codex alimentarius commission

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

WORLD HEALTH ORGANIZATION

JOINT OFFICE: Viale delle Terme di Caracalla 00100 ROME Tel: 39 06 57051 www.codexalimentarius.net Email: codex@fao.org Facsimile: 39 06 5705 4593

Agenda Item 15(d) **CX/FAC 02/21**
November 2001

JOINT FAO/WHO FOOD STANDARDS PROGRAMME

CODEX COMMITTEE ON FOOD ADDITIVES AND CONTAMINANTS
Thirty-fourth Session
Rotterdam, The Netherlands, 11-15 March 2002

PROPOSED DRAFT CODE OF PRACTICE FOR THE PREVENTION (REDUCTION) OF MYCOTOXIN CONTAMINATION IN CEREALS, INCLUDING ANNEXES ON OCHRATOXIN A, ZEARALENONE, FUMONISINS AND TRICOTHECENES

Governments and international organizations wishing to submit comments on the following subject matter are invited to do so **no later than 1 January 2002** as follows: Netherlands Codex Contact Point, Ministry of Agriculture, Nature Management and Fisheries, P.O. Box 20401, 2500 E.K., The Hague, The Netherlands (Telefax: +31.70.378.6141; E-mail: info@codexalimentarius.nl, with a copy to the Secretary, Codex Alimentarius Commission, Joint FAO/WHO Food Standards Programme, FAO, Viale delle Terme di Caracalla, 00100 Rome, Italy (Telefax: +39.06.5705.4593; E-mail: Codex@fao.org).

COMMENTS

1. Governments and international organizations are invited to comment at Step 3, as directed above, on the attached proposed draft Code of Practice for the Prevention of Mycotoxin Contamination in Cereals (Appendix I), including Annexes on Zearalenone (Annex 1), Fumonisins (Annex 2), Ochratoxin A (Annex 3) and Tricothecenes (Annex 4), which will be considered at the forthcoming 34th Session of the Codex Committee on Food Additives and Contaminants.

BACKGROUND

2. The 33rd Session (March 2001) of the Codex Committee on Food Additives and Contaminants (CCFAC) agreed to return the proposed draft Code of Practice to Step 2 for redrafting by the delegation of the United States, in cooperation with Argentina, Canada, Norway, South Africa and Sweden, taking into account the comments received as well as the results of the 56th JECFA evaluation. The Committee agreed that the Code should include a new Annex on Trichothecenes.[1]

INTRODUCTION

3. Mycotoxins are toxic metabolites produced by certain fungi that can grow on various agricultural commodities in the field and/or during storage. The occurrence of these toxins on grains and other commodities

[1] ALINORM 01/12A, paras. 148-151.

susceptible to mold infestation is difficult to predict and is influenced by environmental factors such as temperature, humidity, and extent of rainfall during the preharvest, harvest, and postharvest periods.

4. Mycotoxins may exhibit various toxicological manifestations; some affect the immune system, while others are teratogenic, mutagenic and/or carcinogenic in certain susceptible animal species and are associated with various acute and chronic diseases in domestic animals, livestock, and humans in many parts of the world. In many cases, the effects of mycotoxins on human health, at the levels at which humans are often exposed, are not known.

5. The level of contamination of a commodity with a particular mycotoxin varies with the susceptibility of plants to fungal invasion during all phases of growth, storage and processing. Environmental factors (e.g. normal weather, extreme weather conditions) play a major role in the occurrence of mycotoxins on grains and other commodities. Therefore, the incidence of mycotoxin contamination of a particular food crop can vary from year to year and region to region.

6. The public health implications, the health effects on livestock, and the economic effects of mycotoxin contamination of commodities at the local and international levels create the need to control mycotoxin contamination to that level determined by sound science to be the level of concern.

7. Mycotoxin contamination of field crops before harvest cannot be totally prevented. An integrated approach is needed that includes preharvest management, harvest management and postharvest management. Each of these topics is discussed in greater detail in Appendix 1. Minimizing fungal infection and mycotoxin contamination at the preharvest stage is an important strategy in reducing contamination during the postharvest period.

8. Codes of Practice elaborated in Codex Alimentarius should contain general principles for the reduction of mycotoxins in cereals. National authorities should communicate the general principles to producers, taking into account the local crops, climate and production practices, in order to assist producers in minimizing the level of mycotoxins during production and storage of crops. It is also recommended that national authorities make resources available and/or take the lead to study the causes of unusual fungal growth and mycotoxin formation during particular crop years to assist industry in maintaining and enhancing food safety and market value.

Fusarium Toxins

9. Fusarium species may infect the grain preharvest, have the potential to produce mycotoxins, impair the quality, and reduce the yield of cereal crops. The kernels may be discolored, shriveled and may contain various mycotoxins.[2] Symptomless grains may also be infected and contain mycotoxins. Some *Fusarium* species are strongly pathogenic while others are only weak pathogens or even nonpathogenic. Individual *Fusarium* species are known to produce several mycotoxins, of which fumonisin, zearalenone, deoxynivalenol (DON or vomitoxin), nivalenol, HT-2 toxin, and/or T-2 toxin are often the most important. Variation in mycotoxin producing ability is observed between strains within the same species.

10. Cereal plants are most susceptible to mycotoxin-producing *Fusarium* species infection at anthesis (flowering) and are also susceptible to infection in the period between anthesis and ripening. Frequent rainfall, high humidity and heavy dew during the flowering and early kernel-fill periods favors infection and disease development. Timing, rather than the amount of rain, is the most critical factor when sufficient inoculum is available.[3]

---

[2] Parry, D.W., Jenkinson P., McLeod, L. Fusarium ear blight (scab) in small grain cereals - A review. Plant Pathology 44,207-238, 1995.

[3] Miller J. D. Epidemiology of *Fusarium* ear diseases of cereals. In: Miller J D and Trenholm H L (eds.) Mycotoxin in grain; Compounds other than aflatoxin. Eagan Press, St. Paul Minnesota , 1994, pp 19-36.

11. Practices that will reduce *Fusarium* infection and formation of *Fusarium* toxins in the field and after harvest may differ depending on climate of the region and the type of crop. However, general measures to reduce fungal infection of the crop, such as those described in ALINORM 97/12A, Appendix IX, are also applicable to *Fusarium* toxins.[4]

12. In connection with *Fusarium* infection and mycotoxin formation, certain risk factors have been identified including: precipitation during anthesis and in the period between anthesis and ripening, delayed harvest due to wet weather, use of susceptible varieties, rotation between maize and wheat, a high level of inoculum from the previous year, lodging, and reduced tillage. These risk factors vary from region to region, and crop to crop. However, it has been shown that the degree of *Fusarium* infection increases strongly with increased numbers of risk factors. The number of risk factors should therefore be kept to a minimum.

Trichothecenes

13. Deoxynivalenol, nivalenol, HT-2 toxin, and T-2 toxin all belong to the trichothecene group, which consists of a large number of different fungal toxins. Deoxynivalenol is the one most frequently occurring in cereals, while HT-2 toxin and T-2 toxin are the most toxic ones. The toxicity of trichothecenes is largely due to their ability to inhibit protein synthesis. Common effects are diarrhea, haemorrhaging, skin lesions, and immunosupression.

14. The fungal species responsible for deoxynivalenol contamination are mainly *Fusarium graminearum* and *Fusarium culmorum*, both species strongly pathogenic to cereals. Increased rainfall and high humidity favor infection by these species during anthesis. Nivalenol may be produced by the same species, but is also formed by *Fusarium poae*. HT-2 toxin and T-2 toxin are produced by *F. sporotrichioides* and some other *Fusarium* species. The conditions for formation of these toxins are less studied, but seem to differ somewhat from those for deoxynivalenol.

Zearalenone

15. Zearalenone is also produced mainly by *F. graminearum* and *F. culmorum*. However, nearly all pathogenic *Fusarium* species have the ability to produce the toxin. Zearalenone and its structurally-related metabolites show estrogenic and growth promoter activities in domestic and laboratory animals. The co-occurrence of zearalenone and deoxynivalenol has been reported in cereals in many countries of the world.

16. Zearalenone may occur in most cereals like maize, wheat, barley, oats and rye. Toxin production takes place mainly in the field, but may also occur postharvest. Some surveys have indicated that high contamination levels may occur in maize as well as in maize silage.[5, 6] Infected kernels may be discolored and shriveled. They may contain zearalenone, with or without other *Fusarium* mycotoxins. Symptomless grain may be infected by less pathogenic *Fusarium* species which produce zearalenone and/or other mycotoxins. Immediate drying of cereals after harvest and proper storage can prevent further contamination with zearalenone. Selection and planting of cultivars of cereals that are resistant to species of *Fusarium* should be considered as a practicable means for controlling zearalenone contamination. There is need for the development of better screening and quantitative methodology for measuring zearalenone and its structurally-related metabolites in various cereal crops.

---

[4] Codex Code of Practice for the Reduction of Aflatoxin B_1 in Raw Materials and Supplemental Feedingstuffs for Milk Producing Animals (CAC/RCP 45-1997; Codex Alimentarius Volume 1A).

[5] Kuiper-Goodman, T., Scott P.M., and Watanabe, H. Risk assessment of the mycotoxin zearalenone. Regul Toxicol Pharmacol 7, 253-306, 1987.

[6] Scudamore, K.A., and Livesey, C.T. Occurrence and significance of mycotoxins in forage crops and silage:a review. J Sci Food Agric 77,1-7, 1998 .

Fumonisin

17. Fumonisins are a class of recently identified mycotoxins that are produced mainly by *Fusarium verticillioides* [= *F. moniliforme*], *Fusarium proliferatum* and several other *Fusarium* species in the Liseola section. These toxins occur almost exclusively in maize (corn).

18. There are at least 12 fumonisin analogues that have been identified.[7] Fumonisin B_1 (FB_1) and fumonisin B_2 (FB_2), are believed to be the most abundant and most toxic naturally occurring analogues.[8] The ratio of FB_1/FB_2 is approximately 3:1 in naturally contaminated maize.[9]

19. Fumonisin B_1 has been shown to produce a variety of adverse effects in a number of animal species, such as leukoencephalomalacia in horses, pulmonary edema in swine, and hepatic carcinogenesis in rats. In two long-term studies in rodents, purified fumonisin B_1 caused kidney cancer in male rats and liver cancer in female mice.[13,14]

20. *F. verticillioides* is associated with the occurrence of disease at all stages of maize plant development, infecting the roots, stalks and kernels. It is not only the most common pathogen of maize, it is also among the most common fungi colonizing symptomless maize plants.[15] The maize silks can be infected by airborne conidia from crop residues in the soil.

21. The extent of contamination of maize with fumonisins varies with geographical location, and is found to be highest in the warmer regions of the world.[16,17] Agricultural practices and the maize genotype also play a role in determining the susceptibility of the maize plants to fungal infection and subsequent contamination of the maize.[18]

22. The levels of fumonisin produced in maize are influenced by environmental factors such as temperature, humidity, drought stress and the extent of rainfall during the preharvest and harvesting periods; storage of the harvested maize kernels under improper moisture conditions can result in additional accumulation of fumonisins.[19]

23. Generally, the fumonisin level is not believed to increase during storage as long as proper conditions of grain moisture and temperature are maintained.[15] The control of fumonisin in maize is complicated by the existence of

---

[7] Musser, S.M and Plattner, R.D. Fumonisin composition in cultures of *Fusarium moniliforme, Fusarium proliferatum,* and *Fusarium nygami* . J. Agric Food Chem. 45: 1169-1173, 1997.

[8] Sydenham, E.W.; Shephard, G.S.; and Thiel, P.G. Liquid chromatography determination of fumonisins B_1, B_2 and B_3 in foods and feeds. J Assoc. Off. Anal. Chem. 75: 313-318, 1992.

[9] Ross, P.F.; Rice, L.G.; Osweiler, G.D.; Nelson, P.E.; Richard, J.L.; Wilson, T.M. A review and up-date of animal toxicoses associated with fumonisin-contaminated feeds and production of fumonisins by *Fusarium* isolates. Mycopathologia 117: 109-114, 1992.

[13] National Toxicology Program. 1999. Toxicology and Carcinogenesis Studies of Fumonisin B_1[CAS NO.116355-83-0] in F344/N Rats and B6C3F1 Mice. NTP Technical Report 496. National Institutes of Health Publication NO.99-3955, Research Triangle, North Carolina.

[14] JECFA. Fifty-sixth meeting. Summary and Conclusions. Geneva, 6-15 February, 2001.

[15] Munkvold, G.P. and Desjardins, A.E. Fumonisins in maize-Can we reduce their occurrence? Plant Disease 81(6):556-565, 1997.

[16] Shelby, R.A.; White, D.G.; Bauske,E.M. Differential fumonisin production in maize hybrids. Plant Disease 78:582-584,1994.

[17] Miller, J.D. Factors affecting the occurrence of fumonisin in corn. Abstracts of Papers (p.21) –International Conference on the Toxicology of Fumonisin. June 28-30,1999. Arlington,VA.

[18] Doko, M.B.; Rapior, S.; Visconti, A. and Schjth, J.E. Incidence and levels of fumonisin contamination in maize genotypes grown in Europe and Africa. J Agric. Food Chem. 43:429-434, 1995.

[19] Bacon, C.W.; Bennett, R.M.; Hinton, D.M. and Voss, K.A. Scanning electron microscopy of *Fusarium moniliforme* within asymptomatic corn kernels and kernels associated with equine leukoencephalomalacia. Plant Disease 76(2):144-148, 1992.

several different mating populations belonging to *Fusarium* section Liseola that are commonly found in asymptomatic maize plants. Additionally, fumonisin production by *Fusarium* species other than *F. verticillioides* in section Liseola, and by some related species, complicates the development of maize cultivars resistant to the various fumonisin-producing fungi.

Ochratoxin A

24. Ochratoxin A is a mycotoxin of considerable concern for human health in certain regions of the world. It is classified as a possible human carcinogen,[20] and is also found to affect the immune system and to be nephrotoxic. Normally about 50-80% of the average consumer intake of ochratoxin A is derived from cereals,[21,22] depending on the region of the world and the individual diet. In addition, cereals are principal components of diets of food producing animals and mycotoxins in livestock feeds impact directly on animal health and indirectly on food safety.

25. A large number of fungal species have been reported to produce ochratoxin A, especially in the genera *Penicillium* and *Aspergillus*.[23] Of these fungi, only *Penicillium verrucosum* is known to be consistently associated with cereals, but this has only been studied in the Nordic countries. Two species of black *Aspergillus*, *A. ochraceus* and related species have been reported to produce ochratoxin A. These black and ochre coloured *Aspergilli* have usually been associated with coffee, grapes, spices, and much more infrequently, with cereals. However, these species are likely candidates for ochratoxin A production in cereals in warmer regions.

26. Stored cereals may be invaded by storage fungi, like *P. verrucosum*, when they are not properly dried or growth may start from locally-moistened areas. Surveys from countries with a temperate climate, where *P. verrucosum* is the most important ochratoxin A producer, indicate that the problem of ochratoxin A contamination is mainly associated with post-harvest conditions.[24,25,26,27] The minimum moisture content for growth of *P. verrucosum* is 16-17%. For ochratoxin A production the moisture content needs to be approximately 1% higher. There is less information on ochratoxin A production by *Aspergillus* species in warmer climates, e.g., whether the infection and toxin production start in the field on the growing plant.

27. As for *Fusarium* toxins, practices that reduce ochratoxin A contamination may differ depending on the climate of the region and the type of crop. However, general measures to avoid fungal infection of crops, such as those described in ALINORM 97/12A, Appendix IX, would also be applicable to ochratoxin A.

---

[20] IARC Monographs on evaluation of carcinogenic risks to humans: some naturally occurring substances; food items and constituents, heterocyclic aromatic amines and mycotoxins, Vol. 56:489-521, 1993.
[21] Codex Alimentarius: CX/FAC99/14, Position paper on ochratoxin A.
[22] European Commission, SCOOP-task 3.2.2. : Assessment of dietary intake of ochratoxin A by the population in EU member states, Report EUR 17523 EN (revised version), 1997.
[23] Friisvad, J.C. Revision of the taxonomy of *Penicillium* and *Aspergillius* species producing ochratoxin A. Personal communication, manuscript in preparation, 2000.
[24] Holmberg, T.; Breitholtz-Emanuelsson,A.; Hagggblom, P.; Schwan, O. and Hult, K. *Penicillium verrucosum* in feed of ochratoxin A positive swine herds. Mycopathologia 116:169-176, 1991.
[25] MAFF/DH, Food Safety Information Bulletin No. 49:9, 1994.
[26] MAFF/DH, Food Safety Information Bulletin No. 57:14-15, 1995.
[27] Jonsson, N. and Pettersson, H. Evaluation of different preservation methods for cereal grain based on occurrence of moulds and mycotoxins (in Swedish). JTI-rapport, Lantbruk och Industri Nr 263, Jordbrukstekniska institutet, Uppsala, Sweden, 1999.

APPENDIX I

PROPOSED DRAFT CODE OF PRACTICE FOR THE PREVENTION (REDUCTION) OF MYCOTOXIN CONTAMINATION IN CEREALS

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 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.

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.

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 preharvest or postharvest strategy 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 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.

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

PREHARVEST

4. 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.

5. 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.

6. 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.

7. 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.

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

9. 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.

10. 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.

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

12. Minimize mechanical damage to plants during cultivation.

13. 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 favorable 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.

14. 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.

15. 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.

HARVEST

16. 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.

17. 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.

18. During the harvesting operation it is necessary to check the moisture content in several spots of each load of the harvested grain since the moisture content may vary considerably within the same field.

19. 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.

20. 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.

21. 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 mold 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.

22. 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.

STORAGE

23. 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.

24. 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 paragragh (cc) to evaluate the use of approved pesticides.

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

26. 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.

27. Store at the lowest temperature possible consistent with ambient conditions but avoid temperatures near the freezing point. 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.

28. Measure the temperature of the stored grain at several fixed 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.

29. 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.

30. 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 odor of the grain.

31. 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.

TRANSPORT FROM STORAGE

32. 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 insectides may be useful. At unloading, the transport container should be emptied of all cargo and cleaned as appropriate.

33. 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.

34. 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.

II. A COMPLEMENTARY MANAGEMENT SYSTEM TO CONSIDER IN THE FUTURE

35. 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.[28,29]

36. 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 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.

37. 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.

38. 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, Rev.3 (1997) “Hazard Analysis and Critical Control Point (HACCP) System and Guidelines for its Management”.

39. Consideration should also be given to a HACCP manual for mycotoxin control recently published by FAO/IAEA.[30]

40. 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.[31] 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.

---

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

[29] 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.

[30] HACCP Manuel for Mycotoxin Control. Joint FAO/IAEA Training and Reference Centre for Food and Pesticide Control, *in press*.

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

ANNEX 1

REDUCTION OF CONTAMINATION BY ZEARALENONE IN CEREAL GRAINS

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

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

PREHARVEST

2. Refer to paragraphs 4-15 in the General Code of Practice.

3. 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.

HARVEST

4. Refer to paragraphs 16-22 in the General Code of Practice.

STORAGE

5. Refer to paragraphs 23-31 in the General Code of Practice.

TRANSPORT FROM STORAGE

6. Refer to paragraphs 32-34 in the General Code of Practice

PROCESSING

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

ZEARALENONE MANAGEMENT SYSTEM BASED ON HAZARD ANALYSIS CRITICAL CONTROL POINT SYSTEM (HACCP)

8. Refer to paragraphs 35-40 in the General Code of Practice.

ANNEX 2

REDUCTION OF CONTAMINATION BY FUMONISINS IN CEREAL GRAINS

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

PREHARVEST

1. Refer to paragraphs 4-15 in the General Code of Practice.

HARVEST

2. Refer to paragraphs 16-22 in the General Code of Practice.

3. 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.

STORAGE

4. Refer to paragraphs 23-31 in the General Code of Practice.

TRANSPORT FROM STORAGE

5. Refer to paragraphs 32-34 of the General Code of Practice.

FUMONISINS MANAGEMENT SYSTEM BASED ON HAZARD ANALYSIS CRITICAL CONTROL POINT SYSTEM (HACCP)

6. Refer to paragraphs 35-40 in the General Code concerning HACCP.

ANNEX 3

REDUCTION OF CONTAMINATION BY OCHRATOXIN A IN CEREALS

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

PREHARVEST

1. Refer to paragraphs 4-15 in the Draft General Code of Practice.

2. 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.

HARVEST

3. Refer to paragraphs 16-22 on the Draft General Code of Practice.

PRESERVATION

4. 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.

STORAGE

5. Refer to paragraphs 23-31 in the Draft General Code of Practice.

TRANSPORT

6. Refer to paragraphs 32-34 in the Draft General Code of Practice.

OCHRATOXIN A MANAGEMENT SYSTEM BASED ON HAZARD ANALYSIS CRITICAL CONTROL POINTS (HACCP)

7. Refer to paragraphs 35-40 in the General Code of Practice.

ANNEX 4

REDUCTION OF CONTAMINATION BY TRICHOTHECENES IN CEREAL GRAINS

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

PREHARVEST

1. Refer to paragraphs 4-15 in the General Code of Practice.

2. 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.

3. Refer to paragraph 3 in Annex 1.

4. 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 plant protection products, cultivars and strains that will take into account those resistant to *Fusarium* and are available for their location.

HARVEST

5. Refer to paragraphs 16-22 in the General Code of Practice.

STORAGE

6. Refer to paragraphs 23-31 in the General Code of Practice.

7. Refer to paragraph 6 in Annex 1.

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

TRANSPORT FROM STORAGE

9. Refer to paragraphs 32-34 in the General Code of Practice.

TRICHOTHECENE MANAGEMENT SYSTEM BASED ON HAZARD ANALYSIS CRITICAL CONTROL POINT SYSTEM (HACCP)

10. Refer to paragraphs 35-40 in the General Code of Practice.