CODEX ALIMENTARIUS
INTERNATIONAL FOOD STANDARDS

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World Health Organization

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CODE OF PRACTICE FOR THE PREVENTION AND REDUCTION OF MYCOTOXIN CONTAMINATION IN CEREALS

CAC/RCP 51-2003

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1. INTRODUCTION

1.1 The complete elimination of mycotoxin contaminated commodities is not achievable at this time. The elaboration and acceptance of a General Code of Practice by Codex will provide uniform guidance for all countries to consider in attempting to control and manage contamination by various mycotoxins. In order for this Code of Practice to be effective, it will be necessary for the producers in each country to consider the general principles given in the Code, taking into account their local crops, climate, and agronomic practices, before attempting to implement provisions in the Code. It is important for producers to realize that good agricultural practices (GAP) represent the primary line of defense against contamination of cereals with mycotoxins, followed by the implementation of good manufacturing practices (GMP) during the handling, storage, processing, and distribution of cereals for human food and animal feed.

1.2 The recommendations for the reduction of mycotoxins in cereals are divided into two parts: recommended practices based on Good Agricultural Practice (GAP) and Good Manufacturing Practice (GMP); a complementary management system to consider in the future is Hazard Analysis Critical Control Point (HACCP) principles.

1.3. This General Code of Practice contains general principles for the reduction of various mycotoxins in cereals that should be sanctioned by national authorities. National authorities should educate producers regarding the environmental factors that promote infection, growth and toxin production in cereal crops at the farm level. Emphasis should be placed on the fact that the planting, preharvest and postharvest strategies for a particular crop will depend on the climatic conditions of that particular year, taking into account the local crops, and traditional production conditions for that particular country or region. There is need to develop quick, affordable and accurate test kits and associated sampling plans that will allow testing of grain shipments without undue disruption of operations. Procedures should be in place to properly handle, through segregation, reconditioning, recall or diversion, cereal crops that may pose a threat to human and/or animal health. National authorities should support research on methods and techniques to prevent fungal contamination in the field and during harvest and storage.

2. RECOMMENDED PRACTICES BASED ON GOOD AGRICULTURAL PRACTICES (GAP) AND GOOD MANUFACTURING PRACTICES (GMP)

2.1 Planting

2.1.1. Consider developing and maintaining a crop rotation schedule to avoid planting the same commodity in a field in two consecutive years. Wheat and maize have been found to be particularly susceptible to *Fusarium* species and they should not be used in rotation with each other. Crops such as potato, other vegetables, clover and alfalfa that are not hosts to *Fusarium* species should be used in rotation to reduce the inoculum in the field.

2.1.2 When possible and practical, prepare the seed bed for each new crop by plowing under or by destroying or removing old seed heads, stalks, and other debris that may have served, or may potentially serve as substrates for the growth of mycotoxin-producing fungi. In areas that are vulnerable to erosion, no-till practices may be required in the interests of soil conservation.

2.1.3 Utilize the results of soil tests to determine if there is need to apply fertilizer and/or soil conditioners to assure adequate soil pH and plant nutrition to avoid plant stress, especially during seed development.

2.1.4 When available, grow seed varieties developed for resistance to seed-infecting fungi and insect pests. Only seed varieties recommended for use in a particular area of a country should be planted in that particular area.

2.1.5 As far as practical, crop planting should be timed to avoid high temperature and drought stress during the period of seed development and maturation.

2.1.6 Avoid overcrowding of plants by maintaining the recommended row and intra-plant spacing for the species/varieties grown. Information concerning plant-spacing may be provided by seed companies.

2.2 Preharvest

2.2.1 Minimize insect damage and fungal infection in the vicinity of the crop by proper use of registered insecticides, fungicides and other appropriate practices within an integrated pest management program.

2.2.2 Control weeds in the crop by use of mechanical methods or by use of registered herbicides or other safe and suitable weed eradication practices.

2.2.3 Minimize mechanical damage to plants during cultivation.

2.2.4 If irrigation is used, ensure that it is applied evenly and that all plants in the field have an adequate supply of water. Irrigation is a valuable method of reducing plant stress in some growing situations. Excess precipitation during anthesis (flowering) makes conditions favourable for dissemination and infection by *Fusarium* spp.; thus irrigation during anthesis and during the ripening of the crops, specifically wheat, barley, and rye, should be avoided.

2.2.5 Plan to harvest grain at low moisture content and full maturity, unless allowing the crop to continue to full maturity would subject it to extreme heat, rainfall or drought conditions. Delayed harvest of grain already infected by *Fusarium* species may cause a significant increase in the mycotoxin content of the crop.

2.2.6 Before harvest time, make sure that all equipment, which is to be used for harvesting and storage of crops, is functional. A breakdown during this critical period may cause grain quality losses and enhance mycotoxin formation. Keep important spare parts available on the farm to minimize time loss from repairs. Make sure that the equipment needed for moisture content measurements is available and calibrated.

2.3 Harvest

2.3.1 Containers (e.g., wagons, trucks) to be used for collecting and transporting the harvested grain from the field to drying facilities, and to storage facilities after drying, should be clean, dry and free of insects and visible fungal growth before use and re-use.

2.3.2 As far as possible, avoid mechanical damage to the grain and avoid contact with soil during the harvesting operation. Steps should be taken to minimize the spread of infected seed heads, chaff, stalks, and debris onto the ground where spores may inoculate future crops.

2.3.3. During the harvesting operation, the moisture content should be determined in several spots of each load of the harvested grain since the moisture content may vary considerably within the same field.

2.3.4 Immediately after harvest, determine moisture levels of the crop; where applicable, dry the crop to the moisture content recommended for storage of that crop. Samples taken for moisture measurements should be as representative of the lot as possible. To reduce the variation of moisture content within a lot, the grain may be moved to another facility (or silo) after the drying process.

2.3.5 Cereals should be dried in such a manner that damage to the grain is minimized and moisture levels are lower than those required to support mould growth during storage (generally less than 15%). This is necessary to prevent further growth of a number of fungal species that may be present on fresh grains, especially *Fusarium* species.

2.3.6 Freshly harvested cereals should be cleaned to remove damaged kernels and other foreign matter. Kernels containing symptomless infections cannot be removed by standard cleaning methods. Seed cleaning procedures, such as gravity tables, may remove some infected kernels. More research is needed to develop practical procedures for separating symptomless infected kernels from those that are not infected.

2.4 Storage

2.4.1 Avoid piling or heaping wet, freshly harvested commodities for more than a few hours prior to drying or threshing to lessen the risk of fungal growth. Sun drying of some commodities in high humidity may result in fungal infection. Aerate the commodities by forced air circulation.

2.4.2 Make sure that the storage facilities include dry, well-vented structures that provide protection from rain, drainage of ground water, protection from entry of rodents and birds, and minimum temperature fluctuations.

2.4.3 Crops to be stored should be dried to safe moisture levels and cooled as quickly as possible after harvest. Minimize the amount of foreign materials and damaged kernels in stored grains. Refer to paragraph 2.4.8 to evaluate the use of approved pesticides.

2.4.4 The mycotoxin level in in-bound and out-bound grain should be monitored when warranted, using appropriate sampling and testing programs.

2.4.5 For bagged commodities, ensure that bags are clean, dry and stacked on pallets or incorporate a water impermeable layer between the bags and the floor.

2.4.6 Where possible, aerate the grain by circulation of air through the storage area to maintain proper and uniform temperature levels throughout the storage area. Check moisture content and temperature in the stored grain at regular intervals during the storage period.

2.4.7 Measure the temperature of the stored grain at several fixed time intervals during storage. A temperature rise of 2-3°C may indicate microbial growth and/or insect infestation. Separate the apparently infected portions of the grain and send samples for analysis. When separated, lower the temperature in the remaining grain and aerate. Avoid using infected grain for food or feed production.

2.4.8 Use good housekeeping procedures to minimize the levels of insects and fungi in storage facilities. This may include the use of suitable, registered insecticides and fungicides or appropriate alternative methods. Care should be taken to select only those chemicals that will not interfere or cause harm based on the intended end use of the grains and should be strictly limited.

2.4.9 The use of a suitable, approved preservative (e.g., organic acids such as propionic acid) may be beneficial. These acids are effective in killing various fungi and thus prevent the production of mycotoxins in grains intended only for animal feed. The salts of the acids are usually more effective for long-term storage. Care must be taken because these compounds can negatively affect the taste and odour of the grain.

2.4.10 Document the harvesting and storage procedures implemented each season by making notes of measurements (e.g., temperature, moisture, and humidity) and any deviation or changes from traditional practices. This information may be very useful for explaining the cause(s) of fungal growth and mycotoxin formation during a particular crop year and help to avoid similar mistakes in the future.

2.5 Transport from storage

2.5.1 Transport containers should be dry and free of visible fungal growth, insects and any contaminated material. As necessary, transport containers should be cleaned and disinfected before use and re-use and be suitable for the intended cargo. The use of registered fumigants or insecticides may be useful. At unloading, the transport container should be emptied of all cargo and cleaned as appropriate.

2.5.2 Shipments of grain should be protected from additional moisture by using covered or airtight containers or tarpaulins. Avoid temperature fluctuations and measures that may cause condensation to form on the grain, which could lead to local moisture build-up and consequent fungal growth and mycotoxin formation.

2.5.3 Avoid insect, bird and rodent infestation during transport by the use of insect-and rodent proof containers or insect and rodent repellent chemical treatments if they are approved for the intended end use of the grain.

3. A COMPLEMENTARY MANAGEMENT SYSTEM TO CONSIDER IN THE FUTURE

3.1 The Hazard Analysis Critical Control Point (HACCP) system is a food safety management system that is used to identify and control hazards within the production and processing system. The general principles of HACCP have been described in several documents.[1,2]

3.2 The HACCP concept is an all-encompassing integrated management system. When properly implemented, this system should result in a reduction of the levels of mycotoxins in many cereal grains. The use of HACCP as a food safety management system has many benefits over other types of management control systems in some segments of the food industry. At farm level, especially in the field, many factors that influence the mycotoxin contamination of cereals are environmentally related, such as weather and insects, and are difficult or impossible to control. In other words, critical control points often do not exist in the

[1] FAO. 1995. The use of hazard analysis critical control points (HACCP) principles in food control. FAO Food and Nutrition Paper No. 58 Rome.

[2] ILSI. 1997. A simple guide to understanding and applying the hazard analysis critical control point concept, ILSI Europe Concise Monograph series. 2nd edition, ILSI Europe, Brussels.

field. However, after harvesting, critical control points may be identified for mycotoxins produced by fungi during storage. For example, a critical control point could be at the end of the drying process and one critical limit would be the water content/water activity.

3.3 It is recommended that resources be directed to emphasizing Good Agricultural Practices (GAPs) at the preharvest level and Good Manufacturing Practices (GMPs) during the processing and distribution of various products. A HACCP system should be built on sound GAPs and GMPs.

3.4 It is also recommended that before further consideration is given to the HACCP system, reference should be made to the Codex Annex to CAC/RCP 1-1969 “Hazard Analysis and Critical Control Point (HACCP) System and Guidelines for its Management”.

3.5 Consideration should also be given to a HACCP manual for mycotoxin control recently published by FAO/IAEA.[3]

3.6 At the Third International Conference on Mycotoxins, which took place in Tunisia in March 1999, one of the general recommendations was that integrated mycotoxin control programs should incorporate HACCP principles in the control of risks associated with mycotoxin contamination of foods and feeds.[4] The implementation of HACCP principles will minimize mycotoxin contamination through applications of preventive controls to the extent feasible in the production, handling, storage and processing of each cereal crop.

[3] FAO/IAEA training and reference center for food and pesticide control, 2001. Manuel on the Application of the HACCP System in Mycotoxin Prevention and Control. FAO Food and Nutrition Paper No. 73. Rome.

[4] FAO. Preventing mycotoxin contamination. Food, Nutrition and Agriculture No. 23, 1999. Food and Nutrition Division, FAO, Rome.

ANNEX 1

PREVENTION AND REDUCTION OF CONTAMINATION BY ZEARALENONE IN CEREAL GRAINS

1. RECOMMENDED PRACTICES BASED ON GOOD AGRICULTURAL PRACTICE (GAP) AND GOOD MANUFACTURING PRACTICE (GMP)

Good Agricultural Practice includes methods to reduce *Fusarium* infection and zearalenone contamination of cereals in the field and during planting, harvest, storage, transport and processing.

1.1 Planting

Refer to paragraphs 2.1.1 – 2.1.6 in the General Code of Practice.

1.2 Preharvest

Refer to paragraphs 2.2.1 – 2.2.6 in the General Code of Practice.

The establishment of *Fusarium* infection in cereal heads during flowering should be monitored before harvest by sampling and determination of infection by standard microbiological methods. Also, mycotoxin content in representative preharvest samples should be determined. Utilization of the crop should be based on prevalence of infection and mycotoxin content of the grain.

1.3 Harvest

Refer to paragraphs 2.3.1 – 2.3.6 in the General Code of Practice.

1.4 Storage

Refer to paragraphs 2.4.1 – 2.4.10 in the General Code of Practice.

1.5 Transport from storage

Refer to paragraphs 2.5.1 – 2.5.3 in the General Code of Practice.

1.6 Processing

Small, shriveled grain may contain more zearalenone than healthy normal grain. Winnowing grains at harvest or later will remove shriveled grain.

1.7 Zearalenone management system based on hazard analysis critical control point system (HACCP)

Refer to paragraphs 3.1 – 3.6 in the General Code of Practice.

ANNEX 2

PREVENTION AND REDUCTION OF CONTAMINATION BY FUMONISINS IN CEREAL GRAINS

1. RECOMMENDED PRACTICES BASED ON GOOD AGRICULTURAL PRACTICES (GAP) AND GOOD MANUFACTURING PRACTICE (GMP)

Good Agricultural Practice includes methods to reduce *Fusarium* infection and fumonisin contamination of cereals during planting, harvest, storage, transport and processing.

1.1 Planting

Refer to paragraphs 2.1.1 - 2.1.6 in the General Code of Practice.

1.2 Preharvest

Refer to paragraphs 2.2.1 – 2.2.6 in the General Code of Practice.

Refer to paragraphs 2.3.1 – 2.3.6 in the General Code of Practice.

The time of harvest for maize should be carefully planned. It has been shown that maize grown and harvested during warm months may have fumonisin levels significantly higher than maize grown and harvested during cooler months of the year.

1.3 Storage

Refer to paragraphs 2.4.1 – 2.4.10 in the General Code of Practice.

1.4 Transport from storage

Refer to paragraphs 2.5.1 – 2.5.3 of the General Code of Practice.

1.5 Fumonisins management system based on hazard analysis critical control point system (HACCP)

Refer to paragraphs 3.1 – 3.6 in the General Code concerning HACCP.

ANNEX 3

PREVENTION AND REDUCTION OF CONTAMINATION BY OCHRATOXIN A IN CEREALS

1. RECOMMENDED PRACTICES BASED ON GOOD AGRICULTURAL PRACTICES (GAP) AND GOOD MANUFACTURING PRACTICE (GMP)

Good Agricultural Practice includes methods to reduce fungal infection and ochratoxin A contamination of cereals during harvest, storage, transport and processing.

1.1 Planting

Refer to paragraphs 2.1.1 – 2.1.6 in the General Code of Practice.

1.2 Preharvest

Refer to paragraphs 2.2.1 – 2.2.6 in the General Code of Practice.

Factors during preharvest that may affect levels of ochratoxin A in harvested grains include frost damage, presence of competitive fungi, excessive rainfall and drought stress.

1.3 Harvest

Refer to paragraphs 2.3.1 – 2.3.6 in the General Code of Practice.

1.4 Preservation

Grain should be allowed to dry as much as possible before harvest consistent with local environment and crop conditions. If unable to harvest the grain when it has a water activity below 0.70, then dry the grain to a moisture content corresponding to a water activity of less than 0.70 (less than 14% moisture content in small grain) as quickly as possible. To avoid ochratoxin A formation, start the drying process immediately after harvest and preferably use heated-air drying. In the temperate climate region, when intermediate or buffer storage is necessary because of low drying capacity, make sure that the moisture content is less than 16%, that the buffer storage time is less than 10 days, and the temperature is less than 20 °C.

1.5 Storage

Refer to paragraphs 2.4.1 – 2.4.10 in the General Code of Practice.

1.6 Transport

Refer to paragraphs 2.5.1 – 2.5.3 in the General Code of Practice.

1.7 Ochratoxin A management system based on hazard analysis critical control points (HACCP)

Refer to paragraphs 3.1 – 3.6 in the General Code of Practice.

ANNEX 4

PREVENTION AND REDUCTION OF CONTAMINATION BY TRICOTHECENES IN CEREAL GRAINS

1. RECOMMENDED PRACTICES BASED ON GOOD AGRICULTURAL PRACTICES (GAP) AND GOOD MANUFACTURING PRACTICE (GMP)

Good Agricultural Practices includes methods to reduce *Fusarium* infection and tricothecene contamination of cereals during planting, harvest, storage, transport and processing.

1.1 Planting

Refer to paragraphs 2.1.1 – 2.1.6 in the General Code of Practice.

1.2 Preharvest

Refer to paragraphs 2.2.1 – 2.2.6 in the General Code of Practice.

Do not permit mature grains to remain in the field for extended periods of time, particularly in cold, wet weather. T-2 and HT-2 toxins are not usually found in grains at harvest, but can result from grains that are water-damaged in the field or grains that become wet at harvest or during storage.

Refer to the second subparagraph of paragraph 1.2 in Annex 1.

Cereal growers should maintain close relations with local cereal trade groups. Such groups should be important sources of information and advice regarding choice of appropriate plan protection products, cultivars and strains that will take into account those resistant to *Fusarium* and are available for their location.

1.3 Harvest

Refer to paragraphs 2.3.1- 2.3.6 in the General Code of Practice.

1.4 Storage

Refer to paragraphs 2.4.1 – 2.4.10 in the General Code of Practice.

Be aware that cereal grains may be contaminated by more than one tricothecene mycotoxin along with their derivatives; therefore simple, rapid screening methods should be available for the analysis of several tricothecenes. Zearalenone, which is not a tricothecene, has been noted to regularly co-occur in cereals contaminated with DON and other tricothecenes.

1.5 Transport from storage

Refer to paragraphs 2.5.1 – 2.5.3 in the General Code of Practice.

1.6 Tricothecene management system based on hazard analysis critical control point system (HACCP)

Refer to paragraphs 3.1 – 3.6 in the General Code of Practice.

ANNEX 5

PREVENTION AND REDUCTION OF AFLATOXINS AND OCHRATOXIN A CONTAMINATION IN SORGHUM AND SORGHUM PRODUCTS

1. INTRODUCTION

Good Agricultural Practices include methods to reduce the development of aflatoxin- and ochratoxin A-producing fungi and their toxins contamination consequently of sorghum in the field during planting, harvest, storage and transport; and processing.

2. PLANTING

Refer to paragraphs 2.1.1 – 2.1.6 of General Code of Practice.

Avoid planting sorghum on the land where groundnut or other highly susceptible crops were cultivated in the previous year because such soils are likely to be contaminated with *Aspergillus flavus and A. parasiticus.*

Do not grow sorghum in or close to cocoa trees, coffee bean plants or grape vines as these crops are highly susceptible to ochratoxigenic fungi and ochratoxin A contamination and thus will inoculate the soil with *Aspergillus ochraceus* or *Penicillium verrucosum* in tropical and temperate climates, respectively with consequent carryover to the sorghum grains.

As far as practical, crop planting should be timed in such a manner to avoid high humidity during the period of pollination, flowering and/or fertilization. Fungi tend to produce mycotoxins (particularly ergot alkaloids) in such climate conditions.

If available and cost effective, extension officers should assist the farmers in procuring and releasing atoxigenic *A.flavus* and *A.parasiticus* into the agricultural environment to suppress the natural occurrence of the aflatoxigenic fungi following the instructions of the manufacturer.

3. PREHARVEST

Refer to paragraphs 2.2.1 – 2.2.6 in the General Code of Practice.

4. HARVEST

Refer to paragraphs 2.3.1 – 2.3.6 in the General Code of Practice.

Plants damaged and/or infested by pests should be harvested separately.

Avoid stacking the harvested produce when it has a high moisture content, including the panicle, for unduly long periods to prevent fungal growth as spores from panicle will serve as inocula.

Sun drying should be done on clean surfaces; grains should be protected from rain and dew during this process. Drying could also be done using mechanical dryers. Flat bed and re-circulating batch driers are adequate for small scale operations while using continuous flow-dryer will suffice for large scale drying for long storage periods.

5. STORAGE

Refer to paragraphs 2.4.5 – 2.4.10 of the General Code of Practice for types of storage facility to use and documentation of harvesting and storage procedure.

Packaging materials that allow aeration of their contents are preferable.

6. TRANSPORT

Refer to paragraphs 2.3.1 in the General Code of Practice for transport to and from storage.

7. PROCESSING

Sorghum grains for human consumption are usually processed to sorghum flour, from which sorghum dough, meals and other foods are prepared. In general, the process consists of husking, polishing, grinding and scouring. Sorghum grains are also used as feed and care must be taken to maintain proper isolation between good lots and bad lots so that mycotoxin contamination can be avoided.

7.1 Flour

Start with high quality, mature grains which are free from mechanical, insect or mould damage.

Precaution must be taken to reject grains with signs of pest damage or mould growth because of the risk of their bearing aflatoxins and ochratoxin A. Aflatoxins and ochratoxin A test results should be known before allowing lots of raw grains to be processed. Any lot showing raw grains with unacceptable levels of mycotoxins should not be accepted.

Mould infected and/or damaged kernels should be separated and discarded in order to prevent their entry into the food chain and feed manufacturing process.

Cleanse processing equipment and environment thoroughly before and after grinding a batch of produce using approved disinfectant in order to reduce risk of cross contamination.

Commence grain processing with at least one of the following food processing techniques that have been shown to reduce aflatoxin levels in grains: washing, wet and dry milling, grain cleaning, dehulling, roasting, baking and frying.

A major source of mycotoxin contamination in the sorghum traditional processing line is unwholesome household storage of sorghum flour before use. Therefore avoid keeping flour for long periods of time, but if it is unavoidable then it should be stored in proper storage containers and conditions at safe moisture levels with minimum temperature changes. Such containers must deter insect and rodent infestation.

7.2 Beer

The steeping process (soaking and germination phases) raises the seed moisture level to about 45% which is favourable for fungal growth and mycotoxin production. The situation is problematic if the process is done under open, poor sanitary conditions. Therefore, steeping should be carried out in weatherproof containers under controlled atmosphere.

Poorly preserved starter cultures are significant sources of mycotoxin contamination in the traditional brewing system which underscores the need for starter cultures to be stored in clean, weatherproof jars, free from infestation, and sealed to prevent water, pest and mould from reaching them before use.

8. PACKAGING AND MARKETING

Package sorghum grains and products in containers with qualities described in paragraphs 2.4.1 – 2.4.2 above. Such containers should allow for adequate aeration of the produce during transit and marketing.