatoxins, ochratoxins, deoxynivalenol (DON or vomitoxin), zearalenone, fumonisins, T-2 toxin and T-2 like toxins (trichothecenes). Deoxynivalenol, zearalenone, T-2 toxin and fumonisins are all produced by fungi of the genus Fusarium. Crops in tropical and subtropical areas are more susceptible to contamination than those in temperate regions, since the high humidity and temperature in these areas provide optimal conditions for toxin formation (Thomson and Henke, 2000). The Food and Agricultural Organization (FAO) has estimated that up to 25% of the world’s food crops are significantly contaminated with mycotoxins (WHO 2006). However, OTA’s presence in food is often overlooked in Africa due to public ignorance about their existence, lack of regulatory mechanisms, dumping of food products, and the introduction of contaminated commodities into the human food chain during chronic food shortage due to drought, wars, political and economic instability (MERCK, 2006). Ethical considerations also play a role during the manufacturing process of food products using heavily contaminated commodities and sometimes “diluting” contaminated agricultural products such as peanuts with good quality products to an “acceptable” level below the regulatory level (MERCK, 2006; FDA, 1995).

OTA can easily be located in the human food chain directly via plant products (e.g., cereal grains, oilseeds, nuts, coffee, cocoa), fruits and their juices, beverages (wine and beer)(Visconti et al, 2008), spices and, indirectly through foods obtained from animals(milk, pork, dairy product) given diets contaminated with mycotoxins that can leave residues in milk and its derivatives, and, especially, in fresh and cured pork. Of the ochratoxins A, B, and C, the latter two so far have not been found in naturally contaminated products.

**Structure of ochratoxin**

Ochratoxin A is regarded as a polyketide secondary metabolite coupled to the amino acid phenylalanine N-[(3R)-5-chloro-8-hydroxy-3-methyl-1-oxo-3,4-dihydro-1H-isochromen-7-yl]carbonyl]-L-phenylalanine.

**Distribution and health impacts**

Ochratoxins A is the most prevalent and therefore receiving increasing attention for its nephrotoxic effects and its potential carcinogenic activity (Kuiper-Goodman and Scott, 1989; Pohland, 1993.).Also, according to Logrieco et al. (2003), OTA is the only ochratoxin that plays a role as an environmental toxin and it is regarded as a major concern of livestock producers, although the production of ochratoxin B (C_{20}H_{16}O_{6}N) by several Aspergillus Species has been reported (Varga et al., 1996). It has been located in nursing mothers, (Skaug et al., 1998) and human plasma (Coronel et al. 2010 ). In some animals, the evidence of transfer from lactating mother to young ones is recorded (Breitholtz- Emanuelsson et al., 1993) Every step is taken to monitor and reduce its impact in the European union(EFSA 2006).

Ochratoxin A, a toxin produced by Aspergillus ochraceus (Van der Merwe et al., 1965; Searcy et al., 1969) is one of the most abundant food-contaminating mycotoxins in the world. It is reportedly produced by many Aspergilli and two Penicilium species (Geisen and Schmidt-Heydt 2009). These authors also described the correlation between environmental factors, gene activation and ochratoxin A biosynthesis. For example, the ecological reasons for its production on sodium
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Figure 1. Chemical Structures of the Ochratoxins
(Source: Jonsyn-Ellis, 2012).

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chloride rich medium was recently studied (Schmidt-Heydt et al., 2011). Human exposure occurs mainly through consumption of improperly stored food products particularly contaminated grain and pork products, as well as coffee, wine grapes and dried grapes. (Mateo et al., 2007). The toxin has been found in the tissues and organs of animals, including human blood. It was first reported in South Africa as a secondary metabolite produced by a strain inadvertently referred to as *Aspergillus ochraceus* (Van der Merwe et al., 1965). Although exposure to the toxin is usually due to ingestion of contaminated foods and feeds, airborne invasion may also occur in rare cases (Richard et al., 1999).

OTA can easily enter the human food chain directly through cereal grains oilseeds, nuts coffee and cocoa and their juices and beverages (wine and beer), spices. Feed items and animal sources like pork, or dairy products also constitute major candidates for ochratoxin contamination. Poultry feed samples that tested for OTA had this mycotoxin traced to *Aspergillus* and *Penicillium* strains (Rosa et al. 2006; Lund and Frisvad, 2003). *Penicillium nordicum*, a fungal species that produces a lot of OTA, is known to do so in the presence of sodium chloride -rich food items. On its own and while grown on YES medium, *P. nordicum* produces this toxin under a range of salt concentration (Schmidt-Heydt et al., 2012).

The loci of occurrence abound Ochratoxin A are in geography and substrate. (OTA) residues in human milk are common in countries in the temperate and cold areas of the northern hemisphere, such as Italy (Micco et al., 1987, 1991; Miraglia et al., 1995), Switzerland (Zimmerli and Dick, 1995); Sweden (Breitholtz–Emanuelsson et al., 1993); Germany (Gareis et al., 1988). Nevertheless, Jonsyn-Ellis et al. (1995) reported that, due to the high OTA levels in human milk, infants in Sierra Leone are exposed to OTA levels that in some cases far exceed those permissible in animal feed in developed countries. In Norway, Skaug et al. (1998, 2001) examined the relationship between OTA contamination of human milk and dietary intake, finding that the risk of OTA contamination was related to dietary intake of breakfast cereals, processed meat products, cheese, cakes, cookies and juice. Because in the first months of life infants may be fed concurrently breast and dried milk sources, they are at risk for ingesting multiple mycotoxins (e.g., OTA plus AFM1). Its distribution also has a link with both sex and height (Palli et al., 1999).

The occurrence of mycotoxins in milk and its derivatives is a serious problem of food hygiene, as milk is a primary source of human nutrition, particularly for infants and children, who are potentially more sensitive to toxins and whose diet is much less varied than that of adults. Major concerns about milk contamination by mycotoxins are largely limited to AFB1 and OTA. OTA transfer to milk has been demonstrated in rats and humans. Although the in depth study of OTA metabolism in human is limited in literature (Bauer and Gareis 1987, OTA has been associated with human serum (Illichev et al., 2002) and kidney morbidity resulting in Balkan Endemic Nephropathy (BEN) a severe, progressive, and ultimately fatal renal disease affecting populations in the Balkan Peninsula (Pfohl-Leszkowicz and Manderville, 2007). Dietary OTA can also result in residues in cow’s milk but at substantially lower levels except when massive doses are ingested. Indeed, OTA is largely transformed by the rumen microflora into ochratoxin-α. The biochemical effect of OTA results primarily from its structural similarity to the essential amino acid, phenylalanine. The principal effect appears to be the inhibition of protein synthesis, although inhibition of RNA and DNA synthesis has also been implicated in its mechanism of action (Aish et al., 2002). However, Skaug (1999) found that OTA levels in milk from cows in Norway were sufficient to cause a higher intake of OTA than the suggested tolerable daily intake (TDI) of 5 ng/kg BW/day (e.g. in small children who consume large quantities of milk). Dietary OTA in animal feed can survive processing and biotransformation in poultry and pigs, but not in milk and meat of cattle (Scudamore et al., 1996).

Meat and meat products from animals given mycotoxin...
contaminated feeds are a potential route of human exposure. However, meat from ruminant animals can be almost excluded as an important route of exposure for humans due to the degrading/converting action of rumen microflora, particularly protozoa that drastically reduces the carry-over to tissues, making it harmless to human consumers. Among meats from non-ruminant animals pork is the most susceptible to mycotoxin contamination, specifically to OTA. Indeed, OTA can easily be transferred to pork due to its high incidence in pig feeds and the unfavorable elimination toxicokinetics that lead to a relatively long half-life in edible animal tissues (Jorgensen and Petersen, 2002).

OTA contamination of pork is a potential concern particularly in northern European countries and elsewhere where climatic conditions lead to a high incidence of OTA contamination in pig feeds. In Denmark, the implementation of post-mortem inspection programs has been an effective precautionary practice (Mousing et al., 1997), a level of 15 ppb of OTA in a pig liver or kidney results in its confiscation, and levels exceeding 25 ppb result in confiscation of the entire carcass. Surveys performed on pig meat in Denmark (Jorgensen and Petersen, 2002; Jorgensen, 1998); Romania (Curtui et al., 2001), on sausages in Germany (Frank, 1991), on ham in Italy (Chiavaro et al., 2002), on pig liver in France (Dragacci et al., 1999) in South African wine (Shephard et al. 2003) and on liver pates in Spain (Jimenez et al., 2001), reported the detection of different levels with respect to environmental factors. Although pork meat is a route for human exposure to OTA and continuous surveillance is needed, its contribution is proportionately much less significant than that of some other foods. Generally, livestock blood retains OTA for an appreciable period of time before it settles in specific organs. Dwivedi and Burns (1984) had tracked OTA in broiler chicks with greatest concentration in the kidneys (Madsen et al., 1982)

Health impacts

The health risks of ochratoxin contamination is on record (Kuiper-Goodman et al., 2010). OTA is suspected to be involved in the etiology of human nephropathies and tumors of urinary organs. The persistence of OTA in the human body is prolonged as it has a blood half-life of 35 days after a single oral dosage, due to unfavorable elimination toxicokinetics (Studer-Rohr et al., 2000). The long half-life of OTA, together with frequent exposure of humans by ingestion of OTA-contaminated food, results in a high frequency of OTA in human blood samples collected around the world (Speijers and van Egmond, 1993; WHO, 2001). The most frequent found mycotoxin in the blood of people exposed to mycotoxins in their food is OTA (Sangare - Tigori et al., 2006) and following its absorption, its binds to the human serum albumin (Ilichev et al., 2002). OTA has been rated as “possible human carcinogen (Group 2B)” by the IARC, an arm of the WHO. Sometimes, the co-occurrence with aflatoxins may pose a more dangerous effect (Sedmikova et al 2001). Limonciel and Jennings (2014) reported an evidence of OTA being an Nrf2 inhibitor enhancing the link for renal toxicity and renal carcinogenicity. It is classified nephrotoxic, teratogenic, immunotoxic and hepatotoxic to laboratory and domestic animals (O’ Brien and Dietrich, 2005.)

Candidate targets

Plants also constitute a sizeable portion of the targets of contamination. In Africa, OTA has been reported as a contaminant of cocoa and coffee beans, tiger nuts, wines and maize. It has been detected in cocoa powder in Ivory Coast, Guinea, Nigeria and Cameroon up to 4 mg/kg higher than the EU regulatory level (Bonvelli, 2004). Aroyeun and Adegoke (2007) reported over 50% occurrence of A. ochraceus and A. niger in cocoa beans in Nigeria with a corresponding 40–60 ppb OTA concentration and in high doses in coffee (Romani et al., 2000). OTA contamination of green coffee beans and other plant products such as barley wheat, bread and spices is a serious health hazard throughout the world (Smith and Moss, 1985). Coffee can contain OTA produced by Aspergillus ochraceus or A. carbonarius and its presence may relate to immediate post harvest handling. Studies in Brazil have shown that mould growth and OTA production occur only during drying of green coffee beans, and that if drying is rapid and effective, OTA will not be produced. OTA has been found in green coffee for several years, but there has been and still is some uncertainty as to what extent OTA is degraded during the roasting process and further transmitted from roasted coffee to the final coffee brew. The reported reductions caused by roasting vary, but the major source of variation was a low OTA level (generally less than 10 µg/kg) in green coffee submitted to the process. Reports usually showed high rates of OTA reduction, ranging between 30 and 90%. Decaffeination seems to be an effective process, resulting in 92% reduction of OTA. During freeze-dried coffee manufacture or brewing, nearly 80% of OTA initially present in roasted and ground coffee was found to be transferred to the cup (van der Stegen et al., 2001).

Many surveys of roasted coffee demonstrated that OTA incidence is generally low and that levels exceeding 5µg/kg are very rare. Data obtained in Germany, the UK, and Switzerland seem to indicate that coffee on the European market is contaminated with a mean OTA level of around 0.8 µg OTA/kg. On the basis of available contamination rates and mean consumption of food
categories, it was calculated that coffee contributed an average of 2 to 3 ng/kg, while cereals and wine contributed about 25 and 10 ng/kg BW per week, respectively (WHO, 2001) The importance of grapes and wines as sources of OTA in human diet has been increasingly recognized following worldwide surveys on the occurrence of OTA in these products (Battilani and Pietri, 2004; Battilani and Logrieco, 2006). Although Aspergillus westerdijkiae was associated with OTA production in orange (Marino et al., 2009) this fruit and its juice had also been a major target of OTA produced by Aspergillus niger (Marino et al., 2014) just as various spices like Cinnamomum tamala and Piper nigrum present suitable habitat for it (Ramesh and Jayagouda, 2014).

Cocoa beans are the source of cocoa powder, which is a frequent ingredient in several kinds of foods, cakes, biscuits, children’s foods, ice creams, and sweets. The agronomic and storage conditions associated with cocoa beans are favourable for mould growth, mainly Penicillium spp., and consequently OTA biosynthesis is not unexpected. An initial study on OTA in cocoa found that it was present at detectable levels in 67% of analyzed samples. There was no correlation between OTA and visible mould on the beans, or geographic source of the beans. OTA was found at lower levels in cocoa butter than in the non-fat fraction (powder or cake) (Beckett, 1994). In a 1998 survey, the OTA contamination in chocolate bars and cocoa powder was generally low, although OTA was detected in all 20 samples of cocoa powder analysed and three out of four chocolate bars. Considering chocolate samples, 75% of samples were positive for OTA, but at low levels. It was concluded that there is little cause of concern about the level of OTA in cocoa and chocolate. However, wine and beer are also targets (Mateo et al., 2007).

A survey of the levels of OTA contaminations in ready-for-sale cocoa bean samples collected from farmers in three different states in Nigeria showed that out of 59 samples analyzed, greater than 90% were positive for OTA, with concentrations ranging from 1.0 to 277.7 µg kg⁻¹ (Dongo et al., 2008).

Kolanuts which are also used in the production of beverages (in Nigeria) have also been found to be contaminated with OTA. The main center of kola nut production in West Africa is Nigeria, Ghana and the Cote d’Ivoire. Annual production from these countries is in excess of 250,000 tons. Nigeria, however, is the primary producing country. According to a study by Dongo et al. (2007), carried out in Ibadan, Nigeria, 49 out of 50 kola nuts samples tested for contamination contained detectable levels of OTA (98%). In a country where the chewing and eating of kola nuts is a common ‘trado-sociocultural’ practice, this invariably presents an additional public health burden of negative significance.

**Sampling and analyses**

Generally, proper sampling and sample comminution are regular critical steps in arriving at precise results during analytical procedures for OTA (Macarthur et al., 2006; Tittlemier et al., 2011). The levels of OTA in foodstuffs are regulated in several countries, so reliable and sensitive methods are necessary for its determination (Scott, 2002). The AgraQuant® ELISA kits, by Romer Labs, will deliver quantitative results within 15 minutes. There are immunochemical techniques for determination (Meulenburg 2012), just as the Automated On-line Solid-Phase Extraction–Liquid Chromatography–Electrospray Tandem Mass Spectrometry Method and HPLC with Fluorometric Detection (HPLC–FLD) and Immunoaffinity Cleanup have also given reliable results (Bacaloni et al., 2005; Solfrizzo et al., 2008). Determination can be sole (Vargas et al., 2004, 2006) or joint with other accompanying mycotoxins. For example, simultaneous determination were recorded with aflatoxin (Lattanzio et al., 2007; Hierro et al., 2008) patulin (Al-Hazmi, 2010) and DON (Biselli et al., 2008) Available test kits include Ochra Test WB and Myco6 in 1, as well as the HPLC and LC-MS/MS. The HPLC can either be used separately as used in Saudi Arabia and south Africa (Shephard et al., 2003; Al-Hazmi, 2010) or to validate ELISA test results (Zheng et al., 2005) or as independent reliable detection equipment (Ramesh and Jayagouda, 2014). Also, highly stable colorimetric aptamer sensors have been reliably applied for detection (Lee et al., 2014) As at date, there are no regulatory standards for both feeds and foods in Japan.

OTA is neither stored nor deposited in the body, but numerous laboratory and animal studies clearly demonstrate that it is distributed via the blood mainly to the kidneys (Hult and Fuchs, 1986). Human chronic nephropathy in Tunisia was reported by Abid et al. (2003). Regional selectivity to ochratoxin A in rat brain was confirmed by Belmadani et al. (1998) In several mammalian species, even at low doses, OTA is nephrotoxic, which is likely to hold true in humans. There is also a direct link between dietary OTA and the level of the toxin in animal blood (Hult et al., 1980). Despite the numerous epidemiological studies performed, the causality of OTA exposure with human nephropathies has never been proven (WHO, 2001).

The usual investigative approach is to analyze OTA in foods and in biological fluids (mainly plasma) of a healthy population and/or restricted groups of patients suffering from nephropathies. Many studies conclude a possible involvement of OTA in the etiology of a fatal human disease referred to as Balkan Endemic Nephropathy (BEN) (Stoev, 1998), which is found in some regions of Bosnia and Herzegovina, Bulgaria, Croatia, Serbia, and Romania (Petkova-Bocharova et al., 2002), even though
definitive causal link to Balkan endemic nephropathy and the etiology of the characteristic urothelial tumors also remain to be established. (O’Brien and Dietrich, 2005). First in Bulgaria, and afterwards in other countries where BEN is present, an unusually high incidence of urinary tract tumors was noted (Ceovic et al., 1992; Pfohl-Leszkwicz et al., 2002). Several epidemiological studies have been conducted in countries in northern Africa, such as Egypt (Wafa et al., 1998), Algeria (Khalef et al., 1993), Morocco (Filali et al., 2002) and, particularly, Tunisia (Eko-Ebongue, 1994; Maarou et al., 1995). It is a key factor in the development of urinary tract tumors (Creppy, 1999) and it is nephrotoxic to animals. OTA and is among the strongest carcinogenic compounds that affect rat and mice, in which the kidney is the principal site and the liver as the major secondary site of tumor formation (Petzinger and Weidenbach, 2002; Aish et al., 2004), even when the possibility of an additive in the presence of other mycotoxins and nutrients have been established (Stormer and Heiby, 1996; Sednikova et al., 2001).

Impact on livestock

Clinical indications of ochratoxosis include kidney enlargement and failure, increase water intake and attendant equivalent release through urination, oedema in piglets and reduced reproductive capacity. Ochratoxin A is known to be dangerous to pigs even at levels close to 0.2ppm (Krogh, 1991; Mantle et al., 2012).

Just like other mycotoxins, country and occupation based distribution pattern can also be reported for OTA (Bankole and Adebanjo, 2003). Ochratoxin A (OTA) residues are common in countries in the temperate and cold areas of the northern hemisphere, such as Italy (Micco et al., 1991,1995; Miraglia et al., 1995), Switzerland (Zimmerli and Dick, 1995), Sweden (Bretholtz-Emanuelsson et al., 1993), and Germany (Gareis et al.,1988). It affects both the young and old. (Kuiper-Goodman et al. 2010) The risk is probably higher for the non-vegetarians since they consume contaminated cereals and the animal products. It is found all over the world, from Egypt (Hassan et al., 2006) Chile (Munoz et al., 2010) to Canada (Ominski et al., 1996; Ng et al., 2009) and Portugal (Duarte et al., 2010).

Economic damage due to ochratoxin A

Over 50 developing countries grow coffee earning over US$20 billion per year, the second largest source of export revenue after oil. For some countries, coffee comprises up to 3/4 of export income, and contamination of such an important product by ochratoxin A can incur untold damage to local economies if left uncontrolled. As discussed above, the threat of OTA to coffee beans and human health, as well as hygienic and regulatory control measures have been addressed. An expert economic analysis reports a worldwide rejection rate of 3% due to ochratoxin A contamination and warns that this can result in a loss of 300 million € (over $470 million) per year. An ounce of prevention with another ounce of regulatory monitoring can drastically reduce this economic damage. During the initial phase of wine processing OTA was detected in grape (Esti et al., 2012).

Prevention of exposure to ochratoxins

In some countries like Canada, certain are targeted for special focus. According to Good Grading Guides of Canada the crops include barley, oats and wheat all with the overall intention of keeping their moisture level safe. Generally, other attractive interventions include:

Good agricultural practices

The growth of the mould and subsequent production of OTA is dependent upon several factors including temperature, humidity, and water activity during the harvesting, drying and storage of the crops (Dongo et al., 2007). Consequently, the role which good agricultural practices plays in mitigating the production of OTA along any length of the food chain cannot be over emphasized. Agronomic practices have been shown to have profound effect on mycotoxins contamination of crops in the field.

i. Early harvesting — Early harvesting reduces fungal infection of crops in the field before harvest and consequent contamination of harvested produce. Even though majority of farmers in Africa are well aware of the need for early harvesting, unpredictable weather, labour constraint, need for cash, threat of thieves, rodents and other animals compel farmers to harvest at inappropriate time (Amin, 1983; Rachaputti et al., 2002).

ii. Proper drying—Rapid drying of agricultural products to low moisture level is critical as it creates less favourable conditions for fungal growth and proliferation, insect infestation and helps keep longer. During storage, transportation and marketing, maintenance of low moisture levels should be maintained by avoiding leaking roofs and condensation arising from inadequate ventilation.

iii. Sanitation — Basic sanitation measures such as removal and destruction of debris from previous harvest would help in minimizing infection and infestation of produce in the field (Cleveland et al., 2003). Cleaning stores before loading new produce has been shown to be correlated with reduced aflatoxin levels (Hell et al., 2000).

iv. Proper storage — To preserve quality in storage, it is necessary to prevent biological activity through adequate drying to less than 10% moisture, elimination of insect
activity that can increase moisture content through condensation of moisture resulting from respiration, low temperatures, and inert atmospheres (Turner et al., 2005).

v. Insect management — The level of insect damage influences the extent of mycotoxins contamination. Avantaggio et al. (2002) found that insect damage of maize is good predictor of mycotoxins contamination. Insects carry spores of mycotoxins producing fungi from plant surfaces to the interior of the stalk or kernels or create infection wounds through their feeding habits (Munkvold, 2003). Therefore, proper management of insect pests through any appropriate control strategy would reduce mycotoxins contamination problem.

vi. Other methods — Cultural practices including crop rotation, tillage, and management of irrigation and fertilization, have limited effects on infection and subsequent mycotoxins accumulation (Munkvold, 2003; Champeil et al., 2004). For an acceptable storage situation against OTA, Magan and Aldred has proposed the following permissible and safe moisture content of 14-14.5% for wheat and barley; 14% for maize; 13-14% for rice and 7-8% for rape seed.

**Biological control**

The International Institute for Tropical Agriculture (IITA) has for the last couple of years been researching on biological control of mycotoxins-producing fungi through competitive exclusion strategy. The organization's researchers have found a less toxigenic strain of A. flavus that grows on grain stored under warm humid conditions, which can displace harmful strains that produce large amounts of toxins. Masoud and Kalttof (2006) reported in vitro inhibition of OTA production by A. ochraceus by three yeasts (Pichia anomala, P. kluveri and Hanseniaspora uvarum) No in-field competitive exclusion strategy has been found in relation to OTA. Logrieco (2013) showed that Beauveria bassiana ITEM-1559 is a reliable bioinsecticide against Lobesia botrana and that grape moth biocontrol is a strategy to reduce OTA contamination. Shi et al., 2014, also reported a successful biocontrol and biodegradation by Bacillus subtilis CW 14 while de Felice et al. (2008) had earlier investigated the activity of Aureobasidium pullulans in lowering ochratoxin A contamination. Similar promising efforts included that of Ponsone et al, (2012).

**Chemical control**

Appropriate use of pesticides during the production process could help in minimizing the fungal infection or insect infestation of crops and consequently mycotoxin contamination. However, use of fungicides is being discouraged due to economic reasons and growing concern for environment and food safety issues. Bertelli et al. (2005) studied the effect of wine and ethanol on the nephrotoxicity of OTA, they found that the red wine, but not ethanol, protected against the nephrotoxicity of OTA by limiting its oxidative damage.

**Decontamination**

Although prevention of growth and mycotoxin production of fungi on plants and in feedstuffs is usually considered as the best approach to impede the harmful effects of mycotoxins on animal and human health, detoxification of contaminated agricultural products is also of prime importance. Decontamination of food/feed contaminated with ochratoxins could be achieved through either chemoprotection or enterosorption. Essential oils and aqueous extracts of Aframomum danielli were recently reported to reduce OTA in spiked cocoa powder by between 64 and 95% Aroyeun and Adegoke (2007). Although ochratoxin molecule is stable, it is acknowledged that around 40 to 90% of OTA is destroyed during roasting of coffee bean. It is generally not advisable to mix ‘non conform’ items with ‘conform’ ones as a way to reduce ochratoxin contamination (EC 2001).

**Legislation**

Data on mycotoxin exposure and/or risk assessment are available in the literature for OTA and different tolerable daily intakes (TDI) have been suggested over the last 15 years. In 1998, the European Commission's Scientific Committee on Food (SCFOO, 1998) recommended that it would be prudent to minimize exposure to OTA as much as possible, to below 5 ng/kg/BW/day. A cautious TDI (5 ng/kg BW) has also been proposed by the Working Group of the Nordic Council of Ministers (Olsen et al., 1991), whereas the Canadian authority proposed a TDI in the range 1.2 to 5.7 ng/kg BW (Kuiper-Goodman, 1996). The currently accepted virtually safe dose (VSD) for human renal cancer risk is 0.2 ng/kg/day (O’Brien and Dietrich 2005). According to the European Union, and with regard to cereal derived products, OTA contamination was fixed to 3 µg/kg. This regulation fixes also the contamination of dry grapes to a limit of 10 µg/kg (EC 2002). These differences in recommendations also reflect differences in risk management measures, resulting in varying legal limits applied to different commodities and to the same commodity in different countries (Walker, 2002). In any case, as pointed out by Skaug (1999), to date OTA risk assessments do not differentiate between risk to adults and children. The latter represent a particularly sensitive population that warrants a customized TDI, considering the unfavorable conditions.
dose/body weight ratio. Some countries have set limits for their food items. Table 1.

CONCLUSION

OTA is among the most common mycotoxins, the one that should be monitored with the maximum attention because of its occurrence in almost all foods, thus leading to potentially high total dietary intake and therefore an enlarged risk domain. Here in Africa where there is paucity of data on the occurrence of OTA, governments should team up with all other relevant stakeholders to conduct country wide assessments for OTA levels in foods and food products. Baseline assessment data so collected will aid in generating relevant results which in turn will serve as guidelines for establishing standard regulatory limits for OTA in foods for human consumption and also in animal feeds. In Africa, regulated policies should be enforced to protect the health of the country and to save the source of our revenue by getting the best return out of our agricultural products. Awareness of what ochratoxin A are and the dangers that they pose to human and animal health could be done through government bodies, private organizations, and non-governmental organizations. At present, the current Africa Union effort i.e Partnership for Aflatoxin Control in Africa (PACA) is a good starting point. However, for an effective holistic food and feed safety programme and policy, all regulated mycotoxins should attract immediate attention and should be focussed on at once.

REFERENCES


Belmadani A, Tramu G, Betbeder AM, Steyn PS, Creppy EE (1998). Regional selectivity to ochratoxin A, distribution and cytotoxicity in rat brain Archives of Toxicology. 72(10), 656-662


Table 1. Ochratoxin A limits for various countries (April 2011)

<table>
<thead>
<tr>
<th>Country</th>
<th>Product</th>
<th>Ochratoxin A limit (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iran (Duarte et al 2010)</td>
<td>Wheat</td>
<td>5</td>
</tr>
<tr>
<td>Israel (Duarte et al 2010)</td>
<td>Cereals, cereal products</td>
<td>50</td>
</tr>
<tr>
<td>Switzerland (Duarte et al 2010)</td>
<td>All foodstuffs</td>
<td>5</td>
</tr>
<tr>
<td>Turkey (Duarte et al 2010)</td>
<td>Raw grain</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Food made from grain</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Unprocessed cereals</td>
<td>5</td>
</tr>
<tr>
<td>European Union EC2006</td>
<td>All products made from unprocessed cereals, intended for direct human consumption</td>
<td>3</td>
</tr>
<tr>
<td>China/USDA 2010</td>
<td>Cereals</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Legumes</td>
<td>5</td>
</tr>
<tr>
<td>USA/USDA 2010</td>
<td>FDA has not set advisory limits or action levels for ochratoxin A in any commodity</td>
<td>5</td>
</tr>
</tbody>
</table>


Kuiper-Goodman T, Scott PM (2000). Risk Assessment of the Mycotoxin Ochratoxin A. Biomedical Environmental Science, 2(1):
Ochratoxin A. Food Addit. Contam, 16:75-78.
Toxicol, 21:241-245.