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Prevention and Reduction of Food and Feed Contamination

First edition

World Health Organization

Food and Agriculture Organization of the United Nations

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WORLD HEALTH ORGANIZATION

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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THE CODEX ALIMENTARIUS COMMISSION

The Codex Alimentarius Commission is an intergovernmental body with over 180 members established by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO).

The **CODEX** ALIMENTARIUS is the main result of the Commission's work: a set of international food standards, guidelines and codes of practice with the goal to protect the health of consumers and ensure fair practices in the food trade.

PREVENTION AND REDUCTION OF FOOD AND FEED CONTAMINATION
First edition

This first edition contains all the codes of practice related to the prevention and reduction of contaminants (e.g., mycotoxins, heavy metals and chemicals) in foods and/or feeds.

Further information on these texts, or any other aspect of the Codex Alimentarius Commission, may be obtained from:

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

CAC/RCP 51-2003

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.

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 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

Adopted 2003.

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)

Planting

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.

Preharvest

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. 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.

17. 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.

18. 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.

19. 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.

20. 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.

21. 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.

Storage

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.

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 paragraph 29 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. 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 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.

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 insecticides 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.[1,2]

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.

[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.

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. 4 (2003) "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.[3]

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.[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

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 planting, harvest, storage, transport and processing.

Planting

2. Refer to paragraphs 4-9 in the General Code of Practice.

Preharvest

3. Refer to paragraphs 10-15 in the General Code of Practice.

4. 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

5. Refer to paragraphs 16-21 in the General Code of Practice.

Storage

6. Refer to paragraphs 22-31in the General Code of Practice.

Transport from storage

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

Processing

8. 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)

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

ANNEX 2

PREVENTION AND REDUCTION OF CONTAMINATION BY FUMONISINS IN CEREAL GRAINS

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

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

Planting

2. Refer to paragraphs 4-9 in the General Code of Practice.

Preharvest

3. Refer to paragraphs 10-15 in the General Code of Practice.

4. Refer to paragraphs 16-21 in the General Code of Practice.

5. 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

6. Refer to paragraphs 22-31 in the General Code of Practice.

Transport from storage

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

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

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

ANNEX 3

PREVENTION AND REDUCTION OF CONTAMINATION BY OCHRATOXIN A IN CEREALS

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

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

Planting

2. Refer to paragraphs 4-9 in the General Code of Practice.

Preharvest

3. Refer to paragraphs 10-15 in the General Code of Practice.

4. 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

5. Refer to paragraphs 16-21 in the General Code of Practice.

Preservation

6. 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

7. Refer to paragraphs 22-31 in the General Code of Practice.

Transport

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

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

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

ANNEX 4

PREVENTION AND REDUCTION OF CONTAMINATION BY TRICOTHECENES IN CEREAL GRAINS

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

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

Planting

2. Refer to paragraphs 4-9 in the General Code of Practice.

Preharvest

3. Refer to paragraphs 10-15 in the General Code of Practice.

4. 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.

5. Refer to paragraph 4 in Annex 1.

6. 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.

Harvest

7. Refer to paragraphs 16-21 in the General Code of Practice.

Storage

8. Refer to paragraphs 22-31 in the General Code of Practice.

9. 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.

Transport from storage

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

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

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

CODE OF PRACTICE FOR THE REDUCTION OF AFLATOXIN B_1 IN RAW MATERIALS AND SUPPLEMENTAL FEEDINGSTUFFS FOR MILK-PRODUCING ANIMALS

CAC/RCP 45-1997

1. BACKGROUND

1.1 Aflatoxin B_1 contamination of animal feedingstuffs can be a very serious problem, occurring in part due to inadequate storage conditions. Contamination may also occur at the preharvest stage and be exacerbated by inadequate storage conditions. Good cropping practices, use of seed varieties bred for resistance to seed infecting fungi and insect pests as well as the use of appropriate approved pesticides represent reasonable preventive measures to control contamination in the field. Even with application of these practices, conditions created by the environment and/or traditional agricultural procedures may defeat any preventative measures.

1.2 Practices that reduce aflatoxin B_1 contamination in the field and after harvest should be an integral part of animal feedingstuff production, particularly for the export market because of the additional handling and transport steps required to get the product to the final destination. The factors most amenable for prevention of fungal infection and aflatoxin B_1 production involve proper drying and storage of the feedingstuff prior to transport. The problems created by too much moisture are magnified greatly by deficient post harvest crop handling techniques.

1.3 Investigations concerning the biological fate of aflatoxin B_1 (AFB_1) in lactating dairy cattle have demonstrated the transmission of residues into milk, occurring as the metabolite aflatoxin M_1 (AFM_1). Although AFM_1 is considered to be less carcinogenic than AFB_1 by at least an order of magnitude, its presence in dairy products should be limited to the lowest level practicable. The amount of daily ingested AFB_1 which is transferred into milk is in the range of 0.17 to 3.3%.

1.4 To ensure the lowest possible level of AFM_1 in milk, attention should be given to residues of AFB_1 in the lactating dairy animal's daily feed ration.

Adopted 1997.

1.5 To date there has been no widespread government acceptance of any decontamination treatment intended to reduce aflatoxin B_1 levels in contaminated animal feedingstuffs. Ammoniation appears to have the most practical application for the decontamination of agricultural commodities, and has received limited regional (state, country) authorization for its use with animal feed under specified conditions (i.e. commodity type, quantity, animal). Also, research suggests that the addition of the anticaking/binding agent "hydrated sodium calcium aluminosilicate" to aflatoxin contaminated feeds may reduce AFM_1 residues in milk, depending on the initial concentration of AFB_1 in the feed.

2. RECOMMENDED PRACTICES

2.1 Crop production

2.1.1 Prepare seed bed for new crop by destroying or removing the seed heads or fruits (e.g. corn ears, peanuts, etc.) of aflatoxin susceptible crops.

2.1.2 Utilize soil tests if possible to determine fertilizer needs and apply fertilizer and soil conditioners to assure adequate soil pH and plant nutrition to avoid plant stress, especially during seed development.

2.1.3 When feasible, use seed varieties bred for fungal resistance and field tested for resistance to *Aspergillus flavus*.

2.1.4 As far as practicable, sow and harvest crops at times which will avoid high temperature and drought stress during the period of seed development/maturation.

2.1.5 Minimize insect damage and fungal infection by the proper use of appropriate approved insecticides and fungicides and other appropriate practices within an integrated pest management program.

2.1.6 Use good agronomic practice, including measures which will reduce plant stress. Such measures may include: avoidance of overcrowding of plants by sowing at the recommended row and intra-plant spacings for the species/varieties grown; maintenance of a weed free environment in the growing crop by the use of appropriate approved herbicides and other suitable cultural practices; elimination of fungal vectors in the vicinity of the crop; and crop rotation.

2.1.7 Minimize mechanical damage to crops during cultivation.

2.1.8 Irrigation is a valuable method of reducing plant stress in some growing situations. If irrigation is used ensure that it is applied evenly and individual plants have an adequate supply of water.

2.2 Harvest

2.2.1 Harvest crops at full maturity unless allowing the crop to continue to full maturity would subject it to extreme heat, rainfall or drought conditions.

2.2.2 As much as possible avoid mechanical damage during harvest.

2.2.3 Where applicable dry crops to a minimum moisture content as quickly as possible.

2.2.4 If crops are harvested at high moisture levels dry immediately after harvest.

2.2.5 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.

2.2.6 Ensure adequate protection from rain during sun drying.

2.3 Storage

2.3.1 Practice good sanitation for storage structures, wagons, elevators and other containers to ensure that stored crops will not be contaminated. Proper storage conditions include dry, well ventilated structures that provide protection from rain or seepage of ground water.

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

2.3.3 Ensure that crops to be stored are free of mould and insects and are dried to safe moisture levels (ideally crops should be dried to a moisture content in equilibrium with a relative humidity of 70 %).

2.3.4 Prevent insect infestation by the use of appropriate approved insecticides.

2.3.5 Ensure that the storage facilities are free of insects and mould by good housekeeping and/or the use of appropriate approved fumigants.

2.3.6 Prevent access by rodents and birds.

2.3.7 Store at as low a temperature as possible. Where possible aerate commodities stored in bulk through continuous circulation of air through the storage vessel to maintain proper temperature and moisture.

2.3.8 Use of a suitable authorized preservative e.g. an organic acid such as proprionic acid, may be beneficial in that such acids are effective in killing moulds and fungi and preventing the production of mycotoxins. If organic acids are used, it is important that the amounts added are sufficient to prevent fungal growth and is consistent with the products end use.

2.4 Transport

2.4.1 Make sure that transport containers and vehicles are free of mould, insects and any contaminated material by thoroughly cleaning before use or re-use. Periodic disinfestation with appropriate approved fumigants or other pesticides may be useful.

2.4.2 Protect shipments from moisture by appropriate means such as airtight containers, covering with tarpaulins, etc. Care must be taken in the use of tarpaulins to avoid sweating of the commodity that could lead to local moisture and heat build up which are prime conditions for fungal growth.

2.4.3 Avoid insect and rodent infestation during transport by the use of insect resistant containers or insect and rodent repellent chemical treatments.

2.5 Feed production and disposition of AFB_1 contaminated animal feeds

2.5.1 Ensure that milling equipment is kept clean, free of dust and feed accumulation.

2.5.2 Use an appropriate sampling and testing program to monitor outbound and inbound shipments for the presence of AFB_1. Because AFB_1 concentration in shipments may be extremely heterogeneous refer to FAO recommendations for sampling plans. Adjust frequency of sampling and testing to take into account conditions conducive to aflatoxin B_1 formation, the regional source of the commodity and prior experience within the growing season.

2.5.3 If aflatoxin B_1 is detected, consider one or more of the following options. In all cases ensure that the aflatoxin B_1 level of the finished feed is appropriate for its intended use (i.e. maturity and species of animal being fed) and is consistent with national codes and guidelines or qualified veterinary advice.

2.5.3.1 Consider the restriction of AFB_1 contaminated feed to a percentage of the daily ration such that the daily amount of AFB_1 ingested would not result in significant residues of AFM_1 in milk.

2.5.3.2 If feed restriction is not practical, divert the use of highly contaminated feedingstuffs to non-lactating animals only.

CODE OF PRACTICE FOR THE PREVENTION AND REDUCTION OF AFLATOXIN CONTAMINATION IN TREE NUTS

CAC/RCP 59-2005

INTRODUCTION

1. The elaboration and acceptance of a Code of Practice for tree nuts by Codex will provide uniform guidance for all countries to consider in attempting to control and manage contamination by various mycotoxins, specifically aflatoxins. In order for this Code of Practice to be effective, it will be necessary for the producers and processors in each country to consider the general principles given in the Code, taking into account the agronomic and extractivistic[1] practices associated with the tree nuts produced in their regions, before attempting to implement provisions enumerated in the Code. It is important for producers or extractivists to realize that Good Agricultural Practices (GAP) represent the primary line of defence against contamination of nuts with aflatoxins, followed by the implementation of Good Manufacturing Practices (GMP) Good Extractivistic Practices and Good Storage Practices (GSP) during the handling, processing, storage and distribution of nuts for human consumption. Only by effective control at all stages from the farm through to processing can excellent quality of the final product be assured. However, the complete elimination of mycotoxin contaminated commodities, including tree nuts, is not achievable at this time.

2. This Code of Practice applies to all varieties of tree nuts of commercial and international concern, including almonds (*Prunus amygdalus*), Brazil nuts (*Bertholletia excelsa*), cashews (*Anacardium occidentale*), hazel nuts (*Corylus* spp.), macadamia nuts (*Macadamia* spp.), pecans (*Carya* spp.), pine nuts (*Pinus* spp.), chestnuts (*Castanea* spp.), pistachio nuts (*Pistacia* spp.) and walnuts (*Juglans* spp.). It contains general principles for the reduction of aflatoxins in tree nuts that should be sanctioned by national authorities. National authorities should educate producers, extractivists, transporters, storage keepers and other operators of the production chain regarding the practical measures and environmental factors that promote infection and

[1] Brazil Nuts Extractivism: this is the process of collection and primarily handling of Brazil nuts in the Amazon rainforest where Brazil nut trees grow in their natural environment.

Adopted 2005. Revisions 2006, 2010.

growth of fungi in tree nuts resulting in the production of aflatoxin in orchards or in the forest (areas of extractivism). Emphasis should be placed on the fact that the planting, pre-harvest and post-harvest strategies for a particular nut crop depends on the climatic conditions of a particular year, and traditional production, harvesting and processing practices followed in a particular country or region. For Brazil nuts, the specific conditions related to extractivism have to be taken into account. National authorities should also support research on methods and techniques to prevent fungal contamination in the orchard or in the forest and during the harvesting, processing and storage of tree nuts. An important part of this is the understanding of the ecology of *Aspergillus flavus/parasiticus* in connection with tree nuts.

3. Fungi in the *Aspergillus* species are rapidly growing hyaline molds that are common opportunists found in the soil and on decaying matter. Their colonies are usually yellow, yellow-green, yellow-brown, or green; granular, velvety, or cottony; and have a white peripheral apron and a distinct margin.

4. The aflatoxin-producing *Aspergillus* species, and consequently dietary aflatoxin contamination, are ubiquitous in areas of the world with hot humid climates. *Aspergillus flavus/A. parasiticus* cannot grow or produce aflatoxins at water activities less than 0.7; relative humidity below 70% and temperatures below 10 °C. Under stress conditions such as drought or insect infestation, aflatoxin contamination is likely to be high. Improper storage conditions can also lead to aflatoxin contamination after crops have been harvested. Usually, hot humid conditions lead to mould growth on the stored food and to high levels of aflatoxins.

5. Some procedures used to reduce and prevent aflatoxin production include: (1) selection of resistant varieties, if practicable, (2) minimize the presence of insects and other pests in the orchard during the growing phase, (3) minimize physical damage to nuts during harvesting and transportation, and (4) ensure that nuts are properly cleaned, dried and labelled when placed in a storage facility equipped with temperature and moisture controls.

1. SCOPE

6. This document is intended to provide guidance for all persons involved in producing tree nuts for entry into international trade for human consumption. All tree nuts should be prepared and handled in accordance with general hygienic principles and practices that are pointed out in appropriate sections of

the Code of Hygienic Practice for Tree Nuts[2], and the General Principles of Food Hygiene[3], which are relevant for all foods being prepared for human consumption. These codes of practice indicate the measures that should be implemented by all persons that have the responsibility for assuring that food is safe and suitable for consumption.

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

2.1 Criteria for orchard sites or picking sites

7. Growers should obtain background information concerning the potential orchard site to determine if: (1) the soil composition is ideal to support the growth of the desired tree variety(2) there is adequate drainage of ground water (3) there are any environmental factors inherent to that location (such as wind-, soil- and dust-borne contaminants and pollutants) that might have a negative impact on safety concerns for human foods and (4) there is an available source of water suitable for irrigation and other purposes.

8. Neighbouring fields should not be used for plants which are known to be easily infected with *A. flavus/parasiticus* (e.g. maize) and consequently serve as a source of infection (spores spread by winds, insects, etc). Furthermore plants carrying specific insects that damage tree nut kernels, which may be a vector in the infection process, should also be avoided.

9. If the tree nuts are obtained from around cultivation, the picker should ascertain that there are not any environmental factors inherent to that location (such as wind-, soil- and dust-borne contaminants and pollutants) that might have a negative impact on safety concerns for tree nuts.

2.2 Planting

10. In designing the layout of the orchard, information concerning plant spacing may be obtained from plant breeders or agricultural personnel. Adequate spacing is necessary so that trucks and equipment needed for spraying trees can be accommodated and that ventilation of the orchard is maintained to reduce the growth of fungi.

[2] Code of Hygienic Practice for Tree Nuts, CAC/RCP 6-1972.
[3] General Principles of Food Hygiene, CAC/RCP 1-1969.

11. Where possible and practical, the orchard surface area should be prepared before planting by destroying or removing all debris that may have served, or may potentially serve as substrates for the growth of mycotoxin-producing fungi. If there are areas vulnerable to soil erosion, no-till practices may be required in the interests of soil conservation.

12. Before planting, growers should consult with appropriate plant breeding authorities or tree nursery personnel to ascertain the availability of species that are resistant to various factors (e.g., frost, microbial and fungal diseases) that can have an impact on the safety and quality of nuts produced in the orchard.

13. Growers should be familiar with GAPs associated with the use of formulated fertilizers, manure and other biosolids that may be used to enhance the nutritional state of the soil, without increasing the risks of introducing hazards originating from microbial or fungal sources in the orchard.

14. Growers should consult with local or national authorities to determine insects and other pests that are commonly found in their region that might attack tree nuts causing them to be more susceptible to fungal infections that can lead to aflatoxin production.

15. Growers should take adequate precautions to ensure that human and animal wastes are disposed of in such a manner as not to constitute a public health or hygienic hazard, and take extreme care to protect the products from contamination with these wastes.

2.3 Preharvest

16. During the growing seasons, roadways near the orchards should be watered or oiled periodically to minimize outbreaks of mites as a result of dusty conditions. Cultivation practices, in the vicinity of the orchard, that might disperse *Aspergillus flavus/A. parasiticus*, and other fungal spores in the soil to aerial parts of trees should be avoided.

17. Pesticides approved for use on tree nuts, including insecticides, fungicides, herbicides, acaricides, and nematocides should be used to minimize damage that might be caused by insects, fungal infections, and other pests in the orchard and adjacent areas. Accurate records of all pesticide applications should be maintained.

18. Irrigation should be implemented in regions with high temperatures and very little rainfall during the growing season to minimize tree stress, however, irrigation water should be prevented from contacting the nuts and foliage.

19. Water used for irrigation and other purposes (e.g., preparation of pesticide sprays) should be of suitable quality, according to the legislation of each country, for the intended use.

20. All equipment and machinery, which is to be used for harvesting, storage and transportation of crops, should not constitute a hazard to health. Before harvest time, all equipment and machinery should be inspected to ascertain that they are clean and in good working condition to avoid contamination of the nuts with soil and other potential hazards.

21. Trade Associations, as well as local and national authorities should take the lead in informing growers of the hazards associated with aflatoxin contamination of tree nuts and how they may practice safe harvesting procedures to reduce the risk of contamination by fungi, microbes and pests.

22. Personnel that will be involved in harvesting nuts should be trained in personal hygienic and sanitary practices that must be implemented in processing facilities throughout the harvesting season.

2.4 Harvest

23. Harvesting of nuts should begin as soon as practicable after maturation to minimize diseases caused by fungal attack and insect infestation. Some varieties of nuts become contaminated with aflatoxins while still on the tree as a result of insect infestation and hull splitting, therefore, the earlier the harvest, the less chance there is for contamination to occur because there is a greater chance that the outer hull will remain intact to protect the underlying shell from insects and fungal spores. The area under the trees should be cleared of any debris or decayed materials where A. flavus or A. parasiticus might reside.

24. Nuts, harvested by shaking the trees, should ideally be collected by mechanical harvesters with catching frames, or on some type of protective sheets or tarps under the trees to prevent nuts from falling to the ground. In regions where certain varieties of nuts are traditionally harvested by shaking the trees and/or allowing mature nuts to fall freely to the ground for collection by harvesting equipment or by hand, the orchard should not be

used for grazing or holding cattle or other animals. If the land has been so used, the land should be worked immediately prior to harvesting (disced, rotilled, soil turned in some manner, or other feasible methods), to lesson the hazard of fecal contamination of tree nuts. In addition, procedures should be in place to ensure their removal as soon as possible to decrease exposure to *Aspergillus flavus/A. parasiticus* spores that may be denser in the air near the ground and associated with plant debris.

25. The nuts, after collection, should be sorted to remove damaged, rotten, empty and rancified nuts, foreign materials, and transported, as soon as possible, to a processing facility for immediate processing (hull removal) in containers (e.g., trucks, conveyers) that are clean, dry, protected against humidity and free of insects and visible fungal growth. High humidities, which are conducive to proliferation of mold and development of mycotoxins, should be avoided to the greatest extent practical. Conveyances for transporting nuts should be constructed of a material that will permit thorough cleaning and maintenance so as not to constitute a source of contamination for tree nuts. If the nuts cannot be transported immediately to a processing facility they should be temporarily stored in a way that will keep them dry and protected from rain, insects, rodents, birds and drainage of ground water.

2.5 Post-harvest

26. Nuts remaining on the trees after harvest should be removed during the winter months to reduce the over wintering of various insect populations.

27. Trees should be pruned and, when needed, treated with appropriate pesticides prior to each growing season.

28. The orchard floor or woodland should be cleared of litter and debris from the harvesting operations in order to decrease the colonization of *Aspergillus* fungi in the orchard or woodland.

29. Containers, equipment and machinery that have been used for harvesting operations should be cleaned and stored in a clean location to minimize inadvertent contamination with fungi, chemicals, fertilizers or toxic substances.

30. Harvesting and storage procedures implemented each crop year should be documented by making notes of measurements (e.g., temperature, moisture, and humidity) and any deviation or changes from traditional practices. This

information may be 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.

2.6 Processing

31. Personnel involved in all stages of tree nut processing should maintain a high degree of personal cleanliness, wear suitable protective clothing, be trained in food hygiene and general sanitation procedures to a level appropriate to the operations they are to perform in the processing facility. A system should be in place to ensure that all personnel remain aware of all precautions necessary to reduce the risk of aflatoxin contamination in the processing operations.

32. Areas where raw materials are going to be received or stored should be physically separated from areas in which final product preparation or packaging is conducted as to preclude contamination of the finished product. The hulling of nuts should be carried out in a location that is separated by partitions from the main processing area of the facility. Care should be taken to ensure that dust-laden air is not introduced into other areas of the facility through a vent system or other openings.

33. Processors should establish good quality control, traceability/product tracing and safety procedures at every step in the processing sequence to avoid cross contamination of aflatoxins between various lots of nuts during processing.

34. Hulling of nuts should begin as soon as possible after harvest. If a short delay in hull removal is anticipated, the nuts should be stored under conditions that will protect them from insects, mites, vermin, domestic animals, fungi, chemicals or microbiological contaminants, debris and dust. If a long delay is anticipated, nuts should be stored under controlled conditions to prevent aflatoxin production. If needed, appropriate fumigation could be used to control insects.

35. Dehulled nuts should be dried as soon as possible; the drying rate and heat intensity should be determined by the intended end use of the final nut product(s). The nuts should be dried to a safe moisture level that corresponds to a water activity, Aw, of less than 0.70 at 25 °C. *Aspergillus flavus*/*A. parasiticus* cannot grow and produce aflatoxin at water activities less than 0.70. Dehulled nuts that are allowed to sun-dry are at a greater risk of becoming contaminated during the drying process as a result of fungal growth and/or damage by pests.

36. Moisture levels should be checked after drying by taking samples as representative of the lot as possible. Make sure that the equipment needed for moisture measurements is calibrated.

37. Mechanical driers should be available and used to reduce the potential of further aflatoxin contamination in regions where steam or aqueous solutions are traditionally used to facilitate dehulling, and segregation of defective nuts; the water used should be of suitable quality for intended use and never recycled.

38. Personnel and equipment used in the hulling/selection/preparation/drying/ storage areas of a processing facility should not enter into other areas of the facility; this will reduce the risk of contaminating other areas of the facility. Waste materials should be frequently removed from the working area during operation and adequate waste receptacles should be provided for the removal of the waste.

39. Various visual (manual) and/or electronic sorting techniques should be used to remove foreign materials and nuts with various defects. Nuts should not be used for processing unless they are free from obvious faecal contamination, infestations, decomposition and other defects. Special precautions must be taken to reject insect-damaged or early-split nuts because they are associated with a high risk of aflatoxin contamination.

40. For nut varieties that are traditionally preconditioned with moisture (steam or water of potable quality) to reduce kernel breakage during cracking, the moisture level of the kernels after cracking should be lowered immediately, to a level that will not support the growth of fungi by rapidly circulating dry air through the kernels.

41. The finished processed products (raw, shelled or in-shell, bulk or consumer ready) should be of the appropriate moisture and packaged so as to maintain their quality under normal transportation and storage conditions without significant deterioration by decay, mould, or enzymatic changes.

42. It is desirable that each plant has access to quality control facilities. The amount and type of such control will vary with different nut products as well as the needs of management. Some type of screening or recognized analytical procedure should be used to determine aflatoxin levels and

preferable moisture content before products are released from the processing facility.

2.7 Transport of processed nuts to storage

43. Transport containers should be clean, dry, and free of visible fungal growth, insects and any contaminated material. The containers should be well constructed to withstand handling abuse without breaking or puncturing, and tightly sealed to prevent any access of dust, fungal spores, insects or other foreign material.

44. The nuts should be transferred from transport containers to the storage facility as soon as practicable. If different lots or sub-lots are transported together, they must be physically separated in a way that will ensure that identification of the lot is maintained. The lots must be indelibly marked with an identification number that can be traced back to the accompanying documentation (identification number of the lot must correspond to the identification number mentioned on the accompanying documents).

2.8 Storage

45. Storage facilities should be clean and dry (if possible keep the relative humidity < 70%), well-vented structures that provide protection from rain, entry of rodents and birds, drainage of ground water and have minimum temperature and humidity fluctuations. If possible, temperature should be kept between 0 °C and 10 °C to minimize fungal growth during storage.

46. Good storage practices should be implemented 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. Nuts stored in sacks should be placed on pallets which are positioned to allow good ventilation and access.

47. Water activity, which varies with moisture content and temperature, should be carefully controlled during storage. *Aspergillus flavus/A. parasiticus* cannot grow or produce aflatoxins at water activities less than 0.7.

48. Consideration should be given to fumigating nuts as they are removed from storage for export to control any storage pests that may be present and to prevent infestation during shipment.

3. SPECIAL CONDITIONS FOR SPECIFIC NUT SPECIES

3.1 Pistachio nuts

49. Pistachio nuts are exposed to airborne fungal spores while in the field, during harvesting and/or processing. When the nuts are still on the tree, sometimes the outer hull splits when the shell splits open (early-splits) and sometimes the hull is damaged by wind, insects or other pests. If insects or other pest damages the nut shell, then conditions exist for *Aspergillus* spores to invade and grow on the inner kernel and potentially produce aflatoxins.

50. During the growing season, growers should irrigate carefully and in good time to limit early splitting of the outer hull and reduce the risk of aflatoxin contamination. The mature nuts should be harvested early to reduce the chance for contamination since there is a greater chance that the outer hull will remain intact. The nuts should be delivered directly to the plant for hulling and drying within 24 hours of harvest to prevent shell staining.

3.2 Brazil nuts

51. Measures for the prevention and reduction of aflatoxin in Brazil nut are included as a separate appendix to this Code given the very specific conditions related to the Brazil nut collection and processing.

4. A COMPLEMENTARY MANAGEMENT SYSTEM TO CONSIDER IN THE FUTURE

52. 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 earlier documents.[4,5]

53. The HACCP concept is an all-encompassing integrated management system. When properly implemented in the tree nut industry, this system should result in a reduction in the levels of aflatoxins observed in tree nuts. The use of HACCP as a food safety management system has many benefits over other types of management control systems used in some segments of the food industry. In orchards, many factors that influence aflatoxin contamination of

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

[5] 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.

tree nuts are environmentally related, such as weather and insects; these are difficult or impossible to control. After harvesting, critical control points may be identified for aflatoxins 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 moisture content or water activity.

54. Good Agricultural Practices (GAPs), Good Manufacturing Practices (GMPs) and Good Storage Practices (GSPs) are programs that should be in place before attempts are made to establish and implement a HACCP system. A manual on the application of the HACCP system for mycotoxin prevention and control was recently published that included a plan developed for controlling aflatoxins in pistachio nuts in S.W. Asia[6]. It is recommended that tree nut producers, processors and others involved in the tree nut industry review this example, the concepts of which should be applicable to all tree nuts.

55. At the Third International Conference on Mycotoxins, which was held 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[7]. The implementation of HACCP principles will minimize aflatoxin contamination through applications of preventive controls to the extent feasible in the production, handling, storage and processing of each tree nut crop. Since all countries may not have the required technical expertise and experience to establish effective integrated mycotoxin management systems, the Food and Agriculture Organization (FAO) has given high priority to the provision of training professionals in developing countries on the HACCP approach and its application.

[6] FAO/IAEA training and reference center for food and pesticide control, 2002. Manuel on the Application of the HACCP System in Mycotoxin Prevention and Control. FAO Food and Nutrition Paper No. 73, Rome.

[7] FAO. Preventing Mycotoxin Contamination. Food, Nutrition and Agriculture No. 23, 1999. Food and Nutrition Division, FAO, Rome.

APPENDIX

ADDITIONAL MEASURES FOR THE PREVENTION AND REDUCTION OF AFLATOXIN CONTAMINATION IN BRAZIL NUTS

INTRODUCTION

1. The formulation and acceptance of an appendix to the Code of Practice for the Prevention and Reduction of Aflatoxins Contamination in Tree Nuts will provide uniform guidelines for producing countries to consider in attempting to control and manage contamination of Brazil nuts by aflatoxins. In order for these measures to be effective, it will be necessary for collectors, processors and other members of the production chain to consider the general principles established by the Code, while taking into account the fact that the Brazil nut tree (*Bertholletia excelsa*) is not cultivated. This species exists all over the Amazon Region however the largest concentrations of trees are in the Brazilian Amazon.

2. This appendix applies only to Brazil nuts, given the very specific conditions related to their collection and processing.

RECOMMENDED PRACTICES BASED ON GOOD EXTRACTIVISTIC PRACTICES (GEP)

Pre-collection

3. The extractivists should clear the area under the Brazil nut trees, removing residual pods and nuts from the former crop. Pods left from the last crop season should never be mixed with pods from the present crop season, as they represent a potential source of contamination with *Aspergillus*.

Collection

4. Collection should proceed continuously as soon as possible after the pods have fallen from the trees. A certain delay in the collection is expected because during the crop season remaining pods may fall, posing a risk to the lives of the collectors.

5. Pods should be sorted to remove damaged ones and gathered in piles, if possible, in thin layers, for only a short period of time (preferably less than 5 days).

Post collection

6. Pods should be opened as soon as possible after collection, with the nuts being removed and separated from the pods and placed on a clean and dry floor or plastic canvas in good condition, to avoid contact with the soil. During the opening of the pods care should be taken to avoid damage to the nuts as much as possible. The nuts should be sorted to remove damaged and empty ones.

7. Initial transportation of the nuts, from the forest to a storage facility, should occur as soon as possible, using containers that are clean, dry and protected against rain and insects, to the greatest extent possible.

8. To avoid aflatoxin formation the nuts should be dried to a safe moisture level corresponding to a water activity below 0.70 preferably within 10 days from the collection. Sun-drying is normally not sufficient to reach a safe moisture level due to the high relative humidity in the rain forest environment. This recommendation is particularly important when producing Brazil nuts to be traded as "in-shell" where contaminated nuts are difficult to distinguish from sound nuts without cracking the nut. The nuts should be protected against rain and pests, such as birds, rodents and insects and any other source of contamination.

9. After drying, the nuts should be placed in a storage facility with a floor at least 50 cm above ground level; protected against rain and pests and that allow good air circulation. For the purpose of identification and traceability, nuts, in bulk or in bags, from different origins and/or days of collection should preferably be handled separately and kept separated until the final processing and packaging.

10. During the transportation of the nuts from the primary storage facility, in bulk or in bags, either to an intermediate location or to a processing facility, the nuts should be separated from other goods, in containers that are clean, dry, protected against humidity and free from insects and visible fungal growth. Conveyances for transporting nuts should be made of material that will permit thorough cleaning and maintenance so as not to constitute a potential source of contamination for the Brazil nuts.

11. If the nuts are stored at an intermediate location, before reaching the processing facility, the storage facility should have the following:

a) protection from rain and pests;
b) a washable and impermeable floor;
c) drainage of ground water;
d) good air circulation;
e) sufficient area and proper divisions to allow separation of lots.

This intermediate storage is only recommended if the moisture content of the nuts corresponds to a water activity below 0.70. Otherwise no intermediate storage is recommended, especially for nuts expected to be marketed in-shell.

GENERAL RECOMMENDATIONS

12. National, State and local governments, as well as Non Governmental Organizations – NGOs, trade associations and cooperatives should provide basic education and update information on the hazards associated with aflatoxin contamination to the agents involved in the Brazil nuts production chain.

13. Local people (extractivists) involved in the collection of Brazil nuts should be regularly trained in personal hygienic and sanitary practices that must be implemented at all stages of production including the pre-collection, collection, post-collection and processing.

14. It is recommended that further development and validation of the current quality control system, used in most processing plants, by checking the percentage of “bad” nuts in the incoming lots be undertaken. This method may be used as a tool for decision if a lot can be commercialized as “in-shell” nuts or should be shelled and sorted to eliminate the bad nuts.

CODE OF PRACTICE FOR THE PREVENTION AND REDUCTION OF AFLATOXIN CONTAMINATION IN PEANUTS

CAC/RCP 55-2004

1. SCOPE

1. This document is intended to provide guidance for all interested parties producing and handling peanuts for entry into international trade for human consumption. All peanuts should be prepared and handled in accordance with the General Principles of Food Hygiene[1], which are relevant for all foods being prepared for human consumption. These codes of practice indicate the measures that should be implemented by all persons that have the responsibility for assuring that food is safe and suitable for consumption.

2. DEFINITIONS

2. ***"Blows"*** (Pops) means in-shell nuts which are unusually light in weight due to extensive damage from physiological, mould, insect, or other causes and which can be removed, for example, by an air-separation process.

3. ***"Curing"*** means drying of the in-shell peanuts to a safe moisture level.

4. ***"Farmers stock"*** peanuts means in-shell peanuts as they come from farms, after separation from the vines by hand and/or mechanical means.

5. ***"Safe water activity"*** means a water activity of in-shell peanuts and shelled peanuts that will prevent growth of micro-organisms normally present in the harvesting, processing, and storage environment.

6. Water activity (a_w), is a measure of free moisture in a product and is the water vapour pressure of the substance divided by the vapour pressure of pure water at the same temperature. Water activities above 0.70 at 25 degrees Celsius (77 ° Fahrenheit) are 'unsafe' as far as growth of *Aspergillus flavus* and *Aspergillus parasiticus* and possible aflatoxin production are concerned.

[1] General Principles of Food Hygiene (CAC/RCP 1-1969).

Adopted 2004.

3. RECOMMENDED PRACTICES BASED ON GOOD AGRICULTURAL PRACTICES (GAP)

3.1 Pre-harvest

7. To be effective, pre-harvest control of aflatoxin contamination of peanuts must take into consideration all the varied environmental and agronomic factors that influence pod and seed infection by the aflatoxin-producing fungi, and aflatoxin production. These factors can vary considerably from one location to another, and between seasons in the same location. Some environments may be particularly favourable to fungal infection and subsequent aflatoxin contamination of groundnuts, and in these circumstances it would be necessary to consider whether or not the crop should be grown in such areas. However, for most situations it should be possible to devise agricultural practices that should reduce aflatoxin contamination in peanuts.

8. The continued cultivation of peanuts on the same land may lead to a build-up of high populations of *A. flavus*/*A. parasiticus* in the soil, which will increase the probability of infection and aflatoxin contamination. Some studies have been carried out on the effect of crop rotation on aflatoxin contamination. In semi-arid environments, populations of Aspergillus may be very high, and crop rotations may have little influence on the fungal activity. Cropping systems in some regions involve varied cultivation and fertiliser practices that individually or taken together may affect survival or build-up populations of the toxigenic fungi. There is evidence that peanuts grown in different soil types may have significantly different levels of infection by the moulds. Light sandy soils, for example, favour rapid proliferation of the fungi, particularly under dry conditions. Heavier soils have a higher water-holding capacity and, therefore, there is less likelihood of drought stress occurring, which may be partly responsible for the lower than average levels of aflatoxin contamination in peanuts grown on such soils.

9. In areas that are vulnerable to erosion, no-till practices may be required in the interests of soil conservation.

10. Utilize the results of soil tests to determine if there is a need to apply fertilizer and/or soil conditioners to assure adequate soil pH and plant nutrition to avoid plant stress, especially during seed development, which makes peanuts more susceptible to fungal infestation.

11. The choice of peanut variety can be important and therefore before planting, farmers should consult with the appropriate plant breeding

authorities or agricultural extension services to ascertain the peanut cultivars that have been adapted to their region, and the availability of varieties that are resistant to various factors such as insect attack and microbial and fungal attack that can have an impact on the safety and quality of the peanuts produced. A cultivar should be selected that is suitable for a particular growing season and mature at the end of the rainy season so that post-harvest field drying can be done under favourable conditions. It is undesirable that a variety should suffer from drought stress during pod maturation and some compromise may have to be effected between harvesting under dry conditions and avoidance of drought stress by using short-duration cultivars that mature before the rains have ended.

12. Irrigation, if feasible, is recommended to combat heat and drought stress.

13. Irrigation to ensure adequate soil moisture during the last 4-6 weeks of crop growth should minimize pre-harvest aflatoxin contamination of peanuts. This may be achieved by growing a completely irrigated crop or by applying supplementary irrigation to a basically rain-fed crop. If irrigation is used, ensure that it is applied evenly and that all plants in the plot have an adequate supply of water.

14. Water used for irrigation and other purposes (e.g. preparation of pesticide sprays) should be of suitable quality for the intended use.

15. Avoid overcrowding of plants by maintaining the recommended row and intra-plant spacing for the species/varieties grown. Optimum plant populations should be established bearing in mind that too high a population may lead to drought stress where rainfall maybe below the optimum required in a growing season.

16. Excessive weed growth may deplete available soil moisture. Effective weed control by use of registered herbicides, or cultivation is therefore advisable. Care should be taken during cultivation to avoid damage to pegs and pods.

17. Cultivation and crop protection practices that lower the incidence of soil insects, mites, and nematodes should help in reducing aflatoxin contamination. 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. Growers should consult with local or national authorities to determine insects and other pests that are commonly found in their region that might

attack peanuts causing them to be more susceptible to fungal infections that can lead to aflatoxin production.

18. No fungicide, or combinations of fungicides, or other chemical treatments appear to have been adopted for the practical control of *A. flavus*/*A. parasiticus* infection and subsequent aflatoxin contamination of peanuts pre-harvest. The results of studies on the application of fungicides on freshly harvested or windrowed peanuts are equivocal.

3.2 Harvest

19. Trade associations as well as local and national authorities should take the lead in informing growers of the hazards associated with aflatoxin contamination of peanuts and how they may practice safe harvesting procedures to reduce the risk of contamination by fungi, microbes, and pests. Personnel who will be involved in harvesting peanuts should be well-trained in the personal hygienic and sanitary practices that must be implemented throughout the harvesting season.

20. 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 peanut quality losses and enhance aflatoxin formation. Keep important spare parts available on the farm to minimize time loss from repairs.

21. Plan to harvest the peanuts at full maturity, unless allowing the crop to continue to full maturity would subject it to extreme heat, rainfall, and drought conditions. It is very important to harvest the crop at optimum maturity, as excessive numbers of over-mature or very immature pods at harvest can be reflected in high levels of aflatoxin in the product also delayed harvest of peanuts already infected may cause significant increase in aflatoxin content of the crop. A system by which the growing conditions of the farming crop is monitored (soil temperature and precipitation) may be very useful.

22. Individual plants that die from attack by pests, pathogens, such as *Sclerotium rolfsii* or *Fusarium* spp., and diseases, e.g. rosette virus, or insects, such as termites, earwigs, and false wireworms that cause damage to the pods, should be harvested separately as their produce is likely to contain aflatoxin.

23. If peanuts have been irrigated, care should be taken to separately harvest peanuts that are beyond the reach of irrigation systems to avoid mixing aflatoxin-free peanuts with those that are potentially contaminated.

24. Damage to pods at the time of harvest should be avoided as much as possible since this can lead to rapid invasion of the pods by *A. flavus/A. parasiticus*. Peanuts should be handled as gently as possible and every effort made to minimize physical damage at all stages of harvesting and transportation procedures.

25. After harvest, pods should be exposed for maximum rate of drying. This may be accomplished by turning the vines to leave the pods uppermost where they are away from the ground and exposed to sun and wind. Curing should be completed as soon as possible to a safe water activity so as to prevent the growth of microorganisms, particularly moulds that produce aflatoxins. However, drying too rapidly may cause skin slippage and off-flavours in the peanut kernels. When curing by supplemental heat, excessive heat should be avoided since this impairs the general quality of the peanuts, e.g. splitting of kernels after shelling. Close checks of moisture content/water activity of lots of farmer's stock peanuts should be maintained.

26. Peanuts should be dried in such a manner that damage to the peanuts is minimized and moisture levels are lower than those required to support mould growth during storage (generally less than 10%). This is necessary to prevent further growth of a number of fungal species in peanuts.

27. Freshly harvested peanuts should be cleaned and sorted to remove damaged nuts and other foreign matter. Cleaning procedures such as density separators or air legs to remove light pods and slotted screens to remove pre-shelled kernels, may remove some infected nuts.

3.3 Transport

28. The nuts should be moved to a suitable storage, or to the processing area for immediate processing as soon as possible after harvesting or drying.

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

30. 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.

31. Consignments of peanuts should be protected from all additional moisture by using covered or airtight containers or tarpaulins. Avoid temperature fluctuations that may cause condensation to form on the peanuts, which could lead to local moisture build-up and consequent fungal growth and aflatoxin formation.

32. Farmers' stock peanuts should be screened for aflatoxin contamination to more accurately segregate for proper storage. Aflatoxin-free loads should be segregated from loads with low levels of aflatoxin contamination, destined for subsequent processing and clean-up, and from loads that are highly contaminated.

33. Avoid insect, bird, and rodent infestation during transportation by the use of insect and rodent proof containers or insect and rodent repellent chemical treatments provided they are approved for the intended use of the peanuts.

3.4 Segregation of aflatoxin contaminated lots

34. The distribution of aflatoxin in peanuts has been thoroughly investigated. The results from the investigations indicate that sorting for quality removes a large part of the aflatoxin present at harvest. The distribution of aflatoxins is very heterogeneous in a lot of peanuts and consequently the sampling plan used is critical.

3.5 Storage

35. Post-harvest storage of peanuts is the phase that can contribute most to the aflatoxin problem in peanuts. The primary goal for aflatoxin prevention in storage is to prevent mould development of the peanuts due to condensation or leaks in the warehouse.

36. A properly ventilated warehouse with a good roof, preferably double sidewalls and a concrete floor are required to prevent rewetting of peanuts. Make sure that the storage facilities include dry, well-vented structures that provide protection from rain, drainage of ground water, protection from the entry of insects, rodents, and birds, and minimum temperature fluctuations. Painting warehouse roofs with white paint reduces solar heat load when compared to conventional galvanized material. The double roofing concept of installing a new roof over a defective, existing roof with an air space in-

between the two roofs, has proven effective in controlling warehouse condensation.

37. Water activity, which varies with moisture content and temperature, should be carefully controlled during storage.

38. Uniform loading of the warehouse allows excessive heat and moisture to escape and reduces favourable areas for insect infestation. Stock piling of peanuts can cause heat build-up and moisture accumulation with resultant mould growth and aflatoxin contamination.

39. Prevention of aflatoxin increase during storage and transportation depends on keeping a low moisture content, the temperature in the environment, and the hygienic conditions. *A. flavus*/*A. parasiticus* cannot grow or produce aflatoxins at water activities less than 0.7; relative humidity should be kept below 70% and temperatures between 0 and 10 °C are optimal for minimizing deterioration and fungal growth during long time storage.

40. The aflatoxin level in peanuts coming into a storage and peanuts going out of a storage should be monitored, using appropriate sampling and testing programs.

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

42. Store at the lowest temperature possible consistent with ambient conditions but avoid temperatures near freezing point. Where possible aerate the peanuts by circulation of air through the storage area to maintain proper and uniform temperature levels throughout the storage area.

43. Measure the temperature of the stored peanuts at several fixed intervals during storage. A temperature rise may indicate microbial growth and/or insect infestation. Visually check peanuts for evidence of mould growth. Separate the apparently infected portions of the peanuts and send samples for analysis if possible. When separated, lower the temperature in the remaining peanuts and aerate. Avoid using infected peanuts for food or feed production.

44. Use good ‘housekeeping’ procedures to minimize levels of insects and fungi in storage facilities. This may include the use of suitable traps, registered

insecticides or fungicides and fumigants. Care should be taken to select only those chemicals that will not affect or cause harm to the peanuts.

45. 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 causes of fungal growth and aflatoxin formation during a particular crop year and help to avoid similar mistakes in the future.

4. GOOD MANUFACTURING PRACTICE (GMP)

4.1 Receiving and shelling

46. A buyer for a shelling plant, whether located at the plant or at an outlying buying point, should monitor the quality of peanuts offered to him and assist suppliers in eliminating improper practices. Buyers should encourage suppliers of farmer's stock peanuts to follow good production practices as described herein.

47. Farmers' stock peanuts received at the shelling plant should be inspected on arrival. It is advisable to know the origin and history of each lot of peanuts. The transport vehicle should be examined. If the vehicle is not fully enclosed, it should have a covering such as tarpaulin to keep out rain or other forms of water. The general appearance of the peanuts should be observed during the process of unloading. If the peanuts are wet to the touch, they should NOT be mixed with peanuts in a bulk warehouse. The vehicle which contains the peanuts should be set aside until a decision is made for their disposal. If possible, remove a sample from each lot, separate the "loose shelled" kernels and shell the remainder for peanut grade observation before an acceptance decision is made.

48. Specifications for the purchase of peanuts intended for further processing should include a maximum level for aflatoxin based in appropriate methods of analysis and a proper sampling plan.

49. Special precautions must be taken to reject peanuts showing signs of insect damage or mould growth because of the danger of their containing aflatoxins. Aflatoxin test results should be known before allowing lots of raw peanuts to be processed. Any lot of raw peanuts with unacceptable levels of aflatoxins, which cannot be reduced to permitted levels by the available sorting equipment, should not be accepted.

50. The peanut processor must satisfy himself that the supplier of shelled peanuts is able to control properly his own operations to assure that the finished product is within the maximum limit for aflatoxin.

51. Examine all loose-shelled, damaged "Blows" and under-sized kernels for possible presence of mould. If no external mould is visible, split the kernels to disclose possible hidden mould growth. Excessive mould or presence of mould resembling *A. flavus* warrants a chemical test for aflatoxin or rejection of the lot.

4.2 Sorting

52. Sorting is the final step for removing defective kernels. Sorting belts should be well lighted, with peanuts passing through no more than one layer deep, and operated at a speed which enable hand sorters to assure effective removal of foreign material and defective kernels. Sorting machines should be adjusted as often as practicable against standards to assure removal of all defective kernels. Adjustment should be checked frequently and regularly.

53. To remove mould-contaminated nuts effectively, sorting should be performed before and after blanching and roasting. Where splitting is part of the processing operation, nuts that resist splitting should be removed. The effectiveness of sorting techniques should be checked by regular aflatoxin analyses of the sorted peanuts stream or of the finished product, or both. This should be done frequently enough to ensure that the product is completely acceptable.

54. Defective (mouldy, discoloured, rancid, decayed, shrivelled, insect or otherwise damaged) kernels should be bagged separately and tagged as unsuitable for human consumption. Containers of defective peanuts should be removed as soon as practicable form the processing area. Materials which carry the danger of contamination by aflatoxin, or which are contaminated should be diverted to non-food uses.

55. Rejected peanuts from the sorting procedure should be destroyed or segregated from edible products. If they are to be used for crushing, they should be separately bagged and tagged as unsuitable for direct human consumption in their present state.

4.3 Blanching

56. Blanching used in conjunction with gravity tables and manual or electronic sorting is very efficient in removing aflatoxin-contaminated kernels. Colour

sorting, combined with blanching have been shown to reduce aflatoxin contamination by as much as 90%.

4.4 Packaging and storage of end product

57. Peanuts should be packed in clear jute bags, cartons or polypropylene bags. If using jute, ensure bags are not treated with mineral hydrocarbon based oils. All bags/cartons should be lot identified to facilitate traceability of the product before being moved to controlled storage facilities or transported.

58. Peanuts that have been processed should be stored and transported under such conditions as will maintain the integrity of the container and the product within it. Carriers should be clean, dry, weatherproof, free from infestation, and sealed to prevent water, rodents or insects from reaching the peanuts. Peanuts should be loaded, held and unloaded in a manner that protects from damage or water. Well-insulated carriers or refrigerated vehicles are recommended for transport when climatic conditions indicate such a need. Extreme care should be taken to prevent condensation when unloading peanuts from cold storage or from a refrigerated vehicle. In warm, humid weather, the groundnuts should be allowed to reach ambient temperature before exposure to external conditions. This tempering may require 1-2 days. Peanuts that have been spilled are vulnerable to contamination and should not be used for edible products.

5. A COMPLEMENTARY MANAGEMENT SYSTEM TO CONSIDER IN THE FUTURE

59. The Hazard Analysis Critical Control Point (HACCP) system is an all-encompassing integrated 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.

60. When properly implemented, this system should result in a reduction of the levels of aflatoxins in peanuts. The use of HACCP as a food safety management system has many benefits over the types of management control systems in some segments of the food industry. At farm level there are many factors that influence the aflatoxin contamination of peanuts most of which are environmentally related, such as weather and insects, and these are difficult, if not impossible, to control. Particular attention should be paid to the soil population of the fungus, the health of seed material, soil moisture deficit stress at the pod formation and pod maturity stages, and rains at harvest. The critical control points often do not exist at the pre-

harvest level. However, after harvesting, the critical control points may be identified for aflatoxins produced by fungi during drying and 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.

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

62. Intergrated mycotoxin control programs should incorporate HACCP principles in the control of risks associated with mycotoxin contamination of foods and feeds. The implementation of HACCP principles will minimize aflatoxin contamination of peanuts through applications of preventive controls to the extent feasible in the production, handling storage and processing of each peanut crop.

CODE OF PRACTICE FOR THE PREVENTION AND REDUCTION OF AFLATOXIN CONTAMINATION IN DRIED FIGS

CAC/RCP 65-2008

INTRODUCTION

1. The elaboration and acceptance of a Code of Practice for dried figs by Codex will provide uniform guidance for all countries to consider in attempting to control and manage contamination by various mycotoxins, specifically aflatoxins. It is of high importance in order to ensure protection from aflatoxin contamination in both producer and importer countries. All dried figs should be prepared and handled in accordance with the General Principles of Food Hygiene[1] and Code of Hygienic Practice for Dried Fruits[2] which are relevant for all foods being prepared for human consumption and specifically for dried fruits. It is important for producers to realize that Good Agricultural Practices (GAP) represent the primary line of defence against contamination of dried figs with aflatoxins, followed by the implementation of Good Manufacturing Practices (GMP) and Good Storage Practices (GSP) during the handling, processing, storage and distribution of dried figs for human consumption. Only by effective control at all stages of production and processing, from the ripening on the tree through harvest, drying, processing, packaging, storage, transportation and distribution can the safety and quality of the final product be ensured. However, the complete prevention of mycotoxin contamination in commodities, including dried figs, has been very difficult to achieve.

2. This Code of Practice applies to dried figs (*Ficus carica* L.) of commercial and international concern, intended for human consumption. It contains general principles for the reduction of aflatoxins in dried figs that should be sanctioned by national authorities. National authorities should educate producers, transporters, storage keepers and other operators of the production chain regarding the practical measures and environmental factors that promote infection and growth of fungi in dried figs resulting in the production of aflatoxin in orchards. Emphasis should be placed on the fact that the planting, pre-harvest, harvest and post-harvest strategies for a particular fig crop depends on the climatic conditions of a particular year, local production, harvesting and processing practices followed in a particular country or region.

[1] General Principles of Food Hygiene (CAC/RCP 1-1969).
[2] Code of Hygienic Practice for Dried Fruits (CAC/RCP 3-1969).

Adopted 2008.

3. National authorities should support research on methods and techniques to prevent fungal contamination in the orchard and during the harvesting, processing and storage of dried figs. An important part of this is the understanding of the ecology of *Aspergillus* species in connection with dried figs.

4. Mycotoxins, in particular aflatoxins are secondary metabolites produced by filamentous fungus found in soil, air and all plant parts and can be toxic to human and animals through consumption of contaminated food and feed entering into food chain. There are a number of different types of aflatoxin, particularly aflatoxin B_1 have been showed toxigenic effects i.e. it can cause cancer by reacting with genetic material. Aflatoxins are produced by mould species that grow in warm, humid conditions. Aflatoxins are found mainly in commodities imported from tropical and subtropical countries with in particular peanuts (groundnuts) and other edible nuts and their products, dried fruit, spices and maize. Milk and milk products may also be contaminated with aflatoxin M_1 owing to the consumption of aflatoxin contaminated feed by ruminants.

5. Aflatoxigenic fungi are spread on fig fruits during fruit growth, ripening and drying but thrive especially during the ripening and overripening phase. The formation of aflatoxins in dried figs is mainly due to contamination by *Aspergillus* species and particularly *A. flavus* and *A. parasiticus*. The presence and spread of such fungus in fig orchards are influenced by environmental and climatic factors, insects, (insect abundance or control in an orchard is related to the applied plant protection measures so could be included in cultural practices but to point out its significance can be left as another factor), cultural practices, floor management and susceptibility of fig varieties.

6. The aflatoxin-producing *Aspergillus* species and consequently dietary aflatoxin, contamination is ubiquitous in areas of the world with hot humid climates. *A. flavus*/*A. parasiticus* cannot grow or produce aflatoxins at water activities less than 0.7; relative humidity below 70% and temperatures below 10 °C. Under stress conditions such as drought or insect infestation, aflatoxin contamination is likely to be high. Improper storage conditions can also lead to aflatoxin contamination after crops have been harvested. Usually, hot humid conditions favour mould growth on the stored food which can lead to high levels of aflatoxins.

7. Application of the following preventive measures is recommended in dried fig producing regions in order to reduce aflatoxin contamination by application of good practices:
   a) Information on contamination risk.
   Ensure that regional/national authorities and grower organisations:
   - Sample dried figs representatively for analysis to determine the level and frequency of aflatoxin contamination; sampling should reflect differences in areas, time of the year and stage from production to consumption.
   - Combine this information with regional risk factors including meteorological data, cultural practices and propose adapted risk management measures.
   - Communicate this information to growers and other operators along the chain. Use labelling to inform consumers and handlers on storage conditions.

   b) Training of producers.
   Ensure training of producers with regards to:
   - Risk of mould and mycotoxins.
   - Conditions favouring aflatoxigenic fungi and period of infection.
   - Knowledge of preventive measures to be applied in fig orchards.
   - Pest control techniques.

   c) Training of transporters, storage keepers and other operators of the production chain.
   Ensure training regarding the practical measures and environmental factors that promote infection and growth of fungi in dried figs resulting in a possible secondary production of aflatoxins at post harvest handling and processing stages. Besides these, all applications should be documented.

   d) Encourage related research.

8. In developing training programs or gathering risk information, emphasis should be placed on the fact that the planting, pre-harvest, harvest and post-harvest strategies for a particular fig crop depends on the climatic conditions of a particular year, local production, harvesting and processing practices followed in a particular country or region.

1. SCOPE

9. This document is intended to provide guidance for all interested parties producing and handling dry figs for entry into international trade for human consumption. All dried figs should be prepared and handled in compliance with the Recommended International Code of Practice – General Principles of Food Hygiene and Recommended International Code of Hygienic Practice for Dried Fruits, which are relevant for all foods being prepared for human consumption. This code of practice indicates the measures that should be implemented by all persons that have the responsibility for assuring that food is safe and suitable for human consumption.

10. Fig differs from other fruits, which has potential risk of aflatoxin contamination, with its fruit formation and properties. Its increased sensitivity is due to juicy and pulpy skin, and the cavity inside the fruit and the suitable composition rich in sugar. Thus, toxigenic fungi may grow and form aflatoxins on the outer surface or inside the cavity even if no damage occurs on the skin. The critical periods for aflatoxin formation in dried fig fruits starts with the ripening of figs on the tree, continues during the over-ripe period when they lose water, shrivel and fall down onto the ground and until they are fully dried on drying trays. Fungal growth and toxin formation can occur on the outer fleshy skin and/or inside the fruit cavity. Some insect pests as the Dried Fruit Beetle (*Carpophilus* spp.) or Vinegar flies (*Drosophila* spp.) that are active at fruit ripening stage may act as vectors in transferring the aflatoxigenic fungi to the fruit cavity.

11. The main requirement is to obtain a healthy plant and good quality product by applying necessary agricultural techniques for prevention/reduction of aflatoxin formation.

2. DEFINITIONS

12. ***Fig***, *Ficus carica* L., as a dioecious tree has male and female forms that bear two to three cycles of fruits per year.

13. ***Caprification*** is a process applied in case female fig fruits of a certain variety require pollination for fruit set. The "*profichi*" (ilek) fruits of male figs possessing fig wasps (*Blastophaga psenes* L.) and pollen grains are either hung or placed on female fig trees to pollinate and fertilize the main and second crop (iyilop) fruits. The pollen shedding period of the male flowers in

male fig fruits should coincide with the ripening of the female flowers in female fig fruits.

14. ***Ostiole*** or ***eye*** is the opening at the distant end of the fruit that may, if open, provide entrance to the vectors, Dried Fruit Beetle (*Carpophilus* spp.) or Vinegar flies (*Drosophila* spp.) for dissemination of aflatoxigenic fungi.

3. RECOMMENDED PRACTICES BASED ON GOOD AGRICULTURAL PRACTICES (GAP), GOOD MANUFACTURING PRACTICES (GMP) AND GOOD STORAGE PRACTICES (GSP)

3.1 Site selection and orchard establishment (planting)

15. Fig trees grow in subtropical and mild temperate climates and have a short dormancy period which restricts fig growing in low temperatures in winter rather than high temperatures in summer. Low temperatures right after bud-break in the spring and during October – November before shoots are hardened, can damage the tree. Freezing temperatures in winter may affect the fig wasps over-wintering in male fruits and may create problems in fruit set.

16. High temperatures and arid conditions in spring and summer can increase sun-scald, result in early leaf fall if severe, cause substantial problems in quality and trigger aflatoxin formation.

17. The fig varieties may vary regarding their tendency for cracking/splitting however high relative humidity and rainfall during the ripening and drying period must be taken into account before establishing the orchard. High humidity and rainfall can increase ostiole-end cracking, development of fungi and decrease of quality.

18. Fig trees can be grown in a wide range of soils such as sandy, clayey or loamy. A soil depth of at least 1-2 m accelerates the growing of fig trees which have fibrous and shallow roots. The optimum pH range for soil is 6.0 – 7.8. The chemical (such as pH) and physical properties of the orchard soil can influence the intake of plant nutrients and consequently dried fig quality and resistance to stress conditions, thus soil properties must be fully evaluated before orchard establishment.

19. The level of the underground water table must not be limiting. Availability of irrigation water is an asset to overcome drought stress.

20. The orchards should be established with healthy nursery trees that are free from any insects and diseases. Adequate space, which is generally 8 m to 10 m, should be given between the rows and the trees to allow the use of necessary machinery and equipments. Before planting the way the fruits will be utilized (fresh, dried or both) need to be considered. Other species present in the orchard should also be considered. Species which are susceptible to aflatoxin formation such as maize should not be produced around the fig orchards. Materials remaining from the previous crops and foreign materials should be cleaned and if it is needed the field can be fallowed in the following few years.

3.2 Orchard management

21. Practices such as caprification, pruning, tillage, fertilization, irrigation, and plant protection should be applied on time and with a preventive approach in the framework of "Good Agricultural Practice".

22. Cultivation practices, both in the orchard and in the vicinity, that might disperse *A. flavus*/*A. parasiticus*, and other fungal spores in the soil to aerial parts of trees should be avoided. Soil as well as fruits and other plant parts in fig orchards can be rich in toxigenic fungi Soil tillage practices must be terminated one month before the harvest. During the growing seasons, roadways near the orchards should be watered or oiled periodically to minimise outbreaks of mites as a result of dusty conditions. The devices and equipments should not damage fig trees or cause cross contamination with pests and/or diseases.

23. Fig trees must be pruned lightly and all the branches and other plant parts must be removed from the orchard in order to avoid further contamination. Direct incorporation of all parts into the soil must be avoided. After soil and leaves analysis, based on the expert proposal proper composting can be recommended prior to incorporation of the organic matter.

24. Fertilization affects the composition of fruit and stress conditions may trigger toxin formation. Also excess nitrogen is known to enhance fruit moisture content which may extend the drying period. Fertilizer applications must be based on soil and plant analysis and all recommendations must be made by an authorized body.

25. An integrated pest management programme must be applied and fruits or vegetables that promote infestation with dried fruit beetles or vinegar flies should be removed from the fig orchards since these pests act as vectors for the transmission of fungi especially into the fruit cavity. Pesticides approved for use

on figs, including insecticides, fungicides, herbicides, acaricides and nematocides should be used to minimise damage that might be caused by insects, fungal infections, and other pests in the orchard and adjacent areas. Accurate records of all pesticide applications should be maintained.

26. Irrigation should be implemented in regions or during periods with high temperatures and/or inadequate rainfall during the growing season to minimise tree stress, however, irrigation water should be prevented from contacting the figs and foliage.

27. Water used for irrigation and other purposes (e.g. preparation of pesticide sprays) should be of suitable quality, according to the legislation of each country and/or country of import, for the intended use.

3.3 Caprificarion

28. Caprifigs (male fig fruits) are important for fig varieties, which require for fruit set. Caprifigs should be healthy, free from fungi and should have plenty and live pollen grains and wasps (*Blastophaga psenes* L.). During pollination of female fig fruits by fig wasps, which pass their life cycle in caprifig fruits, *Fusarium*, *Aspergillus* spp. and other fungi can be transported to the female fig fruits from the male fruits through these wasps. Since male trees are the major sources of these fungi, male trees are generally not allowed to grow in female fig orchards. It is important to use clean caprifigs, rotten and/or soft caprifigs should be removed prior to caprification. Because caprifigs, which are allowed to stay on the tree and/or in the orchard, can host other fungal diseases and/or pests therefore after caprification they must be collected and destroyed outside the orchard. To make the removal of caprifigs easier, it is recommended to place caprifigs in nets or bags.

3.4 Pre-harvest

29. All equipment and machinery, which is to be used for harvesting, storage and transportation of crops, should not constitute a hazard to health. Before harvest time, all equipment and machinery should be inspected to ascertain that they are clean and in good working condition to avoid contamination of the figs with soil and other potential hazards.

30. Trade Associations, as well as local and national authorities should take the lead in developing simple guidelines and informing growers of the hazards associated with aflatoxin contamination of figs and how they may practice safe harvesting procedures to reduce the risk of contamination by fungi, microbes and pests.

31. Personnel that will be involved in harvesting figs should be trained in personal hygienic and sanitary practices that must be implemented in processing facilities throughout the harvesting season.

3.5 Harvest

32. Harvesting of dried figs is different from harvest of figs for fresh consumption. The figs to be dried are not harvested when they mature but kept on the trees for over-ripening. After they lose water, partially dry and shrivel, an abscission layer forms and the fig fruits naturally fall from the trees onto the ground. The most critical aflatoxin formation period begins with ripening and continues when shriveled until fully dried. The fig fruits need to be collected from the ground daily to reduce aflatoxin formation and other losses, caused by diseases or pests. On the other hand, the collecting containers should be suitable, preventing any mechanical damage and should be free of any fungal sources and clean.

33. Dried fig harvest should be done regularly at short intervals daily to minimize the contacts with soil and thus contamination risks. Frequent harvest also reduces insect infestation especially of dried fruit beetles (*Carpophilus* spp.) and fig moths (*Ephestia cautella* Walk. and *Plodia interpunctella* Hübner).

34. In case of a significant difference between day and night temperatures, dew formation that may trigger aflatoxin production may occur. This is important since wet surfaces favouring the growth of fungi may be formed even after complete drying of the fruit.

3.6 Drying

35. Drying area and time are important factors in aflatoxin formation. The moisture content of the partially dried and shriveled fig, fallen down from the tree, is approximately 30-50% and these fruits are more susceptible to physical damage than the fully dried fig fruits that have approximately 20-22% moisture content. Good soil management that reduces particle size and smoothens the surface before harvest is therefore necessary to reduce the risk of damaging.

36. Fig fruits can be dried artificially in driers or under the sun with the help of solar energy. In artificial driers, the fig fruits are dried in a shorter period and more hygienic products with less pest damage can be obtained. Good drying practice can help preventing aflatoxin formation. Sun-drying is cost efficient and environmentally friendly, however may as a result increase the likelihood of aflatoxin contamination.

37. Fruits shall not be placed directly on the soil surface or on some vegetation. Drying beds should be arranged as single layers in a sunny part of the orchard where air currents are present. The drying trays shall be covered with a material to protect the figs from rain fall in case there is a risk or to prevent infestation of fig moths that lay eggs in the evening. Drying trays that are 10-15 cm above the ground should be preferred in sun-drying since fruits can benefit from the heat at the soil surface and are well aerated. They can dry quickly and the contamination of fruits by foreign materials and sources of infection such as soil particles or plant parts are eliminated.

38. Figs that are dried, possessing moisture = 24% and water activity = 0.65, should be picked from the trays. The fully dried fruits should be collected from the trays preferably in the morning before the temperature of the fruits increase and soften but after the dew goes away. The trays should be re-visited at short intervals to collect fully dried figs. Dried figs taken from drying trays must be treated to prevent storage pests with a method allowed in the legislation of each country, for the intended use.

39. Low quality figs which are separated as cull and have the risk of contamination should be dried and stored separately to prevent cross contamination. Staff who conduct the harvesting or work in storage rooms should be trained in this respect to ensure that these criteria are followed.

3.7 Transportation

If transportation is required the following provisions apply:

40. During the transportation of dried figs from farm to processor, the quality of figs should not be affected adversely. Dried figs should not be transported with products that pungent odours or have the risk of cross contamination. During transportation, increase of moisture and temperature must be prevented.

41. The dried figs should be moved in suitable containers to an appropriate storage place or directly to the processing plant as soon as possible after harvesting or drying. At all stages of transportation, boxes or crates allowing aeration should be used instead of bags. Containers used in transportation shall be clean, dry, and free of visible fungal growth, insects or any other source of contamination. The containers should be strong enough to withstand all handling without breaking or puncturing, and tightly sealed to prevent any access of dust, fungal spores, insects or other foreign material. Vehicles (e.g. wagons, trucks) to be used for collecting and transporting the harvested dried figs from the farm to drying facilities or to storage facilities after drying, should

be clean, dry, and free of insects and visible fungal growth before use and re-use and be suitable for the intended cargo.

42. At unloading, the transport container should be emptied of all cargo and cleaned as appropriate to avoid contamination of other loads.

3.8 Storage

43. Figs must be properly cleaned, dried and labelled when placed in a storage facility equipped with temperature and moisture controls. The shelf life of dried figs can be prolonged, if they are dried to a water activity value at which molds, yeasts and bacteria cannot grow (water activity<0.65). In case further hot spots are formed where temperature and moisture increases, secondary aflatoxin formation may occur. Because of this reason, any possible source enhancing humidity of the dried fruits or of the surrounding environment must be eliminated. Direct contact of dried fig containers with floors or walls need to be prevented by placing a palette or a similar separator.

44. The storage rooms should be far from sources of contamination as in the case of mouldy figs or animal shelters if any are present at the farm, and fruits must not be stored with materials that possess unusual odours. Precautions should be taken to avoid insect, bird or rodent entrance or similar problems especially under farm storage conditions.

45. Low quality figs that are not destined for direct human consumption should be stored separately those intended for human consumption. The storage rooms should be disinfected with effective disinfectants. Areas like cleavage and cavity should be repaired and windows and doors should be netted. The walls should be smoothened and cleaned every year. The storage rooms should be dark, cool and clean.

46. The optimum storage conditions for dried figs are at temperatures of 5-10 °C and relative humidity less than 65%. Therefore, cold storage is recommended.

3.9 Processing

47. Dried figs are fumigated, stored, sized, washed, cleaned, sorted and packed in processing units. Among these processes, removal of aflatoxin-contaminated figs, storage and package material may exert the major impact on aflatoxin levels of the final products. Processed figs must be treated to prevent storage pest with a method allowed in the legislation of each country for the intended use.

48. Dried fig lots entering into the processing plant must be sampled and analyzed as an initial screening for quality moisture content and ratio of bright greenish yellow fluorescent (BGYF) figs. Dried figs contaminated with aflatoxins can have a correlation with BGYF under long wave (360 nm) UV light. BGYF may occur on the outer skin but also inside the fruit cavity; the ratio being dependent on the fruit characteristics and on prevalence of vectors. Dried figs fruits are examined under long wave UV light and the fluorescent ones are removed to obtain a lower aflatoxin content of the lot. Work conditions such as the length of working, break intervals, the aeration and cleanliness of the room, should provide worker safety and product safety.

49. Contaminated figs must be separated, labelled and then destroyed in an appropriate manner in order to prevent their entry into the food chain and further risk of environmental pollution.

50. The moisture content and water activity level of dried fig fruits must be below the critical level (moisture content can be set at 24% and water activity of less than 0.65). Higher levels may trigger fungal growth and toxin formation. Higher water activity levels may trigger aflatoxin formation in areas of high temperature storage at the processing plant or at retail level especially in moisture tight packaging material.

51. Dried figs are washed if demanded by the buyer. The water temperature and the duration of washing should be arranged according to the moisture content of the figs in order to avoid the elevation of the initial moisture content of fruits to critical levels. In case the moisture and water activity levels are increased, a second drying step must be integrated in the process. The water should have the specifications of drinking water.

52. Good storage practices must be applied at the processing plant and should be kept at this standard until the product reaches the consumer (see section 3.8).

53. All equipment, machinery and the infrastructure at the processing plant should not constitute hazard to health, and good working conditions should be provided to avoid contamination of figs.

54. These recommendations are based on current knowledge and can be updated according to the research to be pursued. Preventive measures are essentially carried out in fig orchards and precautions or treatments undertaken at the processing stage are solely corrective measures to prevent any aflatoxin formation.

CODE OF PRACTICE FOR THE PREVENTION AND REDUCTION OF OCHRATOXIN A CONTAMINATION IN WINE

CAC/RCP 63-2007

1. PREAMBLE

Mycotoxins, in particular ochratoxin A (OTA), are secondary metabolites produced by filamentous fungi found in soil and organic matter, which spread and thrive on grapes during the berry ripening phase.

The formation of OTA in grapes is mainly due to berry contamination by certain mould species, and particular strains thereof, belonging essentially to the *Aspergillus* species (in particular *A. carbonarius* strains and to a lesser extent *A. niger*).

The presence and spread of such fungi in vineyards are influenced by environmental and climatic factors, nocturnal dampening condition of grapes, grape bunch shape, susceptibility of vine varieties, aeration level of the grape bunches, health status of grapes and berry injuries which are the main entry points for ochratoxigenic fungi.

2. CULTIVATION PRACTICES IN THE VINEYARDS

Application of the following preventive measures is recommended, in viticulture regions in which the climatic conditions are favourable to the formation of OTA in vine products in order to reduce endemic risk which favours the onset of the most damaging vine diseases:

2.1 Regional risk information

- Ensure that regional authorities and grower organisations:
  - analyse and identify the species and strains of toxigenic fungi present in their region;
  - combine this information with regional risk factors including meteorological data and viticultural techniques and propose appropriate management;
  - communicate this information to growers.

Adopted 2007.

2.2 Training of producers

- Ensure training of producers with regards to:
  - risk of mould and mycotoxins;
  - the identification of ochratoxigenic fungi or the presence of mould spoilage, especially black mould, and period of infection;
  - knowledge of preventive measures to be applied to vineyards and wineries.

2.3 Vineyard establishment

- Favour vine establishment in well aerated areas while avoiding very humid areas.
- Draw up plots of land with adequate planting disposition, and vegetation architecture (trellising system) to:
  - facilitate planting operations;
  - avoid direct contact of grapes bunches with the soil;
  - ensure good pest and disease control;
  - minimise the risk of grapes sun burn;
  - promote the uniform ripening of the grape.

2.4 Plant material

- Choose vigorous rootstock and varieties which are less prone to developing mould and grape rot.
- Choose clones or biotypes within a variety which are better adapted to climatic and soil conditions in the specific cultivation areas and less sensitive to mould and rot development, which are often characterised by less compact grape bunches.
- Lay out homogeneous plots of land (varieties, clones) to facilitate growing operations and to ensure better crop and disease control and to obtain uniform ripening of the grapes.

2.5 Growing techniques

- Apply management practices which favour leaf/fruit balance for vines and which reduce excess vigour, in particular, avoiding inappropriate nitrogenous fertilizer applications.
- Favour vegetation or organic cover of soils and avoid working the soil between the beginning of the grape ripening and grape harvest period in order to limit the transfer of soil particles and the associated fungi to the grapes.
- Favour placing grape bunches in an orderly manner to avoid overcrowding.

- If water input is necessary, irrigate as regularly as possible in order to avoid berry splitting and the onset of cracks on the skin which are sources of mould penetration and development, especially in warm regions.
- Avoid using marc containing toxigenic fungi as a fertilizer in the vineyards.

2.6 Pest and disease control

- Carry out leaf removal in the grape cluster zone while recognising the need to limit the risk of sun burn. This must enable the aeration of clusters. This is particularly necessary under hot and humid weather conditions while the grapes are ripening.
- Avoid lesions on the berries and skin damage caused by diseases, insects, phytotoxicity and sun burn.
- Remove shriveled/desiccated berries.
- Apply vine protection plans in order to control dangerous fungal diseases affecting grape quality (oïdium disease, acidic rot).
- Prevent attacks of grape berry moths, grape mealybugs and grape leafhoppers, which favour mould development on damaged berries; pest control needs to be carried out according to biological and epidemic risk; under high risk conditions preventive treatments must be applied by using specific products and taking into account the warnings of plant protection regional services.
- Apply appropriate and registered protective programmes against grape rot and mould using appropriate management to avoid fungal resistance. Appropriate treatments are recommended in all situations which are favourable to the development of toxin producing species.

3. PRACTICES AT HARVEST

Only a healthy grape harvest can ensure optimal quality and safety of vitivinicultural products. Consequently, only a healthy grape harvest can be used for human consumption without the risk of quality loss and without food safety problems for consumers.

The date of harvest must be decided taking into account grape ripeness, sanitary level, and forecasted climatic changes and endemic risk. In high risk OTA areas, it is recommended to advance the harvest date.

When grapes are extensively contaminated by mould:
- the grapes can not be used for making concentrated musts or wine;
- the grapes can only be used for distillation.

3.1 Production of raisined grapes for wine production

For production used to obtain raisined grapes for wine production (sweet wine), the following actions are recommended:
- Ensure the hygiene of containers to be used for the harvest and/or the drying of grapes.
- Use only grapes not damaged by insects and not contaminated by mould.
- Sort grapes by eliminating damaged or contaminated grapes.
- Place grapes to be dried or raisined in a single layer and avoid overstacking.
- Favour progressive and uniform drying of all parts of the grape bunch.
- Take the necessary measures to avoid development of fruit fly infestation.
- For particular conditions of drying in open air, it is recommended to dry in well ventilated conditions and to cover the grapes at night to prevent condensation and humidity.

3.2 Production of wine grapes

The following actions are recommended if the harvest is moderately contaminated with toxigenic moulds and is to be used in wine production:
- Grapes damaged by insects, mould, or contaminated by dirt particles must be eliminated before harvest or at harvest time depending on harvesting technique.
- Grapes need to be sorted, in order to separate the grape bunches or the damaged parts of bunches. It is important to discard grapes with black mould.
- Harvested grapes must be transported as quickly as possible to the winery in order to avoid extended waiting, especially for grapes with a high proportion of juice.
- It is important to clean containers after each load, especially in the case of harvests where the containers may have been used to harvest grapes that may be rotten.

4. TREATMENT AT THE WINERY

Under conditions with a risk of OTA contamination, it is recommended to measure the level of OTA in the musts to be used in winemaking.

4.1 Pre-fermentation operations and treatments

- Avoid skin maceration in the case of OTA high-risk harvests or carry out short maceration.
- In the case of a significant contamination of red grapes, evaluate possibility of carrying out rosé winemaking.
- Adapt pressing rate to the health status of the grape; in case of contamination, carry out small volume, low pressure quick pressings. Avoid continuous press.
- In the case of contaminated grapes, avoid using pectolytic enzymes for racking must or maceration. Quick clarifications with must filtration, centrifugation and flotation are preferable.
- Avoid post-harvest heating treatments and aggressive and prolonged macerations.
- In the case of contamination by OTA, it is preferable to treat the grapes and the musts with the lowest possible and most effective doses of oenological charcoal in order to avoid possible loss of aromatic and polyphenolic compounds when the treatment is carried out on wine.

4.2 Fermentation treatments

- Carry out, as far as possible, fermentation and maturing in smooth walled containers to avoid sources of contamination linked to previous fermentations or maturing and in order to facilitate cleaning.
- Dry active yeasts or inactive yeasts can help reduce the OTA level.
- For alcoholic or malolactic fermentations, use yeasts or bacteria which have adsorbent properties for OTA; ensure that these characteristics are guaranteed by the supplier. Note that the usage of these products only enables a partial reduction of OTA.
- It is recommended to introduce, as quickly as possible, following fermentation treatments.

4.3 Maturing and clarification treatments

- Maturing on lees can help in reducing the OTA level. The risks of this technique related to the organoleptic quality of wine must be evaluated.
- Current clarification products (organic or inorganic fining agents) have variable levels of efficiency for reducing the level of OTA:
  - Oenological charcoal is the most effective.
  - Certain cellulose and silica gels associated with fining with gelatine only enable a partial reduction.

Before use:

- Become informed of effectiveness of product used and application technology.
- Carry out trials with different dosages to ascertain sensory repercussions and application rate.

5. GENERAL CONDITIONS FOR FOOD CONTACT MATERIALS

Food contact materials used during harvesting, transport and production in the winery should not give rise to contaminant migration or cross-contamination which can endanger human health.

6. CONCLUSION

These recommendations are based on current knowledge and can be updated according to the findings of research to be pursued.

Preventive measures are essentially carried out in vineyards and treatments undertaken at the wineries are solely corrective measures.

CODE OF PRACTICE FOR THE PREVENTION AND REDUCTION OF OCHRATOXIN A CONTAMINATION IN COFFEE

CAC/RCP 69-2009

1. INTRODUCTION

1. Ochratoxin A (OTA) is a toxic fungal metabolite classified by the International Agency for Research on Cancer as a possible human carcinogen (group 2B). JECFA established a PTWI of 100ng/kg bodyweight for OTA. In recognition of this global concern, FAO developed the Guidelines for the Prevention of Mould Formation in Coffee (2006) as a strategy to enable coffee producing countries to develop and implement their own national programmes for the prevention and reduction of OTA contamination. OTA is produced by a few species in the genera *Aspergillus* and *Penicillium*. In coffee, only *Aspergillus* species, specifically *A. ochraceus* and related species (*A. westerdijkiae* and *A. steynii*), *A. niger* and related species, and *A. carbonarius* are involved. OTA is produced when conditions of water activity, nutrition and temperature required for growth and biosynthesis are present.

2. The main commercial coffee varieties produced and traded are *Coffea arabica* (arabica coffee) and *Coffea canephora* (robusta coffee).

3. After harvest, the crop is sorted, dried (as cherries or as beans), stored and traded. The moisture content of the beans is reduced to a maximum of 12.5% to prevent OTA production.

2. DEFINITIONS (BASED ON ISO 3509)

Parts of the coffee fruit, undried (Figure 1)

Coffee Cherry: fresh, complete fruit of the coffee tree.

Bean, fresh bean: endosperm (seed) of the coffee fruit. There are generally two beans per fruit.

Endocarp: scientific term for 'parchment'. The tough integument tightly pressed to the seed when fresh but from which the seed shrinks during drying.

Adopted 2009.

Endosperm: scientific term designating the tissues that feed the embryo during germination, the bean consists of the endosperm and embryo, i.e., the material inside the developing fruit which ultimately forms the coffee beans. The endosperm fills the integument as the coffee cherry ripens.

Epicarp or Exocarp: scientific word designating the skin of the fruit, a mono cellular layer covered with a waxy substance ensuring protection of the fruit.

Floating (or floats) coffee: cherry coffee of low density, buoyant in water.

Mesocarp: intermediate layer of tissues between the epicarp and the endocarp (parchment). It consists mainly of pectinaceous mucilage and pulp.

Mucilage: common word to describe the slimy layer found between the pulp and adhering to the parchment inside a coffee cherry, but not removed by pulping. Not present in unripe and overripe coffee.

Naked beans or endosperm: parchment coffee that has been partly or entirely peeled of its parch during pulping and/or washing.

Pulp: part of the coffee cherry composed of the external exocarp and most of the internal mesocarp (mucilaginous tissue).

Parts of the coffee fruit, dried

Bean in parchment: coffee bean entirely or partially enclosed in its parchment (endocarp, pergamino).

Coffee bean: commercial term designating the dried seed of the coffee plant.

Defects: the general term for common undesirable particles, which can include various types of beans, parts of beans, fruit tissue and foreign matter, found in green and roasted coffee beans. Diverse and specific terms, according to the producing country, are used to describe the defects. The fruit defects are generally caused by faulty processing, pest damage, or adverse climatic conditions. Defects receive specific weight values to assist in the classification and grading of coffee lots under various national and international systems.

Natural coffee, dried coffee cherry, coco: dried fruit of the coffee tree, comprising its external envelops and one or more beans.

Green coffee bean: the dried seed of the coffee plant, separated from non-food tissues of the fruit.

Hull, dried parchment: dried endocarp of the coffee fruit.

Husk, dried cherry pulp: assembled external envelopes (pericarp) of the dried coffee fruit.

Parchment (or Parch) or endocarp: the coffee fruit endocarp located between the fleshy part (pulp) and the silver skin. It is a thin, crumbly paper-like covering left on wet-processed beans after pulping and fermentation, removed during hulling.

Silverskin, dried testa, dried seed perisperm: coat of the coffee bean. It has generally a silvery or coppery appearance.

Washed and cleaned coffee: dry processed green coffee from which the silverskin has been removed by mechanical means in the presence of water.

Processes

Splitting of cherry: a variation of dry processing wherein the cherry is mechanically split open and the fruit and seeds maintained together in a mass.

Gleaning (or Sweeping): coffee fruit found lying on the ground beneath coffee bushes, detached during harvest or abscised during development.

Selection: technological operation intended to eliminate foreign matter (e.g. stones, twigs, leaves) and to sort coffee cherries according to size, density and degree of maturity.

Dry process: treatment of coffee cherries consisting in drying them, either under sunlight or in drying machines, to give husk coffee. This is usually followed by mechanical removal of the dried pericarp (husk) to produce "natural" green coffee.

Dehusking: mechanical removal of the husks (pericarp) from dry coffee cherries.

Wet process: treatment of coffee cherries consisting of the mechanical removal of the exocarp (pulp) in the presence of water, alternatively followed by

- either removal of the mucilage (mesocarp) by fermentation or other methods, followed by washing to give parchment coffee, or
- direct drying of the pulped beans within their mucilaginous parchment, followed by hulling to produce "semi-washed" green coffee. Removal of the mucilage is usually followed by drying and hulling to produce "washed" green coffee.

Pulping: technological operation used in the wet process to remove the pulp (exocarp) and as much as possible of the mucilage (mesocarp) by mechanical means. A portion of the mucilaginous mesocarp usually remains adhering to the parchment (endocarp).

Fermentation process: treatment intended to digest the mucilaginous mesocarp adhering to the parchment of the pulped coffee, allowing its elimination by washing. The fermentation process can be replaced by a mechanical demucilaging system to remove the mucilage by friction.

Washing: technological operation intended to remove by water all traces of the mucilaginous mesocarp from the surface of the parchment.

Drying of parchment coffee: technological operation to reduce the moisture content of parchment coffee to a level that allows hulling under satisfactory technical conditions and that will not be detrimental to further storage of the coffee.

Hulling: removal of the dried endocarp of parchment coffee to produce green coffee.

Polishing: technological operation to remove the residual silverskin (perisperm) from green coffee by purely mechanical means.

Sorting: technological operation intended to remove foreign matter, fragments of coffee and defective beans from green coffee.

Roasting: heat treatment that produces fundamental chemical and physical changes in the structure and composition of green coffee, bringing about darkening of the beans and the development of the characteristic flavour of roasted coffee.

3. PROCESSING OF COFFEE CHERRIES

4. Coffee cherries are processed under two basic systems (Figures 2 and 3): a) the dry processing system which produces what is called natural coffee or dried coffee cherry (the seed is enclosed in the whole fruit) and b) the wet processing system, that generates what is called parchment coffee, where the seed is enclosed in the inner integument or endocarp.

5. In the dry processing of natural coffee, the whole fruit is either directly sun dried, on bare soil, bricks, tiles, concrete or even asphalt, or dried using a combination of sun and mechanical drying (particularly on more technologically advanced farms).

6. In wet processing, the fruit parts are mechanically separated, giving the pulp as by-product and the parchment as the main product. The latter is coated with mucilage, which can be degraded by fermentation and then washed or mechanically removed directly, without fermentation. After removing or not removing the mucilage, the parchment is usually sun dried, in a drying yard, or on suspended tables with many variations and technological innovations. Sun and mechanical drying can be combined and used together.

7. After processing, the dried coffee can be stored, separated from the fruit tissues by hulling and passed through sizing (grading), sorting, polishing, cleaning and bagging, before being sold.

8. Coffee roasting can remove a very significant percentage of OTA. Depending on the roasting process, 65 to 100% reduction of OTA can be achieved.

9. While this code of practices is focused on the reduction of OTA contamination, which is the primary food safety issue in the production of green coffee bean, industry food safety programmes must also effectively manage other potential hazards associated with the production, processing and handling of coffee.

4. RECOMMENDED PRACTICES

4.1 Pre-harvest

10. It is not certain whether OTA-producing fungi can infect coffee fruits and grow to produce OTA still on the plant. It is possible that infection on the plant may involve two different contamination routes: either through the flowers without visible sign, or by insect invasion such as the coffee berry borer (CBB)

(*Hypothenemus hampei*), that can carry spores to the fruit by making holes in the cherries and one or more tunnels in the beans leaving visible signs.

11. Recommended practices to reduce the development and spore load from OTA-producing fungi on coffee plants and beans are:
    a) Keep coffee plants vigorous, through the regular use of good agricultural practices (GAP) at the proper time, such as weeding, improving soil texture, pruning, fertilization, pest and disease control, and irrigation.
    b) Do not use overhead irrigation during the flowering period. This could augment normal spore dispersal rates and increase the chance of infection of beans by OTA producers.
    c) Use traps (such as alcohol traps) for *Hypothenemus hampei* control before harvesting, and encourage the use of the integrated pest management (IPM) programme.
    d) Avoid disposal of uncomposted organic wastes, from coffee or any other source, in or around the plantation. Coffee seeds and seed-associated material, such as dust, earth, parchment and other seed processing residues, can allow proliferation of OTA producing fungi.

4.2 Harvesting

12. The harvesting method chosen on any farm is a conjunction of the requirements of the processing method, economic considerations and labour availability.

13. Four basic harvesting systems are known: (i) single-pass stripping, where all branches bearing fruit are harvested at once; (ii) multi-pass stripping, where only branches bearing mainly ripe cherries are harvested; (iii) multi-pass selective picking (finger picking), where only ripe cherries are harvested and (iv) mechanical harvesting, where different types of machines are used to harvest fruit all at once.

14. Besides these basic main harvest systems, additional procedures can be used, such as a 'fly harvest' to collect prematurely ripe fruit or the collection (gleaning or sweeping) of cherries that fall on the ground or are left on the plants during harvest. In general, berries that fall onto the ground should not be collected, particularly in humid conditions, as fungal growth may occur, which can give rise to OTA contamination. However, brief contact with the ground is not problematic but can become so if the contact period lengthens. In wet or humid climates, only collection from the ground on the same day should be considered acceptable. If it is necessary to harvest beans that have fallen onto the ground, these should be stored separately until they are

processed, to avoid the risk of contaminating the rest of the crop. Care should be taken to ensure that any fallen berries that are collected are rapidly subjected to the processing and drying stages, as these commodities may have a higher likelihood of fungal growth.

15. The harvest should be started as soon as there are sufficient ripe cherries for it to be economically viable. When the right time to commence harvest is decided, the following should first be carried out:
    a) Remove weeds, fallen cherries and brush from the proximity of the trees before harvest.
    b) Where possible, place mats, canvas or tarpaulins beneath the trees to prevent contamination by old fallen cherries.
    c) Ensure that there are adequate arrangements for the subsequent storage and processing of the crop, so that conditions favour mould growth or other damage are avoided.

16. Coffee cherries should be processed as soon as possible after harvesting. The harvesting rate, processing performance and labour availability must follow the pace of the drying rate.

17. Coffee ready to be processed should be uniform and not of mixed categories i.e. wet with dry coffee in dry processing or pulpable with not pulpable in wet processing. Prior to processing low quality cherries (e.g. unripe or overripe fruit, or fruit that has coffee berry disease) should be removed. This can be done either by visual sorting, or via water separation. It should be ensured that any material that is out sorted is disposed of in an appropriate manner.

4.3 Post-harvest

18. Senescence and changes follow once coffee fruit is detached from the plant. The post harvest period is characterized by initial, transitional and final phases.

19. The initial or high moisture phase starts with harvest. The product is then in an unstable state, and spoilage can be controlled through competitor microrganisms, restricting oxygen and reducing the time which is critical in this state. In wet processing the high moisture phase may be extended and controlled through fermentation, but it is desirable to reduce this time.

20. The transitional phase is the least stable and most difficult to predict, when spoilage can only be controlled by time limitation. Mesophilic and xerophilic spoilage microrganisms have enough water to grow but not their hydrophilic competitors. Turning or stirring of the coffee is essential to promote uniform

drying. When harvest coincides with a rainy or high humidity season, measures to optimize drying must be adopted.

21. The final or low moisture phase starts at the end of drying and continues until roasting. The product is in a stable condition and control is necessary to prevent water re-introduction or redistribution in the bulk coffee. At some point during drying, there is no further growth as the product reaches the low moisture phase.

4.4 Dry processing

22. In the dry processing system (Figure 2) the whole harvested fruit is dried. Although it is a simpler process compared to wet processing, a good quality finished product can only be obtained through the application of good practices and proper management.

23. One option used in regions where the harvest time normally occurs under arid weather conditions is to allow the fruit to dry on the plant. This method results in a lower level of immature fruit, which is safe, of good quality and is cheaper than the traditional harvest, as it allows one-pass stripping.

24. Wherever possible, freshly picked cherries should be dried on the same day that they are harvested. In some instances, the harvested fruit is retained in bags or heaps for up to a week. This practice leads to high temperatures and quick fermentation, different in nature from the fermentation process employed in wet processing, causing quality losses and increasing the risk of OTA in the product.

25. Prior to drying, the harvested fruit should be sorted to remove immature and over mature cherries, and cherries damaged to CBD (coffee berry disease). Sorting may be done either visually, or in combination with water floatation.

4.5 Wet processing

26. Wet or washed processing (Figure 3) requires a raw material composed of only ripe cherries that have been selectively picked or are mechanically separated in the process itself. Green immature cherries and dried fruits are removed in a water separator. The mucilage is removed, either by fermentation, mechanically or using chemicals.

27. In the fermentation process, the mucilage is broken down by fermenting the beans in water at ambient temperature (using microrganisms) for between 12

and 36 hours. The fermentation process must be carefully monitored to ensure that the coffee does not acquire undesirable (sour) flavours. After fermentation is complete, the coffee beans are washed in clean water tanks or in special washing machines.

28. After passing through the washer separators and before removal of the pulp, the separation of the green immature cherries from the ripe ones can be performed, using differences in pressure, in a green cherry separator. The soft, ripe cherries pass through the holes of the screen. The hard, unripe cherries, which cannot pass through the holes, go to the edge of the cylinder where a counter weight controls their outflow.

29. Factors that need to be controlled are as follow:
    a) Any equipment should receive regular maintenance, to reduce the possibility of failures which could delay processing and compromise coffee quality and safety.
        a.1) Before the beginning of the crop season: clean, reassemble and lubricate the processing equipment; inspect the installation and check it is operational, so that there is enough time for repairs if any problem occurs.
        a.2) At the end of the crop season: clean, repair, lubricate, dust all equipment and protect from water. Check pulping surfaces for wear.
    b) Provide proper orientation/training to the workers and define their responsibilities. In addition define quality and acceptability criteria, the monitoring procedures and frequencies, and the corrective measures for each key element of the process, regarding:
        b.1) Cherries – maximum acceptable proportion of immature and over-mature/tree-dried cherries.
        b.2) Pulping – acceptable proportion of un-pulped cherries and nipped beans; cost-benefit to increase size uniformity of the cherries and effectiveness of skin removal. The efficiency of the operation can be improved based on the various estimates of the monitoring the quality and safety of the product.
    c) Water quality – clean water[1] should be used for processing, as dirty water could lead to conditions favourable to OTA production.
    d) Fermentation should be as short as possible (12 to 36 hours), to get the mucilage degraded and the beans washable. Monitoring procedures and frequencies should be established as well as the type and level of inoculum (in the in-coming cherry) and ambient temperature.

[1] As defined in the General Principles of Food Hygiene (CAC/RCP 1-1985).

e) Fruit-flies should be monitored, as high populations can affect fermentation.
f) Secondary cherry coffee, which can be defined as products separated by sorting or other procedures and are returned to the processing, should have a specific control program; i.e. good drying practices should be applied, such as maintenance of separate facilities for drying.
g) Washing protocols should be defined and implemented (e.g. by measuring the quantity of broken, nipped and naked beans, and non coffee objects, and the quantity of water used).

4.6 Drying of sorted and processed coffee beans

30. The main purpose of the drying operation is to efficiently decrease the high water content of the just harvested cherries to a safe level in order to get a stable, safe and good quality product.

31. In this section both dry and wet processes will be discussed. Most of the coffee produced is dried using direct sun.

32. In the sun drying process, the product is spread on surfaces such as cement or brick terraces, tarpaulin, plastic canvas, bamboo and sisal mats, raised tables covered in wire mesh or fish farm netting.

33. The drying process can be divided into three stages. In each stage OTA producing fungi will have varying opportunities for growth.

34. At the first stage, there is a slight decrease in moisture content that takes a time interval between 1 to 3 days for cherry coffee and 1 day or less for parchment coffee. The high moisture content ($a_w > 0.95$) provides unsuitable conditions for OTA producing fungi to grow.

35. The second stage is the one of maximum loss in moisture content for both cherry and parchment coffee, under similar conditions at the same period of time. This is mainly dependant on drying conditions and drying yard technology. During this stage, there are favourable conditions for OTA producing fungi to grow and therefore it is necessary to implement precautionary measures as recommended in paragraph 38.

36. At the third stage both cherry and parchment coffee, is much drier compared to the previous two stages. There is a slower slight decrease in the remaining moisture content. Conditions at this stage do not favour the growth of OTA producing fungi.

37. The OTA-producing fungi require favourable conditions during a certain period of time to grow and produce the toxin. The level of available water is the most important factor to be considered. At high water activity (a_w > 0.95) OTA-producing fungi will not likely grow, as fast-growing hydrophilic fungi and yeasts grow first. At lower water activity (a_w <0.80) the OTA-producing fungi can be present but not produce the toxin, and at a_w below 0.78–0.76 they cannot grow. Therefore the most important point is to control the period of time in which coffee remains in the drying yard, in the range of water activity where OTA-producing fungi can grow (a_w 0.8–0.95). According to experimental results, 5 days or less in the drying yard is enough and effective to prevent OTA accumulation. In general, a maximum a_w of 0.67 to 0.70 and moisture content < 12.5% (wet basis) is sufficient for protecting parchment coffee from damage by fungi.

38. Recommended measures to dry the coffee beans efficiently are:
    a) The drying yard should be located away from contaminant sources such as dusty areas and should receive maximum sun exposure and air circulation, during most of the day, to speed up the drying of the beans. Shady and low areas should be avoided.
    b) The surface for the drying yard should be chosen according to the climate of the region, cost and quality of the dried product, as any type of surface has advantages and disadvantages. Bare soil is not appropriate for rainy areas. Plastic canvas gets humid under the coffee layer, promoting fungal growth. In rainy or wet regions coffee must be covered and re-spread, once the surface has dried. If parchment coffee is to be dried, ensure that the drying surface is cleanable, in order to avoid picking up taints.
    c) The pace and total time of the harvest should be based on the available area of the drying yard and the average time necessary for drying, considering both good and bad weather.
    d) The following practical measures should be incorporated into the drying process:
        d.1) Dry coffee only in thin layers, 3 to 5 cm in depth which is equivalent to 25 to 35 kg/m^2 of fresh parchment or cherry coffee. In some cases (e.g. low air humidity, good air circulation and sun intensity, or in usually dry regions), thicker layers can be used.
        d.2) Turn over the coffee layer constantly during the day time to allow faster drying, to reduce the risk of fungi growing and help to produce a better quality product.
        d.3) Allow for the appropriate ventilation of the wet coffee during the night in order to avoid condensation. After one day of drying for parchment and three days for cherry coffee, the coffee can be

heaped and covered at night or during rainy weather, to avoid re-wetting.

d.4) Do not mix different types of coffee nor coffee from different days of harvest. Use a specific identification for each one of them to identify each type of coffee and day of harvest.

d.5) Protect the drying yard area from animals, which can be a source of biological contamination for the drying coffee.

d.6) Regularly control CBB and other pest populations, using integrated pest management in drying yard.

d.7) Monitor the drying process regularly (<12.5% for both parchment and cherry coffee). Start taking samples from different points of each lot, two or three days before it is expected to be fully dry and continue re-evaluating it daily until it reaches the desired moisture content. Instrumental measurements should be adopted at field level. Moisture content measures should be calibrated to ISO 6673 method.

d.8) Avoid rewetting the beans because it favours rapid fungal growth and the possibility of OTA production.

e) Provide a clear and practical training for drying yard workers, including adequate use of moisture measuring equipment.

f) Repair, clean, protect and keep equipments in a clean storage area until the next season. Moisture measuring equipment should be regularly cross checked and calibrated once a year before harvest against the ISO 6673 method.

39. Mechanical driers are generally used as complementary after sun-drying, but in some regions it plays a major role in the drying process. Mechanical driers usually need to have control of two items: inlet temperature and duration of drying time. The most common problem with mechanical drying is over drying, causing weight loss and consequently income loss. The other problem is black beans from immature beans submitted to excessive inlet temperature, decreasing the quality of the product.

4.7 Storage, transportation and trading

40. Properly identified lots of dried cherries or the dried parchment coffee should be stored, at the farm level or in out-of-farm warehouses, in bulk or in clean bags under appropriate storage conditions.

41. In different producing countries handling coffee in local trading varies in relation to the proper structure of the chain and the way the operations are performed. These functions include: post-cleaning, sorting, grading into size classes, re-bagging, sometimes re-drying, storage and transport. These

operations add value to the traded product, before it is sold and sent for roasting.

42. During the entire process, the coffee must also be protected from re-wetting, degradation and cross-contamination. In long term storage conditions, humidity should be kept under strict control. Under a relative humidity below 60% coffee will continue to dry but if the relative humidity is above 80% the coffee will start to absorb water. Moisture in the storage place can originate from damp floors and walls, rain (wind-driven or through leaks), dead air, and the mixing of dry with wet coffee. Appropriate storage facilities, the use of good storage practice and regular monitoring can prevent or reduce problems.

43. In lower grade coffee, it has been observed that fruits with black and sour defects contained the highest levels of OTA. Tolerance for such defects in sorted green beans should be low and the out-sorted defective beans should not be re-blended into clean coffee or sold directly to roasters unless representative sampling plan and direct OTA analysis has shown them to be acceptable.

44. From the production areas coffee may be transported by different means of transportation to the trading points. The main aspect of concern here is to avoid rewetting of coffee, due to possible climatic changes between different regions, and taking the necessary control measures.

45. In the production chain, the local market is the most sensitive part from where improvements in practice can be administered. Here the authorities, through regulatory and non-regulatory mechanisms can enforce and influence practices in order to guarantee that producers reliably operate in a way as to assure the product safety.

46. Stakeholders should adopt procedures to protect coffee in each part of the chain, refuse suspect coffee and avoid practices that could generate or increase a problem. Dried coffee must be protected from re-wetting through contact with water, mixture with wet lots, absorption from wet air or surfaces or redistribution of water within the lot. Defects associated with high levels of OTA should be reduced to acceptable levels. Protection from contamination by other materials is also necessary.
    a) Minimum hygiene requirements and a rapid assessment method (including a sampling method with representative sub-sample of the in-coming lot for moisture content determination, defect levels, general

physical quality assessment and visual or smell signs of mouldiness) should be established.

b) The warehouse design and structure should be adequate to maintain dryness and uniformity of the stored coffee.
   - b.1) The desirable characteristics are: cement floor with a damp proof course; not subject to flooding; water pipelines properly located to avoid wetting coffee in case of plumbing problems; water proof windows and roof and a high ceiling to allow good air circulation.
   - b.2) Do not expose stored coffee to direct sunlight nor store it near heating sources, to avoid the possibility of temperature differentials and water migration.

c) The operation of a storage facility must be optimised to prevent cross contamination, the reintroduction of moisture and to allow the best execution of receiving, sale and value-added operations that will preserve the coffee quality until it is sold to the next stakeholder in the production chain. The main recommendations are:
   - c.1) Record initial condition and age of the received stocks.
   - c.2) Arrange the coffee bags on pallets and away from walls, to allow good air circulation.
   - c.3) Implement cleaning and maintenance programmes in order to ensure that storage facilities are periodically inspected, cleaned and renewed.
   - c.4) Check coffee weevil in the warehouse, using integrated pest management.
   - c.5) Farms and other operations should separate coffee types. This requires planning of the storage area and adoption of a labelling system. Non-food materials should not be stored with coffee to prevent contamination or taints in the product.

d) Coffee cleaning and sorting should not physically damage the product as this will make it more susceptible to contamination/deterioration nor introduce new contamination and should assure reduction of undesirable materials to acceptable pre-determined levels.
   - d.1) Ensure the facilities and equipment are regularly inspected, maintained and cleaned, through implementation of cleaning and maintenance programmes.
   - d.2) When storage is combined with cleaning and sorting, attention is required to avoid contamination of post-cured coffee with the curing by-products of dust and foreign matter, (e.g. through the use of partition walls or extractor fans).
   - d.3) Remove defects from main-crop production, discarding or screening them before their inclusion into the food chain. There is no uniform distribution of defects within the classes of beans separated from bulk coffee and evidence shows that defective beans and husk (also a defect) sometimes contain higher OTA levels than sound beans.

Based on further investigations of OTA contamination of defects authorities should provide clear guidance to the stakeholders.

e) Transport of coffee also requires the adoption of practices to avoid re-wetting, to maintain temperature as uniform as possible and to prevent contamination by other materials. The main requirements here are:
   - e.1) cover coffee loading and unloading areas to protect against rain;
   - e.2) before receiving a new cargo, the vehicles must be cleaned from residues of the previous cargo;
   - e.3) the vehicles must have floor, side walls and the ceiling (in closed vehicles) checked for the presence of points where exhaust fumes or water from rain can be channelled into the coffee cargo. Tarpaulins and plastic canvas used to cover the cargo should also be regularly checked to ensure they are clean and without holes. The vehicles should also receive regular maintenance to be kept in good condition;
   - e.4) reliable transport service-providers that adopt the recommended good transportation practices should be selected by operators.

4.8 Ship transportation

47. Coffee is transported from producing to consuming countries in bags or in bulk, usually in 18 to 22 tonnes capacity containers. Temperature fluctuations, during the transportation time, can cause condensation of the remaining water (present even in well-dried beans) and local re-wetting. The redistribution of water can lead to fungal growth, with the possibility of OTA production. The recommended practices during transportation in the port are:
    a) Cover coffee loading and unloading areas to protect against rain.
    b) Check coffee lots to ensure that they are uniformly dried and below 12.5% moisture content, free of foreign matter and respecting the established defect levels.
    c) Check containers, before loading, to ensure they are clean, dry and without structural damage that could allow water entrance into the container.
    d) Bags should be well stacked and crossed over for mutual support in order to avoid the formation of empty vertical columns (chimneys). The top layer and sides of bags should be covered with materials that can absorb condensed water, such as silica gel or cardboard for protection against the growth of fungi that could result in OTA production. For coffee in bulk a sealable plastic liner (e.g. big bag which allows aeration) is desirable and this should be kept away from the roof of the container.
    e) Choose an appropriate place, not directly exposed to the weather, aboard the ship to reduce the possibility of undesirable situations mentioned that can lead to OTA contamination.
    f) Keep the ventilation holes in the containers free.

g) Avoid unprotected stowage on the deck (top layer) and stow away from boilers and heated tanks or bulkheads.
h) The moisture content level should not exceed 12.5% anywhere, from the point where the coffee leaves the loading area to the point at which the coffee is unloaded, stored and/or subjected to other processing procedures such as roasting.

Figure 1. Coffee Cherry

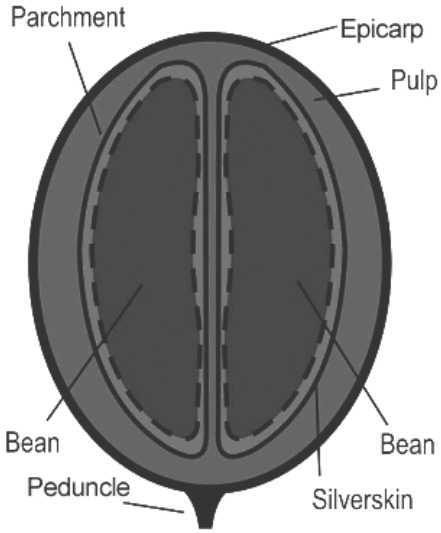


Figure 2. Dry processing flow

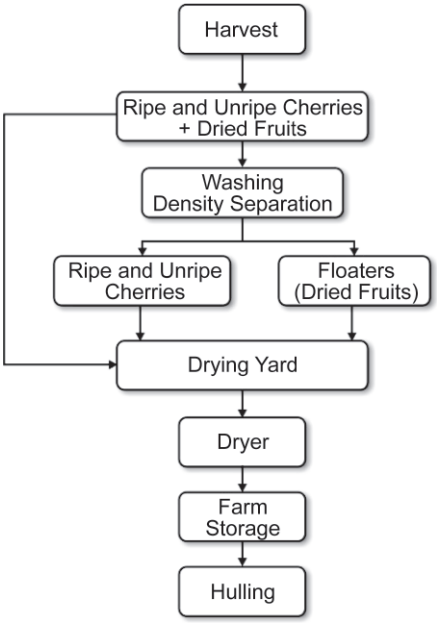
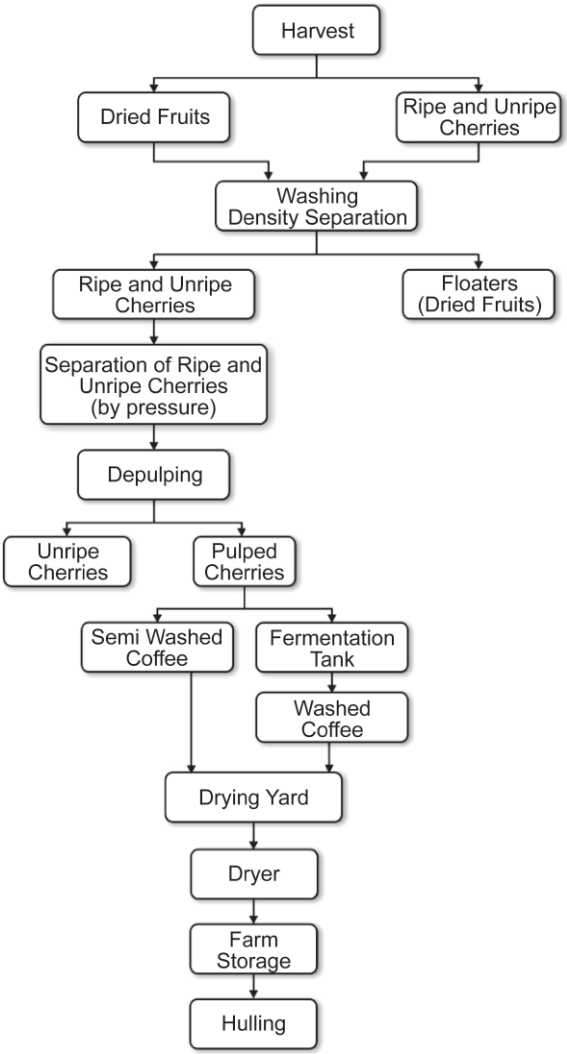


Figure 3. Wet processing flow



CODE OF PRACTICE FOR THE PREVENTION AND REDUCTION OF PATULIN CONTAMINATION IN APPLE JUICE AND APPLE JUICE INGREDIENTS IN OTHER BEVERAGES

CAC/RCP 50-2003

INTRODUCTION

1. Patulin is a secondary metabolite produced by a number of fungal species in the genera *Penicillium*, *Aspergillus* and *Byssochlamys* of which *Penicillium expansum* is probably the most commonly encountered species. Patulin has been found as a contaminant in many mouldy fruits, vegetables, cereals and other foods, however, the major sources of contamination are apples and apple products.

2. Alcoholic fermentation of fruit juices destroys patulin and, therefore, fermented products such as cider and perry will not contain patulin. However, patulin has been observed in apple cider where apple juice was added after fermentation. Ascorbic acid has been reported to cause the disappearance of patulin from apple juice, although the optimal conditions for inactivation have not been fully established. Patulin is relatively temperature stable, particularly at acid pH. High temperature (150 °C) short-term treatments have been reported to result in approximately 20% reduction in patulin concentrations. However, thermal processing alone is not sufficient to ensure a product free of patulin.

3. There is no clear evidence that patulin is carcinogenic, however, it has been shown to cause immunotoxic effects and is neurotoxic in animals. The IARC concluded that no evaluation could be made of the carcinogenicity of patulin to humans and that there was inadequate evidence in experimental animals. Patulin was evaluated by the JECFA in 1990 and re-evaluated in 1995. The latter evaluation took into account the fact that most of the patulin ingested by rats is eliminated within 48 hours and 98% within 7 days. A study on the combined effects of patulin on reproduction, long-term toxicity and carcinogenicity pointed to a harmless intake of 43 μg/kg body weight per day. On the basis of this work and using a safety factor of 100, the JECFA set a provisional maximum tolerable daily intake of 0.4 μg/kg body weight.

4. Patulin occurs mainly in mould-damaged fruits although the presence of mould does not necessarily mean that patulin will be present in a fruit but indicates that it may be present. In some instances, internal growth of moulds may result from insect or other invasions of otherwise healthy tissue, resulting in

Adopted 2003.

occurrence of patulin in fruit which externally appears undamaged. However, it can also occur in bruised fruit after controlled atmosphere storage and exposure to ambient conditions both with and without core rot being present. Washing of fruit, or removal of mouldy tissue, immediately prior to pressing will not necessarily remove all the patulin present in the fruit since some may have diffused into apparently healthy tissue. Washing apples with ozone solution is reported to contribute substantially to the control of patulin during processing.

5. Although the spores of many of the moulds capable of producing patulin will be present on fruit whilst it is still on the tree, they will generally not grow on fruit until after harvest. However, mould growth and patulin production can occur in fruit pre-harvest if the fruit becomes affected by disease or damaged by insects or where fallen fruit is gathered for processing. The condition of the fruit at harvest, the way in which the fruit is handled subsequently (especially during storage) and the extent to which storage conditions are inhibitory to the growth of moulds, will all affect the likelihood of patulin contamination of juice and other products prepared from fresh and stored fruit.

6. The recommendations for reducing patulin contamination in apple juice in this document are divided into two parts:

   I) Recommended practices based on Good Agricultural Practice (GAP).
   II) Recommended practices based on Good Manufacturing Practices (GMP).

I. RECOMMENDED PRACTICES BASED ON GAP

Preharvest

7. During the dormant season cut off, remove and destroy all diseased wood and mummified fruits.

8. Prune trees in line with good commercial practice producing a tree shape which will allow good air movement through the tree and light penetration into the tree. This will also enable good spray cover to be achieved.

9. Measures should be taken to control pests and diseases which directly cause fruit rots or allow entry sites for patulin-producing moulds. These include canker, eye rot (*Botrytis* spp and *Nectria* spp), codling moth, fruitlet mining tortrix moth, winter moth, fruit tree tortrix, blastobasis, sawfly and dock sawfly.

10. Wet weather around the time of petal fall and of harvesting is likely to increase the risk of rot and appropriate measures, such as application of fungicide to prevent spore germination and fungal growth should be considered.

11. Apples of poor mineral composition are more likely to suffer physiological disorders in store and hence are more susceptible to particular types of rot especially by *Gloeosporium* spp and secondary rots such as *Penicillium*. Consignments of apples for the fresh fruit market which do not meet the recommended mineral compositional standards, as determined by fruit analysis, should therefore be excluded from long-term storage i.e. storage for longer than 3–4 months.

12. Where levels of minerals in the fruit for the fresh fruit market are outside optimum ranges, improving calcium and phosphorus levels in the fruit, particularly increasing the calcium/potassium ratio by controlled fertiliser usage, will improve cell structure, which will then reduce susceptibility to rotting.

13. Records of rot levels should be kept each year for individual orchards since historical data is the best guide, at present, to potential rot levels, which will indicate the need for fungicide application and the storage potential of the fruit from that orchard.

Harvesting and transportation of fruit

14. Apples for processing are from two different origins:

a) Mechanically harvested fruit

15. Mechanically harvested fruit is obtained by shaking the tree and collecting the fruit from the ground with appropriate mechanical machinery.

16. All fruit should be handled as gently as possible and every effort made to minimize physical damage at all stages of the harvesting and transportation procedures.

17. Before shaking the trees, deteriorated fallen fruit (rotten, fleshed etc.) should be removed from the ground in order to make sure that only fresh and/or sound fruit is collected.

18. Mechanically harvested fruit has to be transported to processing plants within 3 days after harvest.

19. All containers used to transport harvested fruit should be clean, dry and free of any debris.

b) Fruit for the fresh fruit market

20. Fruit from orchards with a history of high levels of rot should be harvested separately and not considered for storage.

21. Ideally all fruit should be picked in dry weather conditions, when the fruit is mature, and placed in clean bins or other containers (e.g. boxes) suitable for transportation directly to store. Bins or boxes should be cleaned, ideally by hosing with clean water or preferably by scrubbing with soap and water, and fruit and leaf debris should be removed. Cleaned bins and boxes should be dried prior to use. Avoid exposure of fruit to rain.

22. Adequate training and supervision should be provided to ensure good damage-free picking practice.

23. All fruit in which the skin is damaged, or with the flesh exposed, as well as all diseased fruit, should be rejected in the orchard at the time of picking and fruit bruising should be minimised as far as possible.

24. All soil-contaminated fruit, i.e. rain splashed fruit or fruit on the ground, should be rejected for storage purposes.

25. Care must be taken to avoid the inclusion of leaves, twigs etc. in the picked fruit.

26. Fruit should be placed in cold storage within 18 hours of harvest and cooled to the recommended temperatures (see Table 1) within 3–4 days of picking.

27. During transport and storage, measures should be taken to avoid soil contamination.

28. Care must be taken during handling and transport of the bins or boxes in the orchard, and between the orchard and store, to avoid soil contamination of the container and the fruit and to minimize physical damage e.g. bruising of the fruit.

29. Harvested fruit should not be left in the orchard overnight but moved to a hard standing area, preferably under cover.

Post-harvest handling and storage practices of fruit for the fresh fruit market

30. All fruit, whether for the fresh market or for later processing, should be handled as gently as possible and every effort made to minimise physical damage e.g. bruising at all stages of post-harvest handling prior to pressing.

31. Apple growers, and other producers of juice who do not have controlled storage facilities, need to ensure that fruits for juicing are pressed as soon as possible after picking.

32. For controlled atmosphere storage ensure that stores are checked for gas tightness, where appropriate, and that all monitoring equipment is tested before harvesting commences. Pre-cool stores thoroughly before use.

33. Where appropriate post harvest fungicide treatments may be applied in accordance with authorized conditions of use.

34. Stored apples should be examined regularly, at least once a month, for rot levels; a record of the levels should be maintained from year to year. The sampling procedure used should minimize the risk of atmospheric changes occurring in the store (see para. 37).

35. Random samples of fruit should be placed in suitable containers (e.g. net bags) situated close to the inspection hatches to permit monitoring of fruit condition during the storage period (see para. 36). Samples should be examined for rots, general fruit condition and shelf life at least every month. Shorter intervals may be recommended in stores where the fruit storage conditions are less than optimum and/or the fruit has a predicted storage life of less than 3 months, because of adverse growth and/or harvesting conditions.

36. Where samples indicate problems with fruit condition appropriate action should be taken to remove the fruit for use before extensive damage occurs.

37. Mould growth normally occurs in a warm environment. Rapid cooling and maintenance of store atmosphere conditions will improve fruit condition. Ideally fruit should be loaded and cooled to less than 5 °C in 3–4 days and to optimum temperatures within a further 2 days. Controlled atmosphere conditions should be achieved within 7–10 days from the start of loading, and ultra-low oxygen regimes (i.e. less than 1.8% oxygen) should be established within a further 7 days.

Post-storage grading of fruit for the fresh market or juice manufacture

38. All rotten fruits, even those with only small areas of rot, should be eliminated as far as possible and wholesome fruit should be kept in a clean bulk container.

39. When containers are removed from storage to select fruit for retail distribution, the containers of fruit remaining for juicing should be specifically marked and returned to cold store within 12 hours of sorting. The time the fruit is at ambient temperatures should be kept to a minimum. Ideally fruit for juicing should be kept at < 5 °C between withdrawal from store and juicing and should be utilized as soon as possible.

40. Fruit which is to be sent for juicing should be utilized as soon as possible and within the normal shelf life which would be recommended for fruit from the same store. Any bruising will encourage patulin formation hence bruising should be kept to a minimum, especially if fruit is to be stored for longer than 24 hours at ambient temperature before juicing.

II. RECOMMENDED PRACTICES BASED ON GMP

Transportation, checking, and pressing of fruit

Mechanically harvested fruit and fruit for the fresh market

a) fruit for the fresh market

41. Stored fruit should be transported from the cold store to the processor in the shortest time possible (ideally <24 hours to pressing unless cold stored).

42. Varieties with an open calyx are particularly susceptible to core rots. These varieties should be examined for internal rots by regular checks immediately prior to pressing. An appropriate random sample of apples should be preferably taken from each separate batch of fruit. Each apple is then cut across its equator and examined for signs of mycelial growth. If the frequency of core rots exceeds an agreed level the consignment should not be used for juicing. The processor should specify the maximum proportion of supplied fruit which can have any sign of rotting, taking into account the capacity of the processor to remove the rotting fruit during pre-process inspection. If this proportion is exceeded the whole consignment of fruit should be rejected.

43. On arrival at the factory the fruit should be checked for quality, particularly for evidence of both external and internal mould damage (see para. 44).

b) mechanically harvested fruit and fruit for the fresh market

44. During processing and prior to pressing, the fruit should be sorted carefully to remove any visually mouldy fruit (check randomly and routinely for internal mould by cutting some fruit as indicated in para. 42) and washed thoroughly, using potable or suitably treated water.

45. Juice presses and other manufacturing equipment should be cleaned and sanitised in accordance with industry "best practices". Juice presses and other equipment will generally be washed down with pressured water hoses and sanitised by application of a suitable sanitiser, followed by a further rinse with potable cold water. In some plants, which operate almost continuously, this should preferably be a once per shift or once per day cleaning operation.

46. After pressing samples of juice should be taken for analysis. A representative bulk production sample should analysed for patulin by an appropriate method in a laboratory which is accredited to carry out such analyses.

47. The juice should preferably be chilled to <5 °C and maintained chilled until it is concentrated, packaged or pasteurised.

48. Juice should only be sent for packing on a positive release basis after patulin analysis has been confirmed as being below the maximum agreed limit. Specifications for the purchase of apple juice should include an appropriate limit for patulin subject to confirmation by the recipient.

Packaging and final processing of juice

49. Moulds which are capable of producing patulin may occur, together with other moulds and yeasts, particularly in NFC juice. It is essential to prevent the development of such organisms during transport and storage to prevent spoilage of the product and by the same means prevent the production of patulin.

50. If juice is to be held for a period prior to use the temperature should preferably be reduced to 5 °C or less, in order to reduce microbial development.

51. Most juice will be heat processed to ensure destruction of enzymes and spoilage organisms. It must be recognized that whilst such processes will generally destroy fungal spores and vegetative mycelium the process conditions will not destroy any patulin which is already present.

Quality assessment of juice

52. Specifications for the purchase of apple juice or apple juice concentrates should include a maximum limit for patulin based on an appropriate method of analysis.

53. A sampling plan should be developed for random sampling of product to assure that the finished product is within the maximum limit for patulin.

54. The packer must satisfy himself that the juice supplier is able to control properly his own operations to ensure that the recommendations given above are carried out.

55. Assessment of the quality of apple juice by the packer will include °Brix, acidity, flavour, colour, turbidity, etc. The microbiological quality should be carefully monitored since this indicates not only the risk level of potential organisms for the production of patulin but also the hygienic aspects of the previous stages in the production cycle.

56. Further checks should be carried out on the packaged product to ensure that no deterioration has taken place during the packaging stage.

Table 1: Recommended temperatures for storage of apples in air

Variety	Temperature °C	Temperature °F	Variety	Temperature °C	Temperature °F
Bramley	3.0-4.0	37-39	Idared	3.0-4.0	38-39
Cox's orange pippin	3.0-3.5	37-38	Jonagold	0.0-0.5	32-33
Discovery	1.5-2.0	35-36	Red delicious	0.0-1.0	32-34
Egremont	3.0-3.5	37-38	Spartan	0.0-0.5	32-33
Golden delicious	1.5-2.0	35-36	Worcester	0.0-1.0	32-34
Crispin	1.5-2.0	35-36			

CODE OF PRACTICE FOR THE PREVENTION AND REDUCTION OF LEAD CONTAMINATION IN FOODS

CAC/RCP 56-2004

INTRODUCTION

1. Lead is a toxic heavy metal with widespread industrial uses, but no known nutritional benefits. The toxic effects of lead in food have been reviewed several times by the FAO/WHO Joint Expert Committee on Food Additives (JECFA). Chronic exposure to lead at relatively low levels can result in damage to the kidneys and liver, and to the reproductive, cardiovascular, immune, hematopoietic, nervous, and gastrointestinal systems. Short-term exposure to high amounts of lead can cause gastrointestinal distress, anemia, encephalopathy, and death. The most critical effect of low-level lead exposure is reduced cognitive and intellectual development in children.

2. Lead exposure can occur through food and water, as well as in the workplace, through hobbies, and through exposure to lead-contaminated soil and air.

3. Lead contamination of food arises from numerous sources, including air and soil. Atmospheric lead from industrial pollution or leaded gasoline can contaminate food through deposition on agricultural crop plants. Soil lead arising from lead-containing ordnance stored on former munitions sites and from ammunition used in rifle or military firing, atmospheric deposition, or inappropriate application of pesticides, fertilizers, or sewage sludge can contaminate agricultural crop plants through uptake or through deposition of the soil on plant surfaces. Contaminated plants and soil are, in turn, a source of contamination of livestock.

4. Water is also a source of lead contamination of food. Surface water sources can be contaminated through runoff (drainage), atmospheric deposition, and, on a local level, by leaching of lead from game shot or fishing sinkers. Contaminated surface waters are a potential source of contamination of aquatic food animals. For drinking water and water for food preparation, the use of lead pipes or lead-containing fixtures in water distribution systems is a primary source of contamination.

5. Lead contamination of food can also arise from food processing, food handling, and food packaging. Sources of lead in food processing areas include lead paint and lead-containing equipment, such as piping and lead-soldered machinery. In

Adopted 2004.

the packaging area, lead-soldered cans have been identified as a very important source of lead contamination of food. Other packaging items that are potential sources of lead contamination include colored plastic bags and wrapping papers, cardboard containers that contain lead or are colored with lead-containing dyes, lead foil capsules on wine bottles, and lead-glazed ceramic, lead crystal, or lead-containing metal vessels used for packaging or storing foods.

6. There have been worldwide efforts to reduce lead exposure from food. Such efforts have focused on implementing standards for allowable lead levels in food and food additives; ending the use of lead-soldered cans, particularly for infant foods; controlling lead levels in water; reducing leaching from lead-containing vessels or restricting their use for decorative purposes; and identifying and reacting to additional sources of lead contamination in foods or dietary supplements. Although not targeted specifically at food, efforts to reduce environmental sources of lead, including restrictions on industrial emissions and restricted use of leaded gasoline, have also contributed to declining lead levels in food.

7. Codex, intergovernmental organization, and many countries have set standards for allowable levels of lead in various foods. Low levels of lead in foods may be unavoidable, because of the ubiquitous nature of lead in the modern industrial world. However, following good agricultural and manufacturing practices can minimize lead contamination of foods. Because many useful interventions for reducing lead rely on actions by consumers, a section with suggestions for modifying consumer practices has also been included in this Code.

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

1.1 Agricultural

8. Leaded gasoline is a major contributor to atmospheric lead. National authorities should consider reducing or eliminating the use of leaded gasoline in agricultural areas.

9. Agricultural lands near industrial facilities, roadways, and ordnance depots, rifle ranges and military firing ranges may have higher lead levels than more isolated lands. Land near buildings with weathered exterior paint also may have high lead levels, a particular concern when such buildings are situated near livestock or small gardens. Where possible, farmers should test lead levels in soils that are near lead sources or that are suspected of having elevated lead

levels to determine if lead levels exceed recommendations for planting by local authorities.

10. Farmers should avoid using lands that have been treated with lead arsenate pesticide, such as former orchards, to grow crops that may accumulate lead internally (such as carrots and other root crops) or on their surface (such as leafy vegetables).

11. Farmers should avoid growing crops on lands that have been treated with sewage sludge that does not adhere to maximum allowable lead levels set by national authorities.

12. Leafy vegetables are more vulnerable than non-leafy vegetables or root vegetables to deposition from airborne lead. Cereal grains also have been reported to absorb lead from the air at a significant rate. In areas where atmospheric lead levels are higher, farmers should consider choosing crops that are less vulnerable to airborne deposition.

13. Farmers should avoid using compounds that contain lead (such as lead arsenate pesticide) or may be contaminated with lead (e.g., improperly prepared copper fungicide or phosphate fertilizer) in agricultural areas.

14. Dryers powered with leaded gasoline have been found to contaminate drying crops with lead. Farmers and processors should avoid using dryers or other equipment powered by leaded gasoline on harvested crops.

15. Crops should be protected from lead contamination (e.g., exposure to atmospheric lead, soil, dust) during transport to processing facilities.

16. Home or small-scale commercial gardeners should also take steps to reduce lead contamination. Avoid planting near roadways and buildings painted with lead-based paint. If gardens are located in an area with potentially high lead levels, test soil before planting. Good gardening practices for soils with mildly elevated lead levels include mixing organic matter into the soil, adjusting soil pH to reduce availability of lead to plants, choosing plants that are less vulnerable to lead contamination, and using liners to reduce contact deposition of soil on plants. Some lead levels are considered too high for gardening. It may be possible to build up gardening beds with lead-free soil in such areas. Gardeners should consult with local agricultural services, where available, for advice on what lead levels are too high for gardening and advice on how to garden safely in lead-contaminated soils.

17. Agricultural water for irrigation should be protected from sources of lead contamination and monitored for lead levels to prevent or reduce lead contamination of crops. For example, well water used for irrigation should be properly protected to prevent contamination and routinely monitored.

18. Local and national authorities should make farmers aware of appropriate practices for preventing lead contamination of farmlands.

1.2 Drinking water

19. National authorities should consider establishing allowable lead levels or appropriate treatment techniques for controlling lead levels in drinking water. The WHO has established a guideline value for maximal lead levels in drinking water of 0.010 mg/L.

20. Administrators of water systems with high lead levels should consider treatment techniques, such as increasing the pH of acidic waters, to minimize corrosion and reduce leaching of lead in the distribution system.

21. Where appropriate, administrators of water systems should consider replacing problematic lead piping and other lead-containing fixtures.

1.3 Food ingredients and processing

22. National authorities should consider establishing standards limiting the amount of lead allowed in foods and food ingredients, including the traditional foods of their countries. Selected foods and dietary supplements should be monitored to ensure that lead levels do not rise above normal background levels.

23. Food processors should choose food and food ingredients, including ingredients used for dietary supplements that have the lowest lead levels possible. They should also consider whether the land used to produce crops has been treated with lead-containing pesticides or sewage sludge.

24. During processing, maximum removal of surface lead from plants should be practiced, e.g., by thoroughly washing vegetables, particularly leafy vegetables; removing the outer leaves of leafy vegetables; and peeling root vegetables, where appropriate. (Home gardeners should also follow such steps if their soil has elevated lead levels.)

25. Food processors should ensure that the water supply for food processing complies with maximum limits for lead established by the national or local authorities.

26. Food processors should examine piping within facilities to ensure that older piping is not adding lead to water supplies inside the facility. Such piping may include brass fixtures, in addition to lead-soldered pipes.

27. Food processors should use food-grade metals for all metal surfaces that come into contact with food and beverages.

28. Food processors should not use lead solder to repair broken equipment in food processing facilities. They should also not substitute non-food-grade equipment that may be present in a food processing facility for broken food-grade equipment.

29. Food processors should ensure that lead paint peelings do not become a source of lead contamination in processing facilities. If food processors carry out lead paint abatement, they should also ensure that appropriate cleanup procedures are followed to prevent further dispersion of lead paint and dust, which could create a greater hazard.

30. Food processors should occasionally test incoming raw materials and finished products for lead to verify that their control measures are functioning effectively.

1.4 Production and use of packaging and storage products

31. To provide maximum protection against lead contamination, food processors should not use lead-soldered cans. Alternatives to lead-soldered cans are discussed in Food and Nutrition Paper 36 from the FAO, "Guidelines for can manufacturers and food canners. Prevention of metal contamination of canned foods," as well as JECFA Monograph 622. These alternatives include using two-piece cans (which lack side seams) rather than three-piece cans, using cementing and welding to bond seams instead of soldering, using lead-free (tin) solders, and using alternative containers, such as glass.

32. Where it is not feasible to avoid the use of lead-soldered cans, methods for reducing lead exposure from lead-soldered cans are discussed in depth in FAO Food and Nutrition Paper 36. Lead can be released from the solder surface itself, or from solder dust or solder splashes deposited inside the can during the can-making process. Methods for reducing splashing and dust formation

include avoiding the use of excess flux, controlling exhaust over the work area to minimize dust deposition, controlling the temperature of the fluxed can body and solder, post-solder lacquering of the interior surface or interior side seams of cans, careful wiping of excess solder from finished cans, and washing soldered cans before use. For a detailed description of proper manufacturing practices with lead-soldered cans, the FAO paper should be consulted.

33. Tinplate used for food cans should meet international standards for maximum allowable lead concentration. ASTM International has set a maximum concentration of 0.010 percent lead for "Grade A" tinplate.

34. Lead dyes or lead-based printing inks should not be used for packaging, such as for brightly colored candy wrappers. Even if such wrapping does not come in direct contact with foods, children may be tempted to put the brightly colored wrappers in their mouths.

35. Plastic bags or boxes with exteriors treated with lead-based dyes or lead-based printing inks should not be used for packing food. Handling of these items during cooking or reuse by consumers for storing other food items can cause lead contamination.

36. Packing foods for sale in traditional lead-glazed ceramics should be avoided because these ceramics may leach significant quantities of lead into the foods.

37. Lead foil capsules should not be used on wine bottles because this practice may leave lead residues around the mouth of the bottle that can contaminate wine upon pouring.

38. National authorities should consider setting standards for lead migration from lead-glazed ceramic ware, lead crystal, and other lead-containing items that might potentially be used for food storage or preparation by consumers.

39. Decorative ceramic ware that has the potential to leach unacceptable quantities of lead should be clearly labeled as not for food use.

40. Ceramic ware producers should use manufacturing procedures and quality control mechanisms that minimize lead leaching.

1.5 Consumer practices

41. Local and national authorities should consider educating consumers about appropriate practices to reduce lead contamination in the garden and the home.

42. Consumers should avoid storing foods, particularly acidic foods or foods for infants and children, in decorative ceramic ware, lead crystal, or other containers that can leach lead. Foods should not be stored in opened lead-soldered cans or stored in reused lead-dyed bags and containers. Consumers should avoid frequent use of ceramic mugs when drinking hot beverages such as coffee or tea, unless the mugs are known to have been made with a lead glaze that is properly fired or with a non-lead glaze.

43. Consumers should wash vegetables and fruit thoroughly to remove dust and soil that may contain lead. Washing hands before preparing food will also help remove any lead-contaminated dust or soil from hands.

44. Where lead in water distribution systems is a problem, consumers should let water run from faucets before use to allow corroded lead from piping to be flushed out of the system, particularly if they are preparing foods for infants or children. Hot water from the faucet should not be used for cooking or food preparation.

1.6 Consideration for certain foods

45. Calabash chalk, also known by other names such as Argila, La Croia, Calabarstone, Ebumba, Mabele, Nzu, and Ulo, is eaten by some women as a traditional food to help alleviate morning sickness during pregnancy. Levels of lead in this product are often high (greater than 10 mg/kg) and may have consequences for the health of the developing fetus. If the product cannot be produced without high levels of lead, the product should no longer be consumed.

CODE OF PRACTICE FOR THE PREVENTION AND REDUCTION OF TIN CONTAMINATION IN CANNED FOODS

CAC/RCP 60-2005

INTRODUCTION

History of use of tin

1. Tin is a soft, white, lustrous metal with an atomic weight of 118.7 and the chemical symbol Sn after its Latin name, *Stannum*. It has a relatively low melting point (231.9 °C) and is highly resistant to corrosion, which makes it an ideal element for the protective coating of metals. Over 50% of the world's tin production is used for plating steel or other metals.

2. Today some 15 million tonnes of tinplate are produced each year using rapid and highly sophisticated production methods. These methods are able to control steel thicknesses and tin coating masses to within the extremely fine tolerances required for modern can making processes such as high speed welding.

Tin as packaging for canned food

3. Tin is used to protect the steel base from corrosion both externally (aerobic conditions) and internally when in contact with foods (anaerobic). Under the anaerobic conditions expected inside an internally plain processed food can, tin will normally behave as the sacrificial anode, dissolving very slowly whilst protecting the steel base from corrosion and creating a reducing environment in the can. It is this mechanism that has enabled the plain tinplate can to maintain its long history and proven track record of providing wholesome food on a year round basis and safe storage for long periods of time.

4. The later development of can linings (lacquers) enabled different types of food products to be satisfactorily packed. For example, some highly pigmented foods (beetroot, berry fruits) have their colours bleached by tin dissolution and are best protected from contact with tin by use of linings. A small number of food products (e.g. sauerkraut) have a different corrosion mechanism, in which the tin does not behave sacrificially and direct corrosion of the steel base can occur. These products should also have the additional protection of an internal lacquer system.

Adopted 2005.

5. The uses of tin have changed considerably over the years. Humans have, however, been exposed to tin for centuries, through the food they eat, with no known negative long term effects. Only limited data is available on the toxicological effects of inorganic tin as present in canned foods, resultant from dissolution of the tin coating. The main potential hazard from acute ingestion seems to be gastric irritation in some individuals from exposure to high levels.

6. Hence the canning industry worldwide and government regulators consider it both desirable and in accordance with good manufacturing practice that measures be adopted to minimise the levels of tin in canned foods, whilst continuing to allow for the functional use of plain tinplate cans.

Technological and commercial implications

7. Metal packaging faces strong competition from glass and plastics. Even with innovations such as easy opening tear top cans, metal containers are below the average growth of market share for packaging products.

8. The best solution to prevent or reduce detinning of cans by aggressive foods is internal lacquering. The use of lacquers has permitted the extension of the use of cans to additional products, including highly aggressive ones.

9. The coating thickness greatly affects the performance of the lacquered food can. Non-aggressive products such as apricots and beans require a thickness of 4-6 µm while tomato concentrate needs layers of 8-12 µm to prevent interaction between the can and its contents.

10. Adhesion is required to prevent reactions between the can and its contents. Currently adhesion is tested by measuring the force required to lift a dry lacquer coating from the metal in a peel test. While this test readily identifies films which are unsuitable there is no guarantee that those which pass would give satisfactory long term results when in contact with specific foods.

11. Toxicologically significant contamination of canned food from tin dissolution may arise as a result of poor manufacturing practices or prolonged/incorrect storage or both.

12. Although lacquering of cans significantly reduces the risk of tinplate corrosion, the use of lacquer coatings is not always practicable or cost effective.

13. It could be argued that "since lined cans are readily available, then why not use them for all canned foods and thus prevent any tin uptake?" There are, however, very valid technical and marketing reasons why some products require to be packed into plain cans.

Flavour and colour

14. The need for tin dissolution to maintain the desired colour and flavour attributes of products such as asparagus, light coloured fruits and juices and tomato based products has long been established. It is believed that the presence of tin creates a reducing atmosphere in the can preventing undesirable oxidative changes in these products, which would otherwise develop brown discolourations and unacceptable flavours. Such quality loss would severely affect their marketability and sales with significant implications for the canning industry and their suppliers.

15. It is interesting to note that this concept also works in reverse – some highly pigmented foods, such as acidified beetroot and berry fruits, must always be packed into fully lined cans because, apart from their aggressive behaviour towards tin, colour bleaching via tin dissolution can be a significant problem.

Corrosion factors

16. Most of the products normally packed into plain cans are relatively high acid products. In addition to the organoleptic considerations, should these products be packed into lined cans a change of corrosion mechanism would result. For the more aggressive products this would result in a greater tendency for underfilm corrosion/delamination (particularly for tomato products) and to pitting corrosion of the steel base and subsequent implications of potential for perforation failure.

17. The tin level is dependent on a large number of factors, many of which relate to natural variations or occur after the can has left the control of the manufacturer:

Corrosion mechanisms

18. With respect to the internal tinplate surface of cans, there are four main corrosion mechanisms:
    i) Normal detinning;
    ii) Rapid detinning;
    iii) Partial detinning; and,
    iv) Pitting.

19. **Normal detinning** is the slow corrosion of the tin coating, and is an essential process in plain cans to provide electrochemical protection to any exposed areas of base steel. This process leads initially to etching of the tinplate and much later to detinning of the surface. Normally, etching should occur evenly over the wetted internal surface of the can; in the first month or so the mirror surface should change to one in which the shape of the individual tin crystals may be seen with the eye. Grey detinned areas should not be evident in cans stored for less than 1.5–2 years. Under normal detinning conditions tin is anodic to steel and offers complete cathodic protection. Dissolved tin enters into unobtrusive complexes with product constituents. The hydrogen is oxidised by depolarisers or diffuses through the steel wall. This corrosion situation is characteristic of some citric products, stone fruit products and most low-acid products.

20. **Rapid detinning** is caused by the use of plate with a tin coating mass that is too light, or by a product that is intrinsically too corrosive or contains corrosive accelerators. Whilst the tin is sufficiently anodic to protect steel, the electrochemical rate is high, often resulting in hydrogen evolution and early product failure. Nitrate in products with pH less than 6 has been implicated in incidents of rapid detinning. This is one type of mechanism for rapid detinning. The other is 'direct attack on the tin'. During detinning no hydrogen forms, can vacuum remains unchanged. Examples are depolarisers like nitrate, oxygen, and sulphite. Certain azo dyes, anthocyanins, phosphates and dehydroascorbic acid have also been implicated in rapid detinning.

21. **Partial detinning** together with pitting is a rare form of corrosion. Tin is anodic to steel but localised anodes develop on exposed steel causing iron dissolution (pitting). Early failure takes place due to hydrogen swelling or to perforation at the sites of pitting. This mode of corrosion occurs with tinplate with poor corrosion resistance, or in certain products that have high corrosivity, such as prunes and pear nectar.

22. **Pitting** corrosion occurs when the normal tinplate tin/iron couple is reversed and iron becomes anodic to tin. Tinplates containing high arsenic levels can promote pitting corrosion in can products containing corrosion accelerators. Preferential absorption of protective substance onto the tin surface, such as can occur in sauerkraut, leads to pitting. Products formulated with acetic or phosphoric acids have also suffered spoilage losses due to pitting. Perforation and hydrogen swells occur within a year in such products. Products containing copper and nickel residues can promote pitting

corrosion. Products containing proteins and associated amino acids can produce sulphur compounds during heating, including mercaptans, sulphide ions and hydrosulphide ions which readily react with tin to cover the metal surface with thin layers of tin sulphides. Tin sulphides films reduce the passivity of the tinplate surface and may promote pitting corrosion of the base steel.

Corrosion inhibitors

23. **Passivation** refers to the chemical treatment applied after tin deposition which stabilises the surface characteristics of tinplate by controlling tin oxide formation and growth; two levels of passivation are usually available – cathodic dichromate (CDC) is the higher level and the treatment usually applied.

Food chemistry

24. The most obvious influence on internal corrosion in plain tinplate cans is the chemistry of the food product. It should be noted that fruits, vegetables and tomatoes will have significant natural variation in, for example, pH and acid type and concentration, dependent on variety, maturity, time/place/ conditions of harvest, soil chemistry and agricultural practices. These are difficult for the canner to control and may ultimately impact on the level of tin uptake by the product.

Corrosion accelerators

25. The presence of a chemical species with the ability to accept electrons will increase the rate of corrosion. Some products may contain such 'depolarisers' which will accelerate tin dissolution. Good process control by the canners helps to minimize the presence of headspace oxygen and the presence of oxidizing agents like nitrates and sulfites which can accelerate tin dissolution.

Storage temperature

26. A further significant factor influencing tin levels is the length and temperature of storage subsequent to canning. Tin uptake will increase with time and most products exhibit first order reaction rates where the rate of dissolution doubles for every 10 °C rise in temperature.

1. SCOPE

27. Whilst there are other sources of tin exposure in humans, the most common route is via ingestion of inorganic tin from canned foods.

28. This code of practice relates solely to the migration of inorganic tin into foods from the internally plain (i.e. not lacquered) tin coating of tinplate cans.

29. This code of practice is not intended to apply to tin exposure from any other source and is specific to inorganic tin.

30. This code of practice relates to thermally processed canned human foods (including fruit and vegetable juices) which are packed into plain tinplate cans. It is considered that this description covers both:
    i) Hot fill and hold products; and,
    ii) Hot or cold fill and retort products.

31. Dry goods and 100% oil products are not included, because they do not experience tin migration.

2. RECOMMENDED PRACTICES TO MINIMISE TIN UPTAKE BY FOODS PACKED INTO PLAIN TINPLATE CANS

32. There are many factors which may influence the level of product tin uptake in plain tinplate cans. Some are very minor and others, usually specific to the chemistry of the processed food, may have a significant effect on internal can corrosion and product tin dissolution. The recommendations contained below are based on an attempt to identify all of these factors, no matter how minor, and to suggest specific areas where monitoring or other controls would be beneficial.

33. In summary the factors which have been identified can be grouped as follows:
    i) Choice of tin coating mass and passivation level;
    ii) Damage to tin coating or passivation;
    iii) Type of food product, pH and acid content;
    iv) Presence of corrosion accelerators, such as nitrates, in the raw food ingredients;
    v) Presence of sulphur compounds in the food;
    vi) Presence of oxygen within the sealed can;
    vii) Process times and temperatures;
    viii) Storage times and temperatures; and,
    ix) Storage humidity.

2.1 Packaging manufacturer

2.1.1 Tinplate supplier

34. Tinplate customers should state the end use when ordering tinplate. The tinplate supplier should have sufficient expertise to ensure that specifications for the tinplate are appropriate to the stated end use and notify the customer should there be any concerns (e.g. with regard to the passivation level or the requested tin coating mass).

35. The tinplate manufacturer should have quality procedures in place to ensure that every tinplate order conforms to the required standard (e.g. ASTM; ISO etc.). Incorrect tin coating masses or passivation levels could result in abnormal corrosion and increased product tin levels. Low oil levels may lead to abrasive damage to the tin coating during transport and can manufacture.

2.1.2 Can maker

36. Can makers should approve tinplate suppliers on the basis that each supplier has demonstrated compliance to agreed standards and ordering requirements.

37. The can maker should have sufficient expertise to ensure that the customer's ordering requirements (i.e. passivation and tin coating mass) are appropriate for the end use and should notify the customer of any concerns.

38. The can maker should assist the customer in determining the correct can specification for any new food product or recipe change. Such changes should be tested to ensure that product tin uptakes are not excessive.

39. Machine settings for processes where metal working occurs (e.g. beading) should be such as to minimise damage to the tin coating.

40. If a sidestripe is applied to 3 piece cans then excessive heat should be avoided when curing the stripe.

2.2 The canner

2.2.1 Raw Materials

41. The canner should work closely with the can supplier to ensure an appropriately specified can is supplied for any given application. Procedures should be in place to ensure that cans are supplied to specification.

42. The canner should consult with the can maker to determine the correct specification can for any new product or any recipe change of an existing product. It is extremely important that sufficient pack testing is conducted to gain a thorough knowledge of the corrosion mechanism, likely product tin uptakes and overall suitability of the can specification for the product.

43. Canners should be knowledgeable about the shelf life of all their products with respect to likely tin uptakes. It should be noted that fruits and vegetables in particular may have a significant variation in their chemistry, dependent on variety, maturity, time/place/conditions of harvest, soil chemistry and agricultural practices. These are difficult for the canner to control and may ultimately impact on the level of tin uptake by the product.

44. Quality procedures should be in place to ensure that product batches conform to recipe specification.

45. Particular attention should be paid to the pH of the food and the addition of food acids. It should be recognised that corrosion is pH dependent and that too large a drop in pH may give a significant change in corrosive behaviour and tin uptake. Different food acids (e.g. citric, malic fumaric and acetic) behave in different ways with respect to internal corrosion and any ingredient change from one type of acid to another should be thoroughly tested. Acetic acid is particularly aggressive towards tin.

46. The presence of a chemical species with the ability to accept electrons will increase the rate of the corrosion reaction. Nitrate is a corrosion accelerator and its presence, even at low levels (1mg of NO_3^- will yield nearly 8mg of Sn^{2+}) causes rapid de-tinning. In a 400g can, 10mg of NO_3^- will rapidly react to give approximately 80mg of Sn^{2+} or, in other words, a product tin concentration of 200 ppm. In about one year 100 ppm of nitrate will completely de-tin a No. 303 can with an inside coating weight of 11.2 g/m^2. Nitrates originate from over zealous use of fertilizers and some fruits and vegetables can accumulate high levels (e.g. tomatoes and pineapples). It is essential, when nitrates are likely to be a problem that the canned food manufacturer and his suppliers have a system in place to ensure fruits, vegetables and other ingredients are acceptable for use in canning.

47. Sulphur residues have also been known to cause corrosion problems in plain tinplate cans. These residues can be of agricultural origin or may have resulted from bleaching or preserving agents used in some ingredients. The

canned food manufacturer and his suppliers should again carry out any necessary testing and make sure that the raw materials are fit for purpose.

48. Some foods, especially protein rich meat and fish and, to a lesser extent, vegetables (e.g. peas, beans, corn etc.) contain naturally occurring sulphur compounds. These can react with a plain tinplate surface to give a purple-black stain of tin sulphide. Although the stain is harmless, it may serve to change the passivation of the tinplate surface, which, in turn, could alter the rate of tin uptake. The areas of staining may also be localised – stressed areas such as can beads; contact points with a solid product in a liquid medium; headspace/product line interface. Whilst an overall increase in passivation is more likely to slow tin uptake, localised areas of staining can have a detrimental effect, especially if a corrosion accelerator such as oxygen is also present. Degree of sulphide staining is also influenced by pH, process time and temperature and the presence of certain cations. Al^{3+} and Fe^{3+}, Fe^{2+} ions, found in some treated potable water, act as catalysts for the breakdown of naturally occurring sulphur compounds. Subsequently the presence of these ions increases the rate and severity of sulphide staining. Clearly the canner must have an intimate knowledge of his product; the likely variations that could occur in raw materials and process; and the range of effects that these variations could produce within the can. That knowledge should be used to set controls where necessary and to determine consistent supply.

49. All raw materials from all suppliers should be well documented especially when a supplier is changed or a raw material is obtained from another source or location. In the unlikely event that unexpectedly high product tin levels occur, documentation makes it easier to track back to any specific changes and to take appropriate action.

50. Water quality should be monitored as some water supplies may contain corrosion accelerators such as nitrates.

2.2.2 Processing

51. The canned food manufacturer should take all necessary steps to eliminate oxygen from within the can prior to closing and to ensure an adequate can vacuum. Oxygen is a corrosion accelerator and its presence in a can after closing can lead to early tin dissolution, especially from the headspace area. Oxygen can be present in the interstices of the product and steam exhausting plus a high fill temperature will help its removal. Minimising headspace, whilst still allowing for product expansion, also helps eliminate oxygen. Another control method is closing under vacuum. Steam injection to the

headspace must be consistent and controlled. Line stops and delays between filler and closer should be avoided.

52. The primary method used for removing oxygen is closing under vacuum. Steam exhausting is not used as much.

53. Chemical reactions, such as corrosion, are accelerated by increasing temperature. Canners should be aware that excessive processing times at high temperatures may have an effect on advancing tin uptake.

54. Inadequate cooling and drying should be avoided because this means, for a large mass of cans, that they will remain at an elevated temperature for a considerable period of time. Cans should be cooled to 35–40 °C. Cans cooled to a lower temperature may not dry adequately leading to external rusting. Cans that are not adequately cooled can be subject to spoilage by thermophilic bacteria or products may suffer a loss in quality.

2.2.3 Finished goods storage

55. Internal can corrosion, like any chemical reaction, is temperature dependent. In general for every 10 °C rise in temperature the reaction rate will double. The expected level of tin uptake from a can stored at high temperature (i.e. 40 °C) would be significantly higher than from a can stored at lower temperature (i.e. 10 °C) for the same period of time. Canned food manufacturers should consider the location of their finished goods storage areas when determining maximum storage times. For example: - what is the likely maximum temperature; are some areas heated more by the sun; how many days per annum at relatively high temperatures etc.?

56. Stock control is required to ensure finished canned goods from earlier production dates are used first.

57. Warehousing be done under conditions where the temperature can be controlled. Large swings in temperature can lead to condensation of moisture on the exterior of cans which can lead to rusting.

2.2.4 Other considerations

58. Can damage should be minimised as this can lead to local areas of de-tinning. For this reason it is preferable to use ink jet coding rather than embossing.

2.3 Transport and warehousing

59. Please refer to paragraphs 56 and 57 in Section 2.2.3 Finished Goods Storage.

60. Temperatures encountered during Transport need to be considered if the canned goods are likely to remain at these temperatures for any length of time (i.e. during shipping). If possible, it is preferable to export stock from a more recent production date if high temperatures are likely to be encountered during shipping or at the final destination.

2.4 Retailer

61. The retailer should maintain correct stock rotation to ensure that shelves are stocked with cans in production date sequence.

2.5 Consumer

62. The consumer should choose a storage location for canned foods that is not subject to excessive heat. Cupboards should not be close to ovens or heaters and should preferably not be in direct sunlight.

63. Unused food or juice left in plain tinplate cans may rapidly accumulate tin in the presence of air. It should be transferred immediately to a clean plastic or glass container and stored in the refrigerator.

GLOSSARY OF TERMS

64. This glossary defines the main technical terms used in the preceding code and relates specifically to the tinplate, can making and canning industries.

Aerobic	presence of oxygen.
Anaerobic	absence of oxygen.
Annealing	heating process used in tinplate manufacture to soften the steel strip after cold rolling and to impart the required hardness; the process can either be continuous (continuous annealing or CA) or in batches (batch annealing or BA).
BA	see *Annealing*.
Beads, Beading	corrugations rolled into can walls to give added strength to the can body.
CA	see *Annealing*.
Can linings	see *Lacquers*.
Closer	machine used to seal an end onto a can.
Closing under vacuum	applying a vacuum to the closing chamber of the can closer, whilst sealing the end.
Corrosion	chemical action of dissolving the surface of a metal (eg. tin in food medium).
Corrosion accelerator	chemical species with the ability to accept electrons, which will increase the rate of a corrosion reaction.
Corrosion mechanism	specific chemistry of any corrosion reaction; especially for tinplate when 2 metals (tin and iron) are coupled and where one or both has the potential to dissolve.
Detinning	descriptive of the corrosion process where the internally plain tin coating is slowly dissolved by the food medium; rapid detinning refers to abnormally fast tin dissolution, caused by the presence of corrosion accelerators.
DR Tinplate	'double reduced' tinplate where a second rolling is used to reduce steel thickness in order to produce a thinner but stronger product.

Electrolyte	substance which dissociates into ions when dissolved in a suitable medium; hence a tin rich electrolyte is used in tinplate manufacture (see ***Electro-Tinning***); the food in contact with an internally plain can may also be described as an electrolyte.
Electrolyte Tinplate	low carbon mild steel strip coated on both top and bottom surfaces with an electrolytic deposition of tin; the deposited tin exists as an alloyed and free tin and has a passivated surface as well as a coating of oil.
Electro-Tinning	act of plating tin from a tin rich electrolyte onto a continuous steel strip to produce electrolytic tinplate.
Electro-Plating	see ***Electro-Tinning.***
Embossing	use of a die to stamp a product code or manufacturing date into a can end
Environment	see ***Reducing Environment.***
Filler	machine used to automatically fill a can with the desired weight or volume of food.
Fill Temperature	temperature at which the food is filled into the can.
Food Acids	organic acids, naturally occurring in foods, especially in fruits and vegetables; also used to impart flavour and to modify the pH of foods.
Headspace	space left in the top of the can after filling and end sealing, in order to allow for product expansion during thermal processing.
Hot Fill and Hold	process where a high acid food product (usually juice or liquid) is filled at high temperature, the end sealed and cans held for a period of time before cooling; commercial sterility is achieved without retort processing.
Inject Coding	use of an ink jet to print a product code or manufacturing date on the can end
Internal Corrosion	corrosion occurring within a food can (see ***Corrosion***).

Ion	electrically charged (positive or negative) atom or molecule formed by the loss or gain of one or more electrons or by dissolving an electrolyte in a solvent.
Lacquered Tinplate	see ***Lacquers.***
Lacquers	inert organic coatings used to give additional protection to tinplate; usually applied in liquid form and 'cured' at high temperatures.
Linings	see ***Lacquers.***
Pack Testing	storage and regular sampling of canned foods under controlled temperature conditions to determine internal corrosion characteristics and potential shelf life.
pH	measure of acidity.
Plain Cans	cans made from plain tinplate.
Plain Tinplate	bright tinplate without any additional lacquer coating.
Process Temperature	see ***Process Tim.***
Process Time	the calculated time at a particular temperature (process temperature) for which a specific can size and food product need to be heated in order to achieve commercial sterility.
Product Line	maximum level or height of the product in the can; the headspace is above the product line.
Rapid Detinning	see ***Detinning.***
Reducing Environment	conditions expected inside a plain processed food can, whereby the contents are protected from oxidative reactions such as colour change.
Retorting	method of heating cans, usually under steam pressure, to create internal can temperatures well in excess of 100 °C in order to achieve commercial sterility in a shortened period of time; retorts are, in effect, very large pressure cookers.
Retort Processing	see ***Retorting.***

Sacrificial Anode	refers to a metal which slowly dissolves in a corrosion reaction and, in so doing, protects a second metal from corrosion (eg. tin behaving as the sacrificial anode to protect the coupled steel base); see also ***Corrosion mechanis*** **.**
Shelf Life	the expected acceptable commercial life of any canned food.
Shelf Life Testing	see ***Pack Testing*****.**
Sidestripe	thin band of lacquer designed to protect the weld of a can body from corrosion.
Steam Exhausting	passing filled cans through a tunnel of steam, prior to sealing, to assist in oxygen removal from the product and headspace.
Steel Base	low carbon mild steel strip to which the tin coating is electrolytically applied.
Stock Rotation	method of ensuring the oldest canned products are identified, removed first from warehouse storage and are first onto the retailers shelf.
Sulphide Staining	where naturally occurring sulphur compounds in foods react with a plain tinplate surface to form a purple-black stain of tin sulphide.
Thermal Processing	use of any heat process to ensure the commercial sterility of filled cans (see also ***Hot Fill and Hold*** and ***Retorting*****).**
Tin Coating	See ***Electrolyte Tinplate*****.**
Tin Coating Mass	mass of tin, expressed in g/m^2, which is applied to each side of the steel base; standard coating masses generally range from 2.8 to $11.2 g/m^2$ in increments of $2.8 g/m^2$; the internal tin coating mass of plain cans is usually either 8.4 or $11.2 g/m^2$.
Tin Migration	see ***Corrosion*** and ***Detinning*****.**
Tinplate	see ***Electrolyte Tinplate*****.**

CODE OF PRACTICE CONCERNING SOURCE DIRECTED MEASURES TO REDUCE CONTAMINATION OF FOODS WITH CHEMICALS

CAC/RCP 49-2001

1. This document deals with the major sources of environmental chemicals which may contaminate foods and constitute a hazard to human health and therefore, have been considered for regulation by CCFAC/CAC. Apart from environmental contaminants, foods may contain chemicals used as pesticides, veterinary drugs, food additives or processing aids. However, since such substances are dealt with elsewhere in the Codex system, they are not included here, neither are mycotoxins or natural toxins.

2. The main objective of this document is to increase awareness of sources of chemical contamination of food and feed, and of source-directed measures to prevent such contamination. This means that measures recommended in the document may lie outside the direct responsibility of the food control authorities and Codex.

3. National food control authorities should inform relevant national authorities and international organizations of potential or actual food contamination problems and encourage them to take appropriate preventive action. This should result in decreased levels of chemical contamination and, in the long term, could result in a decreasing need to establish and maintain Codex Maximum Levels for chemicals in food.

4. Different approaches may be used to try and ensure that the levels of chemical contaminants in foodstuffs are as low as reasonably achievable and never above the maximum levels considered acceptable/tolerable from the health point of view. Essentially, these approaches consist of a) measures to eliminate or control the source of contamination, b) processing to reduce contaminant levels and, c) measures to identify and separate contaminated food from food fit for human consumption. The contaminated food is then rejected for food use, unless it can be reconditioned and made fit for human consumption. In some cases, a combination of the above approaches must be used, for example, if emissions from a previously uncontrolled source have resulted in environmental pollution with a persistent substance, such as PCBs or mercury. When fishing waters or agricultural land become heavily polluted due to local emissions, it may be necessary to blacklist the areas concerned, i.e. to prohibit

Adopted 2001.

the sale of foods derived from these polluted areas and to advise against the consumption of such foods.

5. Control of final products can never be extensive enough to guarantee contaminant levels below established Maximum Levels. In most cases, chemical contaminants cannot be removed from foodstuffs and there is no feasible way in which a contaminated batch can be made fit for human consumption. The advantages of eliminating or controlling food contamination at source, i.e. the preventive approach, are that this approach is usually more effective in reducing or eliminating the risk of untoward health effects, requires smaller resources for food control and avoids the rejection of foodstuffs.

6. Food production, processing and preparation operations should be analysed with a view to identifying hazards and assessing the associated risks. This should lead to a determination of critical control points and the establishment of a system to monitor production at these points (i.e. the Hazard Analysis Critical Control Point or "HACCP" approach). It is important that care is exercised throughout the whole production-processing and distribution chain, since food safety and quality in other respects cannot be "inspected into " the product at the end of the chain.

7. Pollution of air, water and arable land can result in the contamination of crops grown for food or animal feed, food producing-animals and surface and ground waters used as sources of water for drinking and food production and processing. The relevant national authorities and international organisations should be informed about actual and potential food contamination problems and encouraged to take measures to:
   - control emissions of pollutants from industry, e.g. the chemical, mining, metal and paper industries, and also from weapons testing;
   - control emissions from energy generation (including nuclear plants) and means of transportation;
   - control the disposal of solid and liquid domestic and industrial waste, including its deposition on land, disposal of sewage sludge and incineration of municipal waste;
   - control the production, sale, use and disposal of certain toxic, environmentally-persistent substances, e.g. organohalogen compounds (PCBs, brominated flame retardants, etc.), lead, cadmium and mercury compounds;

- ensure that before new chemicals are introduced onto the market, and especially if they may eventually be released into the environment in significant amounts, they have undergone appropriate testing to show their acceptability from the health and environmental points of view;
- replace toxic environmentally-persistent substances by products which are more acceptable from the health and environmental points of view.

CODE OF PRACTICE FOR THE REDUCTION OF ACRYLAMIDE IN FOODS

CAC/RCP 67-2009

INTRODUCTION

1. Recent concern over the presence of acrylamide in food dates from 2002. Swedish scientists reported that up to "mg/kg" quantities of acrylamide could be formed in carbohydrate-rich foods during high-temperature cooking, e.g. during frying, baking, roasting, toasting and grilling. These findings were rapidly confirmed by other researchers; subsequently, major international efforts have been mounted to investigate the principal sources of dietary exposure, assess the associated health risks and develop risk management strategies. Details of these global research initiatives are provided on the WHO/FAO Acrylamide Information Network (http://www.acrylamide-food.org/) and the "Acrylamide Information Base[1]" http://ec.europa.eu/food/food/chemicalsafety/contaminants/acryl_database_en.htm. There has also been work on acrylamide mitigation studies which are reported in English in the CIAA Acrylamide Tool Box and at http://ec.europa.eu/food/food/chemicalsafety/contaminants/acrylamide_en.htm and http://www.ciaa.be/asp/documents/brochures_form.asp?doc_id=65.

2. Acrylamide is mainly formed in food by the reaction of asparagine (an amino acid) with reducing sugars (particularly glucose and fructose) as part of the Maillard Reaction; acrylamide may also be formed via reactions involving 3-aminopropionamide. Acrylamide formation primarily takes place under conditions of high temperature (usually in excess of 120 °C) and low moisture.

3. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) has undertaken a comprehensive analysis of acrylamide occurrence data from 24 countries, the majority originating from Europe and North America. It was concluded that the major contributing food groups were French fries[2],

[1] A database containing information on projects and activities relating to acrylamide in the EU Member States.

[2] Potato products that are thickly sliced and fried (referred to as French fries in some regions including North America, or as chips in the UK).

Adopted 2009. Revised 2009.

potato crisps[3], coffee, biscuits[4]/pastries, bread and rolls/toasted bread. The full extent of acrylamide present throughout the diet remains unclear.

SCOPE

4. This Code of Practice intends to provide national and local authorities, manufacturers and other relevant bodies with guidance to prevent and reduce formation of acrylamide in potato products and cereal products. The guidance covers three strategies (where information is available) for reducing acrylamide formation in particular products:
   i) Raw materials;
   ii) Control / addition of other ingredients; and
   iii) Food processing and heating.

GENERAL CONSIDERATIONS AND CONSTRAINTS IN DEVELOPING PREVENTATIVE MEASURES

5. Measures aimed at reducing levels of acrylamide cannot be taken in isolation from other considerations. Precautions need to be taken to avoid compromising the existing chemical and microbiological safety of the food. The nutritional qualities of products also need to remain unimpaired, together with their organoleptic properties and associated consumer acceptability. This means all minimisation strategies need to be assessed with regards to their benefits and any possible adverse effects. For example:
   i) When preventative measures for acrylamide are considered, checks should be made to ensure that they will not result in an increase in other process contaminants. These include N-nitrosamines, polycyclic aromatic hydrocarbons, chloropropanols, ethyl carbamate, furan, heterocyclic aromatic amines and amino acid pyrolysates.
   ii) Preventative measures devised for acrylamide must not compromise the microbiological stability of the final product. In particular, regard needs to be paid to the moisture content of the final product.
   iii) Precautions should be taken to avoid detrimental changes to the organoleptic properties of the final product. The formation of acrylamide is intimately associated with the generation of the characteristic colour, flavour and aroma of cooked foods. Proposed changes to cooking conditions, or indeed raw materials and other ingredients, must be assessed from the perspective of the acceptability of the final product to the consumer.

[3] Potato snack product that is thinly sliced and fried (includes foods called potato chips in some regions including North America).

[4] Baked cereal products (referred to as cookies in some regions, including North America).

6. Formal safety assessments, efficacy-in-use demonstration and regulatory approval may be needed for potential new additives and processing aids such as asparaginase. Some companies are producing asparaginase for use in food products and some countries have approved it as a processing aid.

7. It should be noted that the extent of acrylamide formation can be quite variable e.g. within a production batch made at the same manufacturing plant, or between plants using the same process, ingredients and formulations.

8. Manufacturers need to be aware that variability in incoming raw materials and poorly controlled heating devices can complicate trials of mitigation strategies, by obscuring changes in acrylamide levels.

RECOMMENDED PRACTICES TO INDUSTRY FOR THE MANUFACTURE OF POTATO PRODUCTS (E.G. FRENCH FRIES, POTATO CRISPS, POTATO SNACKS)

The mitigation measures discussed in the following sections are not listed in order of priority. It is recommended that all reduction measures are tested to identify the most successful for your own product.

Production stage	Reduction measures
Raw materials	Select potato cultivars with levels of reducing sugars as low as reasonably achievable taking into account regional and seasonal variability. Test incoming deliveries of potatoes for levels of reducing sugars, or fry test them (aim for a light golden colour).
	Avoid using potatoes stored below 6 °C. Control storage conditions from farm to factory and in cold weather, protect potatoes from cold air. Avoid leaving deliveries of potatoes outside (unprotected) in freezing conditions for long periods of time, e.g. overnight. Recondition potatoes from low-temperature storage at higher temperatures (e.g. 12–15 °C) for a period of weeks.
Control / addition of other ingredients	In the case of potato-based snacks produced from doughs, where possible, replace some of the potato with other ingredients with lower reducing sugar/asparagine content e.g. rice flour. Avoid addition of reducing sugars (e.g. as browning agent, spice carrier or coating).
	The addition of asparaginase in some cases has been shown to reduce asparagine and thus acrylamide in potato dough based products.
	Treatment of French fries with sodium pyrophosphate and treatment of potato products with di-and trivalent cations e.g. calcium salts before processing can contribute to the reduction of acrylamide.
Food processing and heating	**French fries:** Blanch potato strips in water to lower levels of reducing sugars before cooking. Lowering the pH with addition of sodium acid pyrophosphate during the latter stages of blanching can reduce levels further. Cut thicker strips; 14x14mm strips have been shown to have lower acrylamide levels than fine cut strips (8x8mm). If appropriate, par fry french fries.
	Potato crisps: Optimise time, temperature and cooker settings to produce a crisp product with a golden yellow colour. If available, consider vacuum frying to process high reducing sugar potatoes. Rapid cooling is recommended if flash frying is being used. Carry out in line colour sorting to remove dark crisps.

RAW MATERIALS

9. A number of factors influence reducing sugar levels including:
   i) Climatic conditions and fertilizer application rate – These factors are known to influence levels of reducing sugars, however, no specific information on reduction measures applicable to manufacturers are currently available.
   ii) Cultivar – Select cultivars with levels of reducing sugars as low as reasonably achievable taking into account regional and seasonal variability for high temperature cooking processes such as frying and baking.
   iii) Storage temperature and time – Control storage conditions from farm to factory; >6 °C has been identified as good practice for long storage for processing. Avoid using potatoes that have been subject to excessive low-temperature sweetening during storage (at, or below 4–6 °C) for frying, roasting and oven-baking. In cold weather protect potatoes from cold air. Avoid leaving deliveries of potatoes standing outside (unprotected) over night in freezing conditions. Some cultivars are less prone than others to low temperature sweetening. Information on some cultivars is contained in a database available from the European Cultivated Potato Database and the German Federal Office of Plant Varieties.
   iv) Reconditioning temperature and time – Potatoes that have been stored at low temperatures should be reconditioned over a period of a few weeks at higher temperatures (e.g. 12–15 °C). The decision to recondition stored potatoes, as well as decisions on the length of time needed for reconditioning, should be made on the basis of the results of fry testing.
   v) Tuber size/immature tubers – Immature tubers have higher reducing sugar levels and produce darker fried products with potentially higher levels of acrylamide. The presence of immature tubers should be avoided by selecting, sorting or grading of potatoes at some stage before processing.

10. Sprout suppressant is often essential in stores held at temperatures over 6 °C, although regional regulations in some cases do not permit the use of sprout suppressants.

11. Manufacturers of French fries and potato crisps should where feasible screen incoming lots by measuring reducing sugar content or assessing the colour of a fried sample. In particular, fry test potatoes that have been stored at low temperatures for long periods of time. When using cultivars with not sufficiently low reducing sugar contents, reconditioning and blanching before high temperature cooking processes, and vacuum frying for heating may lower the level of acrylamide.

CONTROL/ADDITION OF OTHER INGREDIENTS

12. For reconstituted or formed potato-based snacks produced from potato doughs, other ingredients with lower reducing sugar/asparagine content can sometimes be used in some products to partially replace the potato e.g. rice flour.

13. Addition of the enzyme asparaginase has been shown to reduce asparagine and thus acrylamide levels in potato products made from potato doughs.Asparaginase may be best suited for food products manufactured from liquidised or slurried materials. In practice asparaginase can functionally reduce acrylamide in prefabricated potato crisps, however, the amount of asparagines in the raw potato product is generally so high that in order to achieve a meaningful reduction in acrylamide a large amount of asparaginase must be added. This may preclude the use of the enzyme for some potato products.

14. Treatment with various other reagents e.g., sodium pyrophosphate and calcium salts prior to the frying stage has also been demonstrated to reduce acrylamide formation. Additives should be used according to the appropriate national or international legislation.

15. The use of reducing sugars as a browning agent, spice carrier or coating should also be avoided where possible because they can cause the formation of significant levels of acrylamide.

FOOD PROCESSING AND HEATING

16. Decrease of the surface area can be employed; for example in French fries, by cutting potatoes into thicker slices; 14x14mm strips have been shown to have lower acrylamide levels than fine cut strips (8x8mm) or removal of fines (fine pieces of potato) before or after frying to reduce levels of acrylamide in fried or roasted potatoes.

17. Washing, blanching or par-boiling treatments can be employed to leach the asparagine/reducing sugar reactants from the surface of the potato before the cooking step. Various reagents for lowering pH can also be added during the latter stages of blanching to further reduce levels of acrylamide, these include, treatment of French fries with sodium acid pyrophosphate, treatment with calcium salts, and the salts of a number of other di- and trivalent cations (this method has been shown to reduce acrylamide formation in French fries made from potato dough) and blanching in sodium chloride solution (though this method may increase dietary exposure to sodium).

i) Blanching or soaking potatoes has shown to reduce acrylamide levels but can also have an adverse effect on the flavour and texture of the final product. Blanching can also lead to leaching of vitamin C and minerals from potatoes. A blanching step before frying/roasting may lower the fat content of the final product, but there is contradictory information on this topic.
ii) Blanching may also be unsuitable for some products e.g. potato crisps, as it may cause unacceptable moisture uptake, leading to loss of consistency/ crispness or possible microbiological spoilage.

18. Acrylamide levels in potato crisps can be reduced by controlling the thermal input. Vacuum frying might offer the opportunity to reduce acrylamide levels in crisps made from potatoes with high reducing sugar content. Rapid cooling potato crisps that are cooked by flash frying can also reduce levels of acrylamide in the final product. The use of in-line optical sorting to remove dark coloured crisps has been proved to be an effective measure to reduce acrylamide. Par cooking far-infrared heating and dry steam treatments used to make low fat crisps may also reduce acrylamide.

19. In order to achieve significant reductions in the acrylamide content of French fries, when cooking the product immediately prior to consumption, set the initial oil temperature to no more than 170-175 °C and cook to a golden-yellow rather than a golden-brown colour. Depending on the heating power of the fryer, the amount of potato immersed in the oil should aim to give an actual frying temperature starting from about 140 °C and ending at about 160 °C. A bigger long-lasting temperature drop after addition of the potato will increase the fat uptake, and a higher end temperature will result in excessive acrylamide formation.

20. Manufacturers of prefabricated par fried French fries should ensure that their on-pack cooking instructions are consistent with the need to minimise acrylamide formation. Where frying is one of the on-pack suggestions for "Prefabricated" French fries, the recommended frying temperature should not be greater than 175 °C. The cooking instructions should also mention that consumers should reduce the cooking time when cooking small amounts and that they should cook fries to a golden-yellow colour.

21. Some "Oven" French fries or prefabricated potato products are manufactured with a view to storage under refrigerated rather than frozen conditions. Storage at these conditions may be conducive to low-temperature sweetening due to residual amylase activity which leads to reducing sugar formation from

starch. Should this be the case, blanching must be adapted (longer time and/or higher temperature) in order to fully inactivate the amylase activity.

RECOMMENDED PRACTICES TO INDUSTRY FOR THE MANUFACTURE OF CEREAL BASED PRODUCTS (E.G. BREAD, CRISPBREAD, BISCUITS/BAKERY WARES, BREAKFAST CEREALS)

The mitigation measures discussed in the following sections are not listed in order of priority. It is recommended that all reduction measures are tested to identify the most successful for your own product.

Production stage	Reduction measures
Raw Materials	Sulphur deficient soil should be avoided, or well fertilised. Excessive nitrogen fertilization should be avoided.
Control / addition of other ingredients	**General:** Consider the type of flour to be used. High extraction flours contain significantly less asparagine than wholemeal flours. However, lowering the wholemeal content will reduce the nutritional benefits of the final product. Consider part replacement of wheat flour by rice flour.
	Biscuits/bakery wares: When ammonium containing raising agents are used, consider replacements with other raising agents e.g. potassium and sodium containing raising agents. In the production of gingerbread replace fructose with glucose. The addition of asparaginase has been shown to reduce asparagine and thus acrylamide in hard, wheat-dough based products such as cookies and crackers.
	Bread: Avoid using reducing sugars in the recipe. The addition of calcium salts, e.g. calcium carbonate may reduce the formation of acrylamide.
	Breakfast cereals: Minimize reducing sugars in the cook phase. Consider the contribution of other inclusions e.g. roasted nuts, dried fruits and whether they are necessary if they are in a form that potentially can add a significant level of acrylamide.
Food processing and heating	**General:** Do not over bake.
	Bread: Adjust the time-temperature profile of the baking process, i.e., decrease temperatures of the final stages when product reaches low moisture phase. Extend fermentation times of bread doughs.
	Crispbread: Control the final moisture content. In non-fermented crispbread control the process temperature and oven speed.
	Breakfast cereals: Do not over-bake or over-toast. Manage the toasting to achieve a uniform colour for the product.

RAW MATERIALS

22. Typically, asparagine can range from 75 to 2200 mg/kg in wheat, from 50 to 1400 mg/kg in oats, from 70 to 3000 mg/kg in maize, from 319 to 880 mg/kg in rye and from 15 to 25 mg/kg in rice. This level of variation suggests that there may be scope for reducing acrylamide by exploiting the variability of asparagine content in the cultivar pool. However, as in the similar case for potatoes, such approaches are likely to have a significant lead time, and other factors, such as yield and resistance to fungal infections (field mycotoxin formation), would need to be considered.

23. Deficiencies in the sulphur content of soil can cause an increase in asparagine levels in wheat and barley. Therefore, sulphur deficient soil should be avoided, or well fertilised. High nitrogen content in soils may result in higher asparagine content in cereals and excessive nitrogen fertilization should be avoided.

24. In mixed cereal products, there may be scope for reducing the proportion of the predominant source of acrylamide by incorporating cereals with lower asparagine content. For example, this strategy could include replacing rye and wheat with rice, however, nutritional and organoleptic implications must be considered.

CONTROL/ADDITION OF OTHER INGREDIENTS

25. Thought should be given to the type of flours used in products. High extraction flours contain significantly less asparagine than wholemeal flours. Part replacement of wheat flour by rice flour has been shown to reduce acrylamide in short sweet biscuits and gingerbread. However, lowering the wholemeal content will reduce the nutritional benefits of the final product. Types of flours vary in asparagine content and choice should be balanced between nutritional value and minimization of acrylamide formation.

26. Ammonium bicarbonate has been shown to increase the potential yield of acrylamide from a baked product. Thus, manufacturers need to consider whether the use of ammonium-containing raising agents can be reduced. Additives should be used according to the appropriate national or international legislation. Replacement leavening agents used commercially include:
    i) Sodium bicarbonate + acidulants;
    ii) Disodium diphosphate, sodium bicarbonate and organic acids;

iii) Potassium bicarbonate + potassium bitartrate;
iv) Sodium bicarbonate + sodium acid pyrophosphate (SAPP).
v) Replacement of ammonium-containing raising agents with those containing sodium may increase dietary exposure to sodium and may also adversely affect the physical properties of gingerbread and the organoleptic qualities of biscuits. Combination of sodium bicarbonate and organic acids e.g. tartaric acid and citric acid, may result in a product with somewhat lesser leavening. The amount of organic acids added needs to be limited because an acidic taste may be developed and gas release in the dough may be too fast.
vi) Greater amounts of acrylamide are formed if the reducing sugar is fructose rather than glucose. Commercial investigations have shown removal of sources of fructose or replacement by glucose in the product ingredients (sugar syrups, fruit puree, honey) to be successful in reducing acrylamide formation. If glucose syrup (also known as corn syrup in North America) is necessary, the level of fructose in this syrup should be as low as possible. The replacement of reducing sugars by sucrose is another effective way to significantly reduce acrylamide in sweet baked goods if browning is less important.

27. The addition of asparaginase has been shown to reduce asparagine and thus acrylamide in hard, wheat-dough based products such as cookies and crackers.

28. Care should also be exercised in the usage of reducing sugars during the manufacture of breakfast cereals. When such sugars are used they are usually added after the baking process, in which case no additional acrylamide formation will occur. However, addition of reducing sugars prior to baking represents an avoidable source of acrylamide formation.

29. Other minor ingredients can also have an influence. Increases in acrylamide formation have been shown to occur in some recipes when ingredients such as ginger, honey and cardamom are added during biscuit production. Conversely, nutmeg has been shown, in some cases, to result in a decrease in acrylamide. In order to reduce acrylamide levels in final products, manufacturers could investigate the effect of different spices in their own recipes.

30. Use of rework (the practice of re-using scraps) has been shown to increase acrylamide levels in some cases, but not in others. Manufacturers need to examine production processes for individual products to determine whether reducing rework can be used to mitigate acrylamide levels in their products.

FOOD PROCESSING AND HEATING

31. Yeast fermentation of wheat bread doughs reduces the free asparagine content. Fermentation for two hours utilises most of the asparagine in wheat flour dough models; shorter times are less effective, as is sourdough fermentation.

32. Acrylamide formation can be reduced by modifying the time–temperature profile of the baking process, in particular by decreasing the temperature of the final stages when the product reaches the crucially vulnerable, low moisture phase. Compensation by increasing the temperature of the earlier stages of baking should not lead to a significant increase in acrylamide, since the moisture content at this stage should be sufficiently great so as to prevent acrylamide formation. Careful control of oven temperatures and time profiles can be effective in reducing acrylamide levels. These principles have been applied successfully in both a biscuit model and in non-fermented crispbreads.

COFFEE

33. No commercial measures for reducing acrylamide in coffee are currently available.

34. Studies have shown that concentrations of acrylamide decline in storage in coffee powder in closed containers over extended storage periods and work is underway to identify the underlying mechanisms that may provide future opportunities for mitigation. However, any changes to the roasting profile, or deliberate use of extended storage, to decrease acrylamide levels are likely to have a significant impact on the organoleptic properties and consumer acceptability of the product.

CONSUMER PRACTICES

35. National and local authorities should consider advising consumers to avoid over-heating potato and cereal-based foodstuffs when using high temperature cooking processes. Such advice could include recommendations that French fries and roast potatoes be cooked to a golden-yellow rather than golden-brown colour, whilst still ensuring that the food is fully cooked. Similarly, the consumer could be advised to aim for a light brown colour when toasting bread and related products.

36. National and local authorities should also consider encouraging consumers to avoid storing potatoes intended for high-temperature cooking under cold and/or refrigerated conditions.

37. Where relevant, industry should endeavour to provide advice to consumers on appropriate cooking and handling instructions that can help to mitigate acrylamide formation in the product.

CODE OF PRACTICE FOR THE PREVENTION AND REDUCTION OF DIOXIN AND DIOXIN-LIKE PCB CONTAMINATION IN FOOD AND FEEDS

CAC/RCP 62-2006

INTRODUCTION

General remarks

1. Dioxins, including polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) and dioxin-like polychlorinated biphenyls (PCBs) are pervasive in the environment. Although dioxins and dioxin-like PCBs show similarities in their toxicological and chemical behaviour, their sources are different.

2. Current sources of dioxins and dioxin-like PCBs entering the food chain include new emissions and remobilisation of deposits or reservoirs in the environment. New emissions are mainly via the air route. Dioxins and dioxin-like PCBs decompose very slowly in the environment and remain there for very long periods of time. Therefore, a large part of current exposure is due to releases of dioxin and dioxin-like PCBs that occurred in the past.

3. PCBs, including dioxin-like PCBs, were produced intentionally and in considerable amounts between the 1930s and 1970s and were used in a wide range of applications. PCBs are still in use in existing closed systems and contained in solid matrices (e.g., sealing materials and electrical capacitors). Certain commercial PCBs are known to be contaminated with PCDFs and could therefore be regarded as a potential source for dioxin contamination.

4. Today release of dioxin-like PCBs occurs from leakages, accidental spills and illegal disposal and through emissions via air from thermal processes. Migration from sealants and other old matrix applications are of minor importance. The remobilisation of dioxin-like PCBs from environmental reservoirs is similar to dioxins.

5. Dioxins are formed as unwanted by-products from a number of human activities including certain industrial processes (e.g., production of chemicals, metallurgical industry) and combustion processes (e.g., waste incineration). Accidents at chemical factories have been shown to result in high emissions and contamination of local areas. Other dioxin sources include domestic

Adopted 2006.

heaters, agricultural and backyard burning of household wastes. Natural processes such as volcanic eruptions and forest fires can also produce dioxins.

6. When released into the air, dioxins can deposit locally on plants and on soil contaminating both food and feed. Dioxins can also be widely distributed by long-range atmospheric transport. The amount of deposition varies with proximity to the source, plant species, weather conditions and other specific conditions (e.g. altitude, latitude, temperature).

7. Sources of dioxins in soil include deposition from atmospheric dioxins, application of contaminated sewage sludge to farm land, flooding of pastures with contaminated sludge, and prior use of contaminated pesticides (e.g., 2.4.5-trichlorophenoxy acetic acid) and fertilizers (e.g., certain compost). Other sources of dioxins in soil may be of natural origin (e.g., ball clay).

8. Dioxins and dioxin-like PCBs are poorly soluble in water. However, they are adsorbed onto mineral and organic particles suspended in water. The surfaces of oceans, lakes and rivers are exposed to aerial deposition of these compounds which are consequently concentrated along the aquatic food chain. The entry of waste water or contaminated effluents from certain processes, such as chlorine bleaching of paper or pulp or metallurgical processes, can lead to contamination of water and sediment of coastal ocean areas, lakes and rivers.

9. The uptake of dioxins and dioxin-like PCBs by fish occurs via gills and diet. Fish accumulate dioxins and dioxin-like PCBs in their fatty tissue and liver. Bottom dwelling/bottom feeding fish species are more exposed to contaminated sediments than pelagic fish species. However, levels of dioxins and dioxin-like PCBs in bottom dwelling/bottom feeding fish are not always higher than those in pelagic fish depending on the size, diet and physiological characteristics of the fish. In general, fish show an age-dependent accumulation of dioxins and dioxin-like PCBs.

10. Food of animal origin is the predominant route of human exposure to dioxins and dioxin-like PCBs with approximately 80–90% of the total exposure via fats in fish, meat and dairy products. Levels of dioxins and dioxin-like PCBs in animal fat may be related to contamination of the local environment and to contamination of feed (e.g., fish-oil and fish-meal) or, to certain production processes (e.g., artificial drying).

11. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) and the European Union Scientific Committee on Food (EU SCF) derived tolerable intakes and compared these with calculated intakes. They concluded that a considerable proportion of the population may exceed the tolerable intake of dioxins and dioxin-like PCBs.

12. In order to reduce the contamination of food, control measures at the feed level should be considered. These may involve developing Good Agricultural Practice, Good Animal Feeding Practice (see Codex Alimentarius Commission: Code of Practice on Good Animal Feeding), and Good Manufacturing Practice guidance and measures to effectively reduce dioxins and dioxin-like PCBs in feed, including:
    - Identification of agricultural areas with increased dioxin and dioxin-like PCB contamination due to local emission, accidents or illegal disposal of contaminated materials, and monitoring of feed and feed ingredients derived from these areas,
    - Setting guidance values for soil and recommendation for special agricultural use (e.g., limitation of grazing or use of appropriate agricultural techniques),
    - Identification of possibly contaminated feed and feed ingredients,
    - Monitoring compliance with nationally-established guideline levels or maximum limits, if available, and minimizing or decontaminating (e.g., refining of fish oil) non-complying feed and feed ingredients, and
    - Identification and control of critical feed manufacturing processes (e.g., artificial drying by direct heating).

13. Similar control measures, where applicable, should be considered for reducing dioxins and dioxin-like PCBs in food.

Source directed measures

14. Reducing sources of dioxins and dioxin-like PCBs is an essential prerequisite for a further reduction of contamination. Measures to reduce dioxin emission sources should be directed to reducing the formation of dioxin during thermal processes as well as the application of destruction techniques. Measures to reduce dioxin-like PCBs emission sources should be directed to minimizing releases from existing equipment (e.g. transformers, capacitors), prevention of accidents and better control of the disposal of dioxin-like PCBs containing oils and wastes.

15. The Stockholm Convention on Persistent Organic Pollutants (Stockholm Convention) is a global treaty to protect human health and the environment from persistent organic pollutants (POPs) including dioxins and dioxin-like PCBs.

16. Part II of Annex C of the Stockholm Convention lists the following industrial source categories, that have the potential for comparatively high formation and release of dioxins, and dioxin-like PCBs to the environment.
    a) Waste incinerators, including co-incinerators of municipal, hazardous or medical waste or of sewage sludge;
    b) Cement kilns firing hazardous waste;
    c) Production of pulp using elemental chlorine or chemicals generating elemental chlorine for bleaching;
    d) Thermal processes in the metallurgical industry, i.e. secondary copper production; sinter plants in the iron and steel industry; secondary aluminium production; secondary zinc production.

17. Part III of Annex C also lists the following source categories that may unintentionally form and release dioxins, and dioxin-like PCBs, to the environment:
    a) Open burning of waste, including burning of landfill sites;
    b) Thermal processes in the metallurgic industry not mentioned in Part II, Annex C;
    c) Residential combustion sources;
    d) Fossil fuel-fired utility and industrial boilers;
    e) Firing installations for wood and other biomass fuels;
    f) Specific chemical production processes releasing unintentionally formed persistent organic pollutants, especially production of chlorophenols and chloranil;
    g) Crematoria;
    h) Motor vehicles, particularly those burning leaded gasoline;
    i) Destruction of animal carcasses;
    j) Textile and leather dyeing (with chloranil) and finishing (with alkaline extraction);
    k) Shredder plants for the treatment of end of life vehicles;
    l) Smouldering of copper cables;
    m) Waste of oil refineries.

18. Adopting technologies to minimize formation and release of dioxins and dioxin-like PCBs from these sources categories should be considered by national authorities when developing national measures to reduce dioxin and dioxin-like PCBs.

Scope

19. This Code of Practice focuses on measures (e.g., Good Agricultural Practices, Good Manufacturing Practices, Good Storage Practices, Good Animal Feeding Practices, and Good Laboratory Practices) for national authorities, farmers, and feed and food manufacturers to prevent or reduce dioxin and dioxin-like PCB contamination in foods and feeds.

20. This Code of Practice applies to the production and use of all materials destined for feed (including grazing or free-range feeding, forage crop production and aquaculture) and food at all levels whether produced industrially or on farm.

21. Since the global limitation and reduction of dioxins and dioxin-like PCBs from non food / feed related industrial and environmental sources may lie outside of the responsibility of CCFAC, these measures will not be considered within this Code of Practice.

RECOMMENDED PRACTICES BASED ON GOOD AGRICULTURAL PRACTICES (GAPS), GOOD MANUFACTURING PRACTICES (GMPS), GOOD STORAGE PRACTICES (GSPS), GOOD ANIMAL FEEDING PRACTICES (GAFPS), AND GOOD LABORATORY PRACTICES (GLPS)

Control measures within the food chain

Air, Soil, Water

22. To reduce dioxin and dioxin-like PCB contamination in the air, national food authorities should consider recommending to their national authorities responsible for air pollution measures to prevent uncontrolled burning of wastes, including the burning of landfill sites or backyard burning, and the use of PCB treated wood for domestic heaters.

23. Control measures to prevent or reduce contamination of the environment by dioxins and dioxin-like PCBs are important. To reduce possible contamination of feed or food, agricultural land with unacceptable dioxin and dioxin-like PCB contamination due to local emission, accidents, or illegal disposal of contaminated materials should be identified.

24. Agricultural production on contaminated areas should be avoided or should be restricted if a significant transfer of dioxins and dioxin-like PCBs to feed or food produced on these areas is anticipated. If possible, contaminated soil should be treated and detoxified or removed and stored under environmentally sound conditions.

25. The spreading of sewage sludge contaminated with dioxins and dioxin-like PCBs can lead to adhering of contaminants on the vegetation which can increase livestock exposure. Sewage sludge used in agriculture should be monitored, as necessary for dioxins and dioxin-like PCBs. Additionally, sewage sludge should be treated, as necessary, to render it inert or to detoxify it. National guidelines should be adhered to where applicable.

26. Livestock, game, and poultry, exposed to contaminated soil, may accumulate dioxins and dioxin like PCBs by consumption of contaminated soil or plants. These areas should be identified and controlled. If necessary, the production in these areas should be restricted.

27. Source-reduction measures will take many years to reduce contamination levels in wild caught fish due to the long half-lives of dioxins and dioxin-like PCBs in the environment. To reduce exposure to dioxins and dioxin-like PCBs, highly contaminated areas (e.g., lakes and rivers) and relevant fish species should be identified and fishing in these areas should be controlled and, if necessary, restricted.

Feed

28. The bulk of human dietary intake of dioxins and dioxin-like PCBs is due to the deposition of these substances in the lipid component of animal derived foods (e.g., poultry, fish, eggs, meat and milk). In lactating animals dioxins and dioxin-like PCBs are excreted partly with milk fat, and in laying hens the contaminants are concentrated in fat content of the yolk in laid eggs. To reduce this transfer, control measures at the feed and feed ingredients level should be considered. Measures to reduce the dioxin and dioxin-like PCB levels in feed would have an immediate effect on contaminant levels in food of animal origin originating from farm animals, including farmed fish. These measures should involve developing Codes of Good Agricultural Practices, Good Animal Feeding Practices (see, Good Manufacturing Practices, Good Storage Practices, and other control measures e.g., HACCP-like principles) which may reduce levels of dioxins and dioxin-like PCBs. Such measures may include:
    - identification of possibly contaminated areas in the feed supply ecosystem,
    - identification of the origin of frequently contaminated feed or feed ingredients, and
    - monitoring the compliance of feed and feed ingredients with nationally-established guideline levels or maximum limits, if available. Threshold violating commodities should be investigated by the competent national

authority, to determine whether those commodities should be excluded from further feeding.

29. Competent national authorities should periodically sample and analyse, using recognized international methods, suspect feed and feed ingredients to verify dioxin and dioxin-like PCB levels. This information will determine actions, if needed, to minimize dioxin and dioxin-like PCB levels and allow alternative feed and feed ingredients to be located, if necessary.

30. The purchaser and user should pay attention to:
    - origin of feed and feed ingredients to ensure that producers and/or companies have certified production facilities, production processes and quality assurance programmes (e.g., HACCP-like principles);
    - accompanying documents confirming compliance with nationally-established guideline levels or maximum limits, if available, according to national requirements.

Feed of animal origin

31. Due to the position of their precursors in the food chain, animal derived feed has a higher risk for dioxin and dioxin-like PCB contamination compared to plant derived feed. Attention should be paid to avoid these contaminants from entering the food chain through the feeding of animal derived feed to food producing animals. Animal derived feed should be monitored, as necessary, for dioxins and dioxin-like PCBs.

32. Accumulation of dioxins and dioxin-like PCBs in adipose tissues of livestock, with possible resultant violations of nationally-established guideline levels or maximum limits, if available, for meat and milk or their derived products should be prevented. Therefore, feed of animal origin that exceeds nationally-established guideline levels or maximum limits, if available, or contains elevated levels of dioxins or dioxin-like PCBs should not be fed to animals unless the fat has been removed.

33. If intended for use in feed, fish-oil and other products derived from fish, milk and milk substitutes, and animal fats should be monitored to the extent practicable for dioxins and dioxin-like PCBs. If there are nationally-established guideline levels or maximum limits, the feed manufacturer should ensure that the products are in compliance with these provisions.

Feed of plant origin

34. If potential sources of dioxins and dioxin-like PCBs are anticipated in the vicinity of fields, attention should be paid to monitor these areas, as necessary.

35. Cultivation sites irrigated with water or treated with sewage sludge or municipal compost that may contain elevated dioxin and dioxin-like PCB levels should be monitored, as necessary, for contamination.

36. Prior treatment of crops with herbicides from the chlorinated phenoxyalkanoic acid type or chlorinated products like pentachlorophenol should be considered as a potential source for dioxin contamination. Dioxin levels in soil and forage plants from sites treated previously with dioxin-contaminated herbicides should be monitored as necessary. This information will enable competent national authorities, if necessary, to take appropriate management measures in order to prevent the transfer of dioxins (and dioxin-like PCBs) into the food chain.

37. Typically, oilseeds and vegetable oil are not significantly contaminated with dioxins and dioxin-like PCBs. This also applies to other by-products of oilseed processing (e.g., oilseed cakes) used as feed ingredients. However, certain oil refining by-products (e.g., fatty acid distillates) may contain increased levels of dioxins and dioxin-like PCBs and should be analysed, as necessary, if used for feed.

Feed and food processing

Drying processes

38. Certain processes for the artificial drying of feed and food (and feed or food ingredients) and the heating of indoor growing facilities (e.g. hothouses) requires a flow of heated gases, either a flue gas-air mix (direct drying or heating) or heated air alone (indirect drying or heating). Accordingly, fuels which are not generating dioxins and dioxin-like compounds and other harmful contaminants at unacceptable levels should be used. Feed, food and feed or food ingredients that are dried or subjected to heated air should be monitored as necessary to ensure that drying or heating processes do not result in elevated levels of dioxins and dioxin-like PCBs.

39. The quality of commercial dried feed materials, in particular green fodder and commercially dried foods depends on the selection of the raw material and the drying process. The purchaser should consider requiring a certificate from the manufacturer/supplier, that the dried goods are produced

according to Good Manufacturing Practice, especially in the choice of the fuel and are in compliance with nationally-established guideline levels or maximum limits, if available.

Smoking

40. Depending on the technology used, smoking can be a critical processing step for increased dioxin content in foods, especially if the products show a very dark surface with particles of soot. Such processed products should be monitored, as necessary, by the manufacturer.

Milling / Disposal of contaminated milling fractions

41. In agricultural land in the vicinity of dioxin and dioxin-like PCB emission sources, the air borne external deposition of dioxins and dioxin-like PCBs on the surface of all parts of the grain plants as well as the adherent dust fraction from the standing crop is widely removed during the milling process and before the final grinding process. If present, most particle-bound contamination is removed in the loading chute with the remaining dust. Further external contaminations are significantly reduced during aspiration and sieving. Certain grain fractions, especially dust, can have increased dioxin and dioxin-like PCB levels and should be monitored, as necessary. If there is evidence for elevated contamination, such fractions should not be used in food or feed and treated as waste.

Substances added to feed and food

Minerals and trace elements

42. Some minerals and trace elements are obtained from natural sources. However, experience has shown, that geogenic dioxins may be present in certain prehistoric sediments. Therefore, dioxin levels in minerals and trace elements added to feed or food should be monitored as necessary.

43. Reclaimed mineral products or by-products from certain industrial processes may contain elevated levels of dioxins and dioxin-like PCBs. The user of such feed ingredients should verify that dioxin and dioxin-like PCBs are within nationally-established guideline levels or maximum limits, if available, through certification by the manufacturer or supplier.

44. Elevated levels of dioxins have been found in ball clay used as an anticaking agent in soybean meal in feed. Attention should be paid to minerals used as binders or anticaking agents (e.g., bentonite, montmorillonite, kaolinitic clay) and carriers (e.g., calcium carbonate) used as feed ingredients. As assurance to the user that these substances do not contain minerals with

elevated levels (e.g., exceeding nationally- established guideline levels or maximum limits, if available) of dioxins and dioxin-like PCBs, the distributor should provide appropriate certification to the user of such feed ingredients.

45. The supplementation of food producing animals with trace elements (e.g., copper or zinc) depends on the species, age and performance. Minerals, including trace elements, which are by-products or co-products of industrial metal production have been shown to contain elevated levels of dioxins. Such products should be monitored for dioxins and dioxin-like PCBs, as necessary.

Ingredients

46. Feed and food manufacturers should ensure that all ingredients in feed and food have minimal levels of dioxins and dioxin-like PCBs to reduce possible contamination and to comply with nationally-established guideline levels or maximum limits, if available.

Harvesting, transport, storage of feed and food

47. To the extent feasible, it should be ensured that minimal contamination with dioxins and dioxin-like PCBs occurs during the harvest of feed and food. This can be achieved in possibly contaminated areas by minimizing soil deposition on feed and food during harvest by using appropriate techniques and tools according to Good Agricultural Practice. Roots and tubers, grown on contaminated soil, should be washed to reduce soil contamination. If roots and tubers are washed, they should be sufficiently dried before storage or be stored following techniques (e.g. ensilage) aiming to prevent mould formation.

48. After flooding, crops harvested for feed and food should be monitored, as necessary, for dioxins and dioxin-like PCBs, if there is evidence for flood water contamination by these contaminants.

49. To avoid cross-contamination, the transport of feed and food should only be performed in vehicles (including ships) or in containers not contaminated with dioxins and dioxin-like PCBs. Storage containers for feed and food should be painted only with dioxin and dioxin-like PCB-free paint.

50. Storage sites for feed or food should be free from contamination with dioxins and dioxin-like PCBs. Surfaces (e.g., walls, floors) treated with tar-based paints may result in transfer of dioxins and dioxin-like PCBs to food and feed. Surfaces that come in contact with smoke and soot from fires

always bear a risk of contamination with dioxins and dioxin-like PCBs. These sites should be monitored as necessary for contamination before use for storage of feed and food.

Special problems of animal keeping (Housing)

51. Food producing animals may be exposed to dioxins and dioxin-like PCBs found in certain treated wood used in buildings, farm equipment and bedding material. To reduce exposure, animal contact with treated wood containing dioxins and dioxin-like PCBs should be minimized. In addition, sawdust from treated wood containing dioxins and dioxin-like PCBs should not be used as bedding material.

52. Due to contamination in certain soil, eggs from free living or free-range hens (e.g., organic farming) may have elevated levels of dioxins and dioxin-like PCBs compared to eggs from caged hens and should be monitored, as necessary.

53. Attention should be paid to older buildings as they may have building materials and varnishes that may contain dioxin and dioxin-like PCBs. If they have caught fire, measures should be taken to avoid contamination of the feed and feed chain by dioxins and dioxin-like PCBs.

54. In housings without a floor covering, the animals normally will take up soil particles from the ground. If there are indications of increased levels of dioxins and dioxin-like PCBs, the contamination of the soil should be controlled as necessary. If needed, the soil should be exchanged.

55. Pentachlorophenol-treated wood in animal facilities has been associated with elevated levels of dioxins in beef. Wood (e.g., railroad ties, utility poles) treated with chemicals such as pentachlorophenol or other unsuitable materials should not be used as fence posts for enclosures of free-range animals or feed lines. Hay racks should not be constructed from such treated wood. In addition, the preservation of wood with waste oils should also be avoided.

Monitoring

56. Farmers and industrial feed and food manufacturers have the primary responsibility for feed and food safety. Testing could be conducted within the framework of a food safety programme (e.g. Good Manufacturing Practices, On-Farm Safety programmes, Hazard Analysis and Critical Control Point programmes, etc.) In previous sections of this Code, it is mentioned

where it could be appropriate to perform monitoring. Competent authorities should enforce the primary responsibility of farmers, feed and food manufacturers for feed and food safety through the operation of surveillance and control systems at appropriate points throughout the food chain, from the primary production to the retail level. In addition competent authorities should set up own monitoring programmes.

57. As analyses for dioxins are quite expensive in comparison to determination of other chemical contaminants, periodic tests should be performed to the extent feasible at least by industrial feed and food manufacturers including both incoming raw materials and final products and data should be kept (see para. 66). The frequency of sampling should consider results from previous analysis (by individual companies and/or via a pool of industry results within the same sector). If there are indications of elevated levels of dioxins and dioxin-like PCBs, farmers and other primary producers should be informed about the contamination and the source should be identified.

58. Monitoring programmes dealing with contaminations originating from the environment, accidents or illegal disposals should be organized by operators in the feed and food chain to the extent feasible and competent national authorities in order to obtain additional information on food and feed contamination. Products or ingredients at risk or found with elevated contamination should be monitored more intensively. For example, monitoring programmes may include major fish species used in food or feed that have been shown to contain elevated levels of dioxins and dioxin-like PCBs.

Sampling, analytical methods, data reporting and laboratories

59. Advice concerning analytical requirements and qualification of laboratories is given in the literature. These recommendations and conclusions form the basis of the evaluation by JECFA and others. Furthermore, consideration of methods of analysis of dioxins and dioxin-like PCBs is addressed by the Codex Committee of Methods of Analysis and Sampling.

60. Traditional methods for the analysis of dioxin and dioxin-like PCBs rely on high-resolution mass spectrometry which is time-consuming and expensive. Alternatively, bioassay techniques have been developed as high throughput screening methods which can be less expensive than traditional methods. However, the cost of analysis remains an impediment to data collection thus research priority should be given to the development of less costly analytical methods for the analysis of dioxin and dioxin-like PCBs.

Sampling

61. Important aspects of sampling for dioxin and dioxin-like PCB analysis are collecting representative samples, avoiding cross contamination and deterioration of samples and unambiguously identifying and tracing back samples. All relevant information on sampling, sample preparation and sample description (e.g., sampling period, geographic origin, fish species, fat content, size of fish) should be recorded in order to provide valuable information.

Analytical methods and data reporting

62. Analytical methods should be applied only if they are fit for purpose meeting a minimum of requirements. If nationally-established maximum limits are available, the limit of quantification (LOQ) of the method of analysis should be in the range of one fifth of this level of interest. For control of time trends of background contamination, the limit of quantification of the method of analysis should be clearly below the mean of the present background ranges for the different matrices.

63. Performance of a method of analysis should be demonstrated in the range of the level of interest, e.g. 0.5 x, 1 x and 2 x level of maximum limit with an acceptable coefficient of variation for repeated analysis. The difference between upper bound and lower bound levels (see next para.) should not exceed 20% for feed and food with a dioxin contamination of about 1 pg WHO-PCDD/PCDF-TEQ/g fat. If needed, another calculation based on fresh weight or dry matter could be considered.

64. Except for bioassay techniques, the results of total dioxin and dioxin-like PCB levels in a given sample should be reported as lower bound, medium bound and upper bound concentration by multiplying each congener by their respective WHO Toxic Equivalency Factor (TEF) and subsequently summing them up to give the total concentration expressed as Toxic Equivalency (TEQ). The three different TEQ values should be generated reflecting assignment of zero (lower bound), half the limit of quantification (medium bound), and limit of quantification (upper bound) values to each non-quantified dioxin and dioxin-like PCB congener.

65. Depending on sample type, the report of the analytical results may include the lipid or dry matter content of the sample as well as the method used for lipid extraction and for determination of dry matter. This report should also include a specific description of the procedure used to determine the level of quantification (LOQ).

66. A high throughput screening method of analysis with proven acceptable validation could be used to screen the samples with significant levels of dioxins and dioxin-like PCBs. Screening methods should have less than 1% false-negative results in the relevant range of interest for a particular matrix. Use of ^{13}C-labelled internal standards for dioxins or dioxin-like PCBs allows for specific control of possible losses of the analytes in each sample. In this way, false-negative results can be avoided preventing contaminated food or feed being used or marketed. For confirmatory methods, use of these internal standards is mandatory. For screening methods without control of losses during the analytical procedure, information on correction of losses of compounds and the possible variability of results should be given. Levels of dioxins and dioxin-like PCBs in positive samples (above the level of interest) should be determined by a confirmatory method.

Laboratories

67. Laboratories involved in the analysis of dioxins and dioxin-like PCBs using screening as well as confirmatory methods of analysis should be accredited by a recognized body operating in accordance with ISO/IEC Guide 58:1993 or have quality assurance programmes that address all critical elements of accrediting agencies to ensure that they are applying analytical quality assurance. Accredited laboratories should follow the ISO/IEC/17025:1999 standard "General requirements for the competence of testing and calibration laboratories" or other equivalent standards.

68. The regular participation in interlaboratory studies or proficiency tests for the determination of dioxins and dioxin-like PCBs in the relevant feed and food matrices is recommended according to ISO/IEC/17025: 1999 standard.

QUALITY MANAGEMENT AND EDUCATION

69. Good Agricultural Practices, Good Manufacturing Practices, Good Storage Practices, Good Animal Feeding Practices and Good Laboratory Practices are valuable systems for further reduction of dioxin and dioxin-like PCB contamination in the food chain. Farmers and feed and food manufacturers should consider educating their co-workers on how to prevent contamination by the implementation of control measures.

ANNEX

GLOSSARY OF TERMS
(for the purpose of this code of practice)

Term	Explanation
anticaking agent	substance that reduce the tendency of individual particles of a feed or food to adhere
binder	substance that increase the tendency of individual particles of a feed or food to adhere
coefficient of variation	statistical parameter expressing: 100 x standard deviation of a set of values/mean value of set
confirmatory method of analysis	method of analysis with high quality parameters capable to confirm analytical results produced from screening methods with lower quality parameters
congener	one of two or more compounds of the same kind with respect to classification
dioxins (PCDD/PCDF)	Includes 7 polychlorinated dibenzo-p-dioxins (PCDDs) and 10 dibenzofurans (PCDFs) that have dioxin-like activity which belong to a group of lipophilic and persistent organic substances. Depending on the degree of chlorination (1–8 chlorine atoms) and the substitution patterns, 75 different PCDDs and 135 different PCDFs ("congeners"), can be distinguished.
dioxin-like PCBs	Includes 12 non-ortho and mono-ortho substituted polychlorinated biphenyls (PCBs) showing toxicological properties (dioxin-like activity) that are similar to dioxins (25)
fish	cold-blooded vertebrate animals including Pisces, Elasmobranches and Cyclostomes. For the purpose of this code of practice, molluscs and crustaceans are also included (41).
feed	any single or multiple materials, whether processed, semi-processed or raw which is intended to be fed directly to food producing animals (27)

Term	Explanation
food	any substance, whether processed, semi-processed or raw which is intended for direct human consumption, and includes drink, chewing gum and any substance which has been used in the manufacture, preparation or treatment of "food" but does not include cosmetics or tobacco or substances used only as drugs.
feed or food ingredient	a component or constituent of any combination or mixture making up a feed or food, whether or not it has a nutritional value in the diet, including additives. Ingredients are of plant, animal or aquatic origin, or other organic or inorganic substances.
guideline levels	not statutory but recommended maximum levels
HACCP	Hazard Analysis Critical Control Point (HACCP) is a system that identifies, evaluates and controls hazards which are significant for food safety
limit of quantification (LOQ) (valid for dioxins and dioxin-like PCBs only)	the limit of quantification of an individual congener is the concentration of an analyte in the extract of a sample which produces an instrumental response at two different ions to be monitored with an S/N (signal/noise) ratio of 3:1 for the less sensitive signal and fulfilment of the basic requirements such as e.g. retention time, isotope ratio according to the determination procedure as described in EPA method 1613 revision B (38, 54).
maximum limits	statutory maximum limits for contaminants
minerals	Inorganic compounds used in food and feed required for normal nutrition or used as processing aids
PCBs	polychlorinated biphenyls belonging to a group of chlorinated hydrocarbons, which are formed by direct chlorination of biphenyl. Depending on the number of chlorine atoms (1 – 10) and their position at the two rings, 209 different compounds ("congeners") are theoretically possible (25).
pelagic fish species	fish species living in free water (e.g., ocean, lake) without contact to the sediment

Term	Explanation
persistent organic pollutant (POP)	chemical substance that persists in the environment, bioaccumulates through the food web, and poses a risk of causing adverse effects to human health and the environment
Stockholm Convention (POPs Convention)	The Stockholm Convention on Persistent Organic Pollutants is a global treaty to protect human health and the environment from persistent organic pollutants (POPs) including dioxins and dioxin-like PCBs and entered into force on 17th May 2004. In implementing the Stockholm Convention governments will take measures to eliminate or reduce the release of POPs into the environment.
screening method of analysis	method of analysis with lower quality parameters to select samples with significant levels of an analyte
trace elements	chemical elements essential for plant, animal and/or human nutrition in small amounts
Toxic Equivalency (TEQ)	relative value calculated by multiplying the concentration of a congener by the toxic equivalency factor (TEF)
WHO- -TEQ	TEQ value for dioxins and dioxin-like PCBs, established by WHO and based on established Toxic Equivalency Factors (TEFs) (37)
Toxic Equivalency Factor (TEF)	Estimates of the toxicity of dioxin-like compounds relative to the toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), which is assigned a TEF of 1.0

CODE OF PRACTICE FOR THE PREVENTION AND REDUCTION OF ETHYL CARBAMATE CONTAMINATION IN STONE FRUIT DISTILLATES

CAC/RCP 70-2011

1. INTRODUCTION

1. Ethyl carbamate is a compound that occurs naturally in fermented foods and alcoholic beverages such as bread, yoghurt, soy sauce, wine, beer, and particularly in stone fruit distillates, mainly those made from cherries, plums, mirabelles and apricots.

2. Ethyl carbamate can be formed from various substances inherent in food and beverages, including hydrogen cyanide (or hydrocyanic acid), urea, citrulline, and other N-carbamyl compounds. Cyanate is probably the ultimate precursor in most cases, reacting with ethanol to form ethyl carbamate. Therefore ethyl carbamate reduction measures should focus on hydrocyanic acid and other precursors of ethyl carbamate.

3. Ethyl carbamate is genotoxic and a multisite carcinogen in animals and is probably carcinogenic to humans.

4. Stone fruit distillates, in particular, contain ethyl carbamate in manyfold higher concentrations than other fermented foods and beverages. In stone fruit distillates ethyl carbamate can be formed from cyanogenic glycosides that are natural constituents of the stones. When mashing the fruit, the stones may be damaged and cyanogenic glycosides from the stones may come into contact with enzymes in the fruit mash. Cyanogenic glycosides are then degraded to hydrocyanic acid/cyanides. Hydrocyanic acid may also be released from intact stones during a prolonged storage of the fermented mash. During the distillation process hydrocyanic acid may be enriched in all fractions. Cyanide in the distillates may be oxidized to cyanate, which can react with ethanol to form ethyl carbamate. Certain environmental conditions such as exposure to light, high temperatures and the presence of copper ions promote the formation of ethyl carbamate in the distillate.

5. Although no strong correlation between the level of hydrocyanic acid and ethyl carbamate has been established so far, it is evident that under certain conditions high concentrations of hydrocyanic acid lead to higher levels of ethyl carbamate. A potential increase in ethyl carbamate formation has been

associated with levels at or above 1 mg/l hydrocyanic acid in the final distillate. Based on practical experiences it can be assumed that from 1 mg of hydrocyanic acid up to 0.4 mg ethyl carbamate potentially can be formed in a non-equimolar relationship.

2. SCOPE AND DEFINITIONS

6. This Code of Practice intends to provide national and local authorities, manufacturers and other relevant bodies with guidance to prevent and/or reduce formation of ethyl carbamate in stone fruit distillates. Ethyl carbamate formation in other alcoholic beverages and foods is not covered in this Code.

7. The definitions below apply to this Code:
   a) **Stone Fruit** means for the purpose of this Code of Practice certain edible fruit of trees belonging to the genus Prunus of the rose family (Rosaceae), i.e. cherry, plum, peach and apricot.
   b) **Distillates** means, for the purpose of this Code of Practice, alcohol-rich products obtained after the distillation process and ready for consumption.
   c) **Stone Fruit distillates** means, for the purpose of this Code of Practice, the distillates for consumption, obtained after the distillation:
      - of the mash prepared by fermentation of crushed stone fruits,
      - of fermented stone fruit marc (pomace),
      - of mash obtained by fermentation and/or maceration of crushed and/or whole stone fruit in ethyl alcohol or alcoholic beverages.

3. GENERAL REMARKS

8. This Code covers all possible measures that have been proven to prevent and/or reduce high levels of ethyl carbamate in stone fruit distillates. When applying the Code for specific stone fruit distillates, measures should be carefully chosen from the viewpoint of benefit and feasibility. In addition, measures should be implemented in accordance with the relevant national and international legislation and standards.

9. It is recognised that reasonably applicable technological measures – Good Manufacturing Practices (GMP) – can be taken to prevent and reduce significantly high ethyl carbamate levels in stone fruit distillates. The reduction of ethyl carbamate could be achieved using two different approaches: first, by reducing the concentration of the main precursor substances (e.g. hydrocyanic acid and cyanides); second, by reducing the tendency of these substances to react to form cyanate.

4. TYPICAL PRODUCTION PROCESS

10. The production process for stone fruit distillates involves preparing mash by using whole stone fruits or their marc as ingredients, followed by fermentation and distillation. The process typically follows the steps listed below:
    a) preparing mash by crushing the whole ripe fruit for stone fruit spirit drinks or by using stone fruit marc for stone fruit marc spirit drinks;
    b) fermenting the mash in stainless steel tanks or other suitable fermentation vessels;
    c) in the case of using a maceration process, the mash is prepared by macerating crushed or whole fruit in ethyl alcohol or alcoholic beverages and stored for a period, without fermentation process;
    d) transferring the fermented mash into the distillation device, often a copper pot;
    e) heating the fermented mash by a suitable heating method in order to slowly boil off the alcohol;
    f) cooling the alcohol vapour in an appropriate (e. g. stainless steel) column where it condenses and is collected;
    g) separation of three different fractions of alcohol: 'heads', 'hearts' and 'tails';
    h) dilution to the final alcoholic grade.

11. During distillation, the heads boil off first. Components with low boiling point e.g. ethyl acetate and acetaldehyde are part of the heads. This fraction is generally unsuitable for consumption and should be discarded.

12. During the middle distillation run (the 'hearts'), the principal alcohol in all spirits, ethyl alcohol (ethanol), is distilled. This part of the distilling run, where the content of volatiles other than ethanol is lowest and the purest fruit aromas are present, is always collected.

13. The 'tails' of the distillation include acetic acid and fusel oils, which are often identified by unpleasant vinegary and vegetal aromas. They are also discarded, but they may be re-distilled because some ethanol is invariably included with the tails.

5. RECOMMENDED PRACTICES BASED ON GMP's

5.1 Raw materials and preparation of fruit mash

14. The raw materials and preparation of the fruit mash should be suitable to avoid the release of hydrocyanic acid, a precursor of ethyl carbamate.

15. The stone fruits should generally be of a high quality, not mechanically damaged and not microbiologically spoiled, as damaged and spoiled fruit may contain more free cyanide.

16. The fruit should preferably be de-stoned.

17. If the fruits are not de-stoned and/or the residues of fruits (marc) are used for preparing mash, they should be mashed gently avoiding the crushing of stones. If possible, stones should be removed from the mash.

5.2 Fermentation

18. Selected yeast preparations for the production of spirit drinks should be added to the mashed fruits, according to the manufacture's instructions for users, for a fast and "clean" fermentation.

19. Mashed fermented fruits should be handled with high standards of hygiene, and exposure to light should be minimised. Fermented fruit mashes containing stones should be stored as briefly as possible before distillation since hydrocyanic acid may also be released from intact stones during prolonged storage.

20. If the mash is prepared by macerating stone fruit into alcoholic beverages or ethyl alcohol, the stone fruit should be removed soon after the aroma of the stone fruit is adequately extracted.

5.3 Distillation equipment

21. Distillation equipment and the distillation process should be suitable, to ensure that hydrocyanic acid is not transferred into the distillate.
    a) Use of a copper still will limit carryover of ethyl carbamate–forming precursors into the distillate.
    b) The distillation equipment should preferably include automatic rinsing devices and copper catalytic converters. The automatic rinsing devices will keep the copper stills cleaned while the copper catalytic converters will bind hydrocyanic acid before it passes into the distillate.
    c) Automatic rinsing devices are not necessary in the case of discontinuous distillation. The distillation equipment should be cleaned by systematic and thorough cleaning procedures.
    d) When copper catalytic converters or other dedicated cyanide separators are not available, copper (I) chloride preparations can be added to the fermented fruit mash before distillation. The purpose of these preparations containing copper (I) ions is to bind hydrocyanic acid before it passes into the distillate. Copper (II) ions are without effect and should not be used.

22. While copper ions can inhibit formation of ethyl carbamate precursors in the mash and in the still, they can promote formation of ethyl carbamate in the distillate. Therefore, use of a stainless steel condenser at the end of the distillation device rather than a copper condenser will limit presence of copper in the distillate and reduce the rate of ethyl carbamate formation.

5.4 Distillation process

23. Stones settled in the fermented mash should not be pumped into the distillation device.

24. Distillation should be carried out in such a way that alcohol is boiled off slowly and in a controlled manner (e.g. by using steam instead of a direct flame as the heating source).

25. The first fractions of the distillate, called 'heads', should be separated carefully.

26. The middle fraction, called 'hearts', should then be collected and should be stored in the dark. When the alcohol content of the actual distillate reaches 50% vol. at the receiver, collection should be switched to the 'tails', so that any ethyl carbamate that may have been formed is separated in the tail fraction.

27. Some manufacturers may redistill the separated tails, possibly containing ethyl carbamate. If the tails are used for re-distilling, they should be re-distilled separately, however for reduction of ethyl carbamate concentration it is preferable to discard the tail.

5.5 Checks on the distillate, re-distillation and storage

5.5.1 Hydrocyanic acid

28. Testing for hydrocyanic acid may be used as a simple test for ethyl carbamate in distillates. Therefore, the distillates should be regularly checked for their levels of hydrocyanic acid. The determination could be carried out by specific tests including kits for rapid testing of the hydrocyanic acid levels.

29. If the concentration of hydrocyanic acid in the distillate exceeds a level of 1 mg/l, re-distillation with catalytic converters or copper preparations is recommended.

30. Distillates should be stored in bottles that are lightproof (or filter ultraviolet light) or in covering boxes and not at higher temperatures.

5.5.2 Ethyl carbamate

31. Testing of ethyl carbamate is recommended for distillates in which the compound may already have been formed (e.g. distillates with unknown history of production, distillates with higher levels of hydrocyanic acid, or storage at light or at high temperatures).

32. Additional distillation is effective in order to reduce ethyl carbamate in distillates.

6. GENERAL RECOMMENDATIONS

33. The national, state and local governments as well as the non-governmental organizations (NGOs, commercial associations and cooperatives) should provide their own basic training and update the information on mitigating ethyl carbamate in stone fruit distillates.

34. The non-industrial, small-scale preparation of these drinks should have available material with information on the specific recommendations based on good manufacturing practices and guidance on prevention and reduction of ethyl carbamate in the stone fruit distillates. Specifically, material should be made available to small-scale producers of stone fruit distillates.

CODE OF PRACTICE FOR THE REDUCTION OF 3-MONOCHLOROPROPANE-1,2-DIOL (3-MCPD) DURING THE PRODUCTION OF ACID-HYDROLYZED VEGETABLE PROTEIN (ACID-HVPs) AND PRODUCTS THAT CONTAIN ACID-HVPs

CAC/RCP 64-2008

INTRODUCTION

1. 3-Monochloropropane-1,2-diol (3-MCPD) is one of a series of compounds referred to as chloropropanols. These compounds are contaminants that are formed during the processing and manufacture of certain foods and ingredients. They were originally discovered in acid hydrolysed vegetable protein (acid-HVP) in the 1980s. Subsequent research in the 1990s revealed their presence in soy sauces manufactured using acid-HVP as an ingredient.

2. Acid-HVPs are produced *via* the hydrolysis of various proteinaceous vegetable and animal materials with hydrochloric acid. They are used widely as flavour enhancers and as ingredients in processed savoury food products and pre-prepared meals. Typical levels in foods range from *ca*. 0.1 to 20%.

3. The occurrence of chloropropanols in acid-HVP arises from their formation during the hydrochloric acid mediated hydrolysis step of the manufacturing process. During this hydrolytic stage the acid also reacts with residual lipids and phospholipids present in the raw material, resulting in the formation of chloropropanols. It has been industry experience that chloropropanol formation cannot be avoided through the use of defatted protein sources.

4. In addition to formation of chloropropanols during the manufacture of acid-HVP for use as an ingredient, chloropropanols may also be formed in those soy sauces, and related condiments, where the manufacturing process of the sauce itself includes hydrochloric acid treatment of soybean meal. As with acid-HVP the mode of formation also involves acidic hydrolysis of residual lipids and phospholipids.

5. A range of techniques may be employed in the manufacture of soy sauces. Generally, products made exclusively by means of fermentation do not contain chloropropanols, or, if present, they only occur in trace amounts. It is those products that utilise acid-HVP as an ingredient that may contain chloropropanols. Soy sauces, and related products, that are subject to acid treatment during manufacture may also contain chloropropanols.

Adopted 2008.

6. Generally, 3-MCPD is the most widely occurring chloropropanol in foods that contain acid-HVP. It is present as a racemic mixture of (*R*) and (*S*) isomers in protein hydrosylates. Other chloropropanols that can occur, albeit usually in smaller amounts, are 2-monochloropropane-1,3-diol (2-MCPD), 1,3-dichloro-2-propanol (1,3-DCP) and 2,3-dichloro-1-propanol (2,3-DCP).

7. The presence of chloropropanols in food is of concern owing to their toxicological properties. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) considered 3-MCPD and 1,3-DCP in June 2001 and assigned a provisional maximum tolerable daily intake (PMTDI) for 3-MCPD of 2 µg/kg bw/day. The Committee re-evaluated chloropropanols in June 2006 and decided to retain the previously established PMTDI. On evaluating 3-MCPD, the Committee commented that reduction in the concentration of 3-MCPD in soy sauce and related products made with acid-HVP could substantially reduce the intake of this contaminant by consumers of these condiments.

8. Different regional markets may require products with different organoleptic qualities to accommodate specific regional tastes. The individual approaches and combinations thereof, outlined later in this document, to minimise levels of 3-MCPD will have different effects on the organoleptic qualities of the final product and as such, manufacturers should take these effects into account when selecting a strategy to minimise 3-MCPD formation. Whilst it is technically possible to reduce 3-MCPD levels to below 0.1 mg/kg, the organoleptic qualities of such products may be adversely affected as the flavour and taste (umami) directly reflect the quality of the acid-HVP. This is particularly true in aged acid-HVP products.

9. Manufacturers have implemented measures to reduce the levels of chloropropanols in acid-HVPs and related products. Details of the general procedures used to manufacture acid-HVPs with low levels of chloropropanols are given in the following section. Some manufacturers undertook reformulation of their products during the early 1990s so that the effects of changes in organoleptic properties experienced when using the improved methods of manufacture could be minimised. Other production processes resulted in products with lower levels of chloropropanols whilst minimising the effect on organoleptic properties. Implementing manufacturing procedures to reduce 3-MCPD in acid-HVP to low levels can be technically difficult and very expensive, often with new equipment being required. Reformulation of the recipes for processed foods made using aicd-HVP may also be necessary.

10. Chloropropanols have also been detected in a range of other foods that are not subject to acid hydrolysis during manufacture. These foods include processed fruits and vegetables, cereals and bakery products, processed meats, smoked fish and beer.

SCOPE

11. The purpose of this Code of Practice is to describe and disseminate best practice for the manufacture of acid-HVP and soy sauces and related condiments, whose production involves acid hydrolysis, with the aim of facilitating a reduction in the levels of 3-MCPD. Food ingredients produced using methods that do not involve acid hydrolysis of vegetable proteins are not covered by this Code of Practice.

RECOMMENDED PRACTICES BASED ON GOOD MANUFACTURING PRACTICE (GMP)

Acid-HVPs

12. The manufacturing process for acid-HVPs will vary depending on the desired organoleptic properties of the end product. The source of the raw material, molarity of the acid, temperature of the reaction, time of the reaction and other factors can all affect the organoleptic properties of the final product. A generalised description of the acid-HVP manufacturing process can be given (see fig. in Annex). Common vegetable raw materials used in the production of acid-HVP include defatted oil seeds (soy and peanut), and protein from corn maize, wheat, casein, yeast and rice. These are hydrolysed with hydrochloric acid ranging from below 4 M to 9 M, at a temperature between 70 °C and 135 °C for up to 8 hours, although times of up to 20–35 hours have been reported, at pressures usually greater than atmospheric pressure. After cooling, the hydrolysate is neutralised with either sodium carbonate or sodium hydroxide to a pH of 5 to 9 at a temperature between 90 to 100 °C for 90 to 180 minutes and then hydrochloric acid is added to the mixture to adjust the pH to between 4.8 and 5.2. The hydrolysate is filtered to remove the insoluble carbohydrate fraction (humin) and then bleached or refined. Activated carbon treatment can be employed to remove both flavour and colour components, to the required specification. Following further filtration, the acid-HVP may, depending upon the application, be fortified with additional flavouring components. Thereafter, the product can be stored as a liquid at 30–50% dry matter (corresponding to 2–3% total nitrogen), or alternatively it may be vacuum dried, spray-dried, or steamed and stored as a solid (97–98% dry matter).

Methods that can be employed to reduce the levels of 3-MPCD in acid-HVP

13. Three main approaches may be adopted to minimise the concentration of 3-MCPD in the final product. The first of these involves careful control of the acid hydrolysis step; the second, subsequent neutralisation to minimise 3-MCPD formation; and the third employs the use of sulfuric acid as a substitute for hydrochloric acid in the hydrolysis step. These methods can reduce the levels of 3-MCPD in acid-HVPs.

14. Manufacturers should consider the three options below and decide which are most suitable for their method of acid-HVP production. The three approaches are detailed in the following paragraphs, with specific examples given. These approaches are based on a limited amount of information that is available in the public domain; therefore, it has not been possible to provide a full account of how to manufacture low 3-MCPD acid-HVP. The information that follows is general advice; at the national level, manufacturers may need to adjust the measures in their own production processes.

15. With regard to the first strategy, the temperature and the heating time of the acid hydrolysis step must be simultaneously controlled and careful attention paid to the reaction conditions in the subsequent neutralisation step. Typically, the hydrolysis reaction is initially carried out at a temperature between 60 and 95 °C for up to 150 minutes. The temperature of the reaction is then increased gradually until a temperature of 103–110 °C is attained. Once this maximum temperature is reached, it should be maintained for 2–35 hours and then the resulting hydrolysate cooled over 3 hours, neutralised and filtered. Careful control of the acid hydrolysis step has been shown to reduce levels of 3-MCPD in the hydrolysate to below 10 mg/kg.

16. 3-MCPD that is formed during the acid hydrolysis step may be removed by a secondary alkaline hydrolysis. This alkaline treatment is, in essence, an extension of the neutralisation process that follows acid hydrolysis of the starting material; it causes degradation of the chloropropanols present in the hydrolysate. The alkaline treatment can be performed before or after filtration of the hydrolysate, although alkaline treatment is preferable before filtration because the residue will also then be free of 3-MCPD. The hydrolysed protein is treated with food-acceptable alkali such as potassium hydroxide, sodium hydroxide, ammonium hydroxide or sodium carbonate to increase the pH to 8–13. This mixture is then heated in the range 110–140 °C for up to 5 minutes, other reported conditions involved heating in the range 60–100 °C for 90–900 minutes. Generally, alkaline treatments at higher pH and temperature will

require shorter processing times. After cooling, the pH of the resulting hydrolysate should be alkaline (ideally above pH 8 at 25 °C); if the pH is lower, the treatment was most probably not effective and corrective measures should be taken. Following alkaline treatment, the pH of the hydrolysed protein is readjusted to a pH of 4.8–5.5 using a suitable acid (e.g. hydrochloric acid) at a temperature of 10–50 °C. The hydrolysate may now be filtered to remove any insoluble residues and the final product obtained. Use of an alkaline treatment when manufacturing acid-HVP has been shown to yield a final product with 3-MCPD levels below 1 mg/kg. It should be noted that a harsh alkaline treatment will reduce the organoleptic qualities of the final products; therefore, it is advised to start the alkaline treatment with a hydrolysate with low levels of 3-MCPD, which can be achieved through careful control of the acid hydrolysis step. Of course, it is important to pay attention to possible recontamination if secondary alkaline hydrolysis is used to further reduce the 3-MCPD content of acid-HVP produced by careful control of the acid hydrolysis step. The alkali treated hydrolysate (with low levels of 3-MCPD) must be kept away from equipment (e.g. reaction vessels, pipes, pumps and filter presses) that is used when performing the initial acid hydrolysis step.

17. It is possible to manufacture acid-HVP using sulfuric acid, thus eliminating the presence of chloride ions that lead to the formation of 3-MCPD. Soybean meal and sulfuric acid are mixed together for 8 hours at a pressure of 10 psi. The resulting hydrolysate is neutralised and the final product is filtered and washed. The diminished organoleptic properties of sulfuric acid-HVP are improved by combination of the final product with flavourings (e.g. monosodium glutamate, caramel, disodium inosinate, disodium guanylate and lactic acid).

Soy sauces and related products

18. A number of different manufacturing processes are employed in the production of soy sauces and the method used will impact on whether the product contains 3-MCPD.

Soy sauces produced by fermentation

19. Soy sauces that are produced solely by fermentation contain non-quantifiable or, in rare cases, extremely low levels of 3-MCPD. Soybeans (whole or defatted) and other cereal grains such as wheat are the main ingredients used for naturally fermented soy sauce. At the start of the process these materials are pre-cooked, mixed and inoculated with *Aspergillus oryzae* and/or *Aspergillus sojae*. After incubation for 1 to 3 days, at 25–30 °C, salt water is added and the mixture is fermented and aged at a temperature below 40 °C for not less than

90 days. Short-term fermented soy sauce is produced in a similar manner except that the salt water fermentation/ageing stage takes place at or above 40 °C and the process is completed within 90 days.

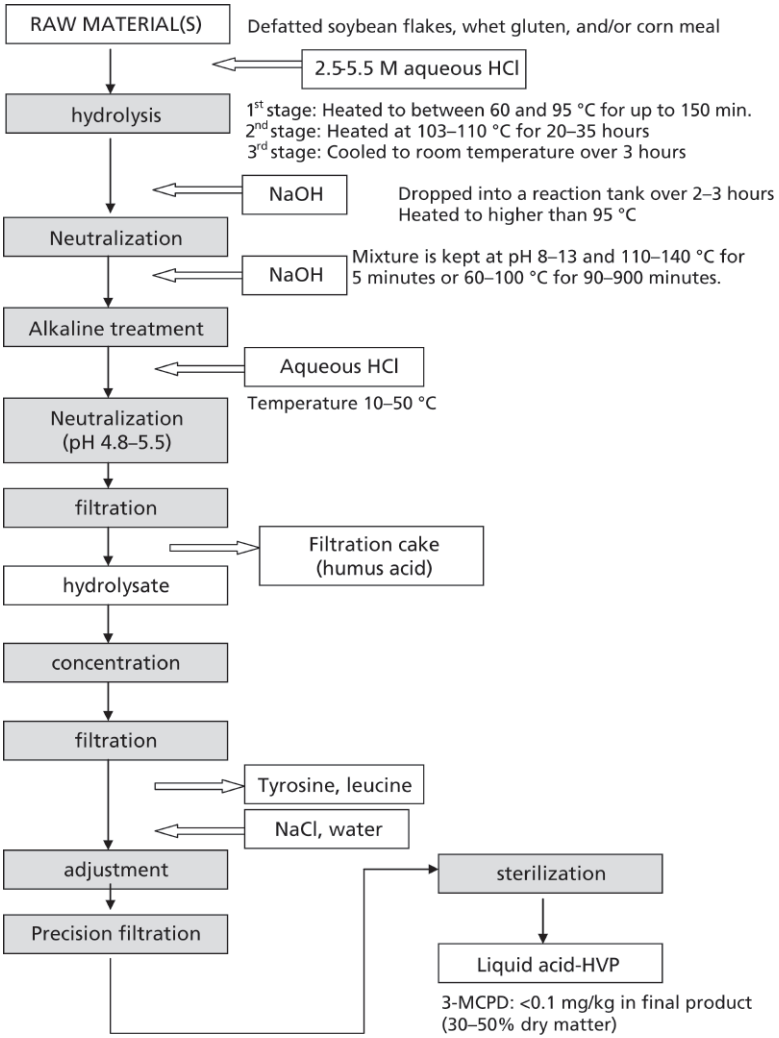
Soy sauces whose manufacture involves an acid treatment stage

20. Alternatively, soy sauces may be manufactured using acid-HVP and other ingredients such as sugars and salt. These products may contain 3-MCPD and measures to prevent its occurrence are described above for acid-HVP. Use of these processes will yield products with low levels of 3-MCPD.

21. A further manufacturing technique involves mixing fermented soy sauces with those derived from acid-HVP. Manufacture of some products involves ageing after mixing. Such products (commonly known as semi-chemical soy sauces) may also contain 3-MCPD and appropriate measures to minimise its presence in the acid-HVP are described earlier.

ANNEX

MANUFACTURING PROCESS OF ACID-HVP AT COMMERCIAL SCALE



CODE OF PRACTICE FOR THE REDUCTION OF CONTAMINATION OF FOOD WITH POLYCYCLIC AROMATIC HYDROCARBONS (PAH) FROM SMOKING AND DIRECT DRYING PROCESSES

CAC/RCP 68-2009

INTRODUCTION

1. Many chemical contaminants are formed during the combustion of fuel both in the smoking and in the direct drying process. Examples include polycyclic aromatic hydrocarbons (PAH), dioxins, formaldehyde, nitrogen and sulphur oxides (relevant for formation of e.g. nitrosamines). Furthermore, heavy metals are also found in combustion gases. The types and amount of contaminants depend on the fuel used, the temperature and possible other parameters.

2. Hundreds of individual PAH may be formed and released as a result of incomplete combustion or pyrolysis of organic matter, during forest fires and volcanic eruptions as well as industrial processes or other human activities, including the processing and preparation of food. Owing to their mode of formation, PAH are ubiquitous in the environment and therefore enter the food chain, especially via air and soil. PAH can be present in the raw materials due to environmental contamination from the air by deposition on crops, from contaminated soils and transfer from water to fresh and marine invertebrates. Commercial and domestic food preparation such as smoking, drying, roasting, baking, barbecuing or frying are recognized as important sources of food contamination. Presence of PAH in vegetable oils can also originate from smoking and drying processes used to dry oil seeds prior to oil extraction.

3. Contamination of food with PAH via environmental contamination should be controlled either by source-directed measures like filtering the smoke from relevant industries (e.g. cement work, incinerator and metallurgy) and limiting the exhaust fumes of PAH from cars. Good practices, including the selection of appropriate farmland/fishing waters, could also decrease the environmental contamination of raw materials with PAH. However, this contribution to the reduction of PAH intake from the final food is not included in this Code of Practice.

Adopted 2009. Revised 2009.

4. Processes such as smoking and direct drying provide a wide variety of food textures and flavours and consequently a broader choice for consumers. Many types of smoked and dried foods are traditional food items, where these types of processes have been used to prolong the storage period, keep quality and provide flavour and consistency required by consumers. The extension of shelf life may also have an effect on the nutritional value of foodstuffs, such as preservation of the vitamin content.

5. The major contributors to intakes of PAH are cereals and cereal products (owing to high consumption in the diets) and vegetable fats and oils (owing to higher concentrations of PAH in this food group). Generally, despite their usually higher concentration of PAH, smoked fish and meats and barbecued foods do not contribute significantly, particularly as they are small components of the diet. However, they do make larger contributions leading to higher PAH intakes where these foods make up a large part of the diet.

6. In its opinion on PAH, JECFA recommended that efforts should be made to reduce contamination with PAH during drying and smoking processes, e.g. by replacing direct smoking (with smoke developed in the smoking chamber, traditionally in smokehouses) with indirect smoking.

OBJECTIVES

7. This Code of Practice intends to provide guidance for national authorities and manufactures to prevent and reduce contamination of food with PAH in commercial smoking and direct drying processes. For this purpose, this Code of Practice identifies important points to consider and provides relevant recommendations. The smoking and direct drying processes are used both in industry and in private households. Food is often smoked by consumers using a direct smoking process, while drying can be done either directly or indirectly, e.g. in the sun or in a microwave oven. The Code of Practice and the guidance could also be used as the basis for information to consumers.

8. The Code of Practice recognizes the benefits of smoking and drying including the availability of traditional smoked food products, prevention of spoilage and microbiological contamination and growth, and the potential for lowering the risks to human health from PAH formed in foods during processing.

SCOPE

9. The scope of this Code of Practice is PAH contamination during commercial smoking, both direct and indirect, and direct drying processes.

10. The Code of Practice does not cover PAH contamination in food originating from
    a) Use of herbs and spices in the smoking process[1];
    b) Indirect drying;
    c) Other food processes, including barbecuing and other types of cooking in private homes or the catering sector; and
    d) Environmental contamination of raw materials.

11. This Code of Practice covers contamination with PAH only. It should, however, be emphasized that conditions that lead to a reduction of one contaminant might lead to increases in the levels of other contaminants or could lower the microbiological safety of the food products. The possible interplay among levels of contaminants like PAH, heterocyclic amines, and nitrosamines is not always well understood, but these contaminants can be food safety problems, either as such or due to the reaction with food components. This is the case of nitrogen oxide reaction with components in the food leading to the formation of nitrosamines. It should be underlined that any guidance given to reduce PAH levels in a final product should not lead to an increased risk to human health due to increases in other contaminants or to reduced microbiological safety.

DEFINITIONS

12. Contaminant is defined as any substance not intentionally added to food, which is present in such food as a result of the production (including operations carried out in crop husbandry, animal husbandry and veterinary medicine), manufacture, processing, preparation, treatment, packing, packaging, transport or holding of such food or as a result of environmental contamination. The term does not include insect fragments, rodent hairs and other extraneous matter.

[1] In the *smoking process*, the fuel used is often various wood species, in some cases with herbs and spices, e.g. juniper berries, to give a characteristic flavour. Such herbs and spices may be a potential source for PAH contamination. However, many different types of herbs and spices can be used, but normally only in smaller quantities and knowledge about the influence of using herbs and spices is limited. Their use is therefore not considered in this Code of Practice.

13. Drying direct refers to two types of drying processes: One is a drying process where the combustion gas is used directly as the drying gas in contact with the foods and the other is sun drying.

14. Sun drying is a direct drying process where sunshine and wind are used for drying under circumstances open to the environment.

15. Drying, indirect is a drying process where the combustion gasses do not come into direct contact with the foods, where the hot air is heated via a heat exchanger, electricity or by other means.

16. HACCP: A system which identifies, evaluates, and controls hazards which are significant for food safety.

17. *Plant materials*, *other* is covering other types of fuels than woods used in the smoking or drying process, e.g. bagasse, corn cobs and coconut husk and shell.

18. *Polycyclic aromatic hydrocarbons* (PAH) are a group of contaminants that constitute a large class of organic compounds containing two or more fused aromatic rings made up of carbon and hydrogen atoms.

19. *Pyrolysis* is the chemical decomposition of organic materials by heating in the absence of oxygen or any other reagents, except possibly steam.

20. *Smoke* consists of liquid and solid particulates suspended in a gaseous phase. Particles in the smoke, generally of a size of 0.2–0.4 μm (or as low as 0.05 to 1 μm), are estimated to constitute 90% of its overall weight. The chemical composition of smoke is complex and more than 300 components have been identified.

21. *Smoke condensates* are products obtained by controlled thermal degradation of wood in a limited supply of oxygen (pyrolysis), subsequent condensation of the resulting smoke vapours, and fractionation of the resulting liquid products.

22. *Smoking* of food is a process used as a preservation method to prolong the shelf life of food due to components of the smoke inhibiting growth of some microorganisms. The smoking process is furthermore used to achieve the characteristic taste and appearance of smoked food.

23. *Smoking, direct* is a smoking process, where the smoke is developed in the chamber in which the food is processed.

24. *Smoking indirect* is a process where smoke generators are used, and the smoke is being developed in a chamber, separate from where the food is smoked. The smoke may be cleaned in various ways, e.g. by use of a water filter or a tar condenser before being fed into the smoke chamber.

GENERAL PRINCIPLES FOR REDUCING PAH CONTAMINATION IN FOOD

25. The food producer should be aware of the conditions under which higher levels of PAH are generated and wherever possible, should control those conditions to minimize their formation. To accomplish this, an analysis of important points to consider in processes used or intended to be used in food production with smoking or direct drying should be carried out.

26. The first step of the analysis is to identify important points to consider. Possible major important points to consider are described later in the code.

27. The producer should evaluate the identified important points to consider such as:
    a) Possible sources of PAH from the environment and the process;
    b) Possible effects on consumer health;
    c) Controllability; and
    b) Possible measures to reduce PAH contamination.

28. The producer should take appropriate measures to control the identified important points for reducing PAH, based on the results of the analysis and other legitimate factors relevant for human health protection and economic activities such as
    a) The microbiological status and possible risks from other contaminants;
    b) The organoleptic properties and quality of the final product (the ideal method would have no adverse effects on the appearance, flavour, taste or nutritional properties of the product); and
    c) Feasibility and effectiveness of controls (cost, commercial availability, occupational hazards).

29. The producer should monitor the effects of the implemented measures and should review them if necessary.

EVALUATION OF COMPLIANCE WITH RELEVANT LEGISLATION

30. Processed food shall be in compliance with relevant national or international legislation and standards, including general requirements for consumer protection. Furthermore, food shall be produced in accordance with relevant Codex or national codes of practice. Some of these may contain further information about drying or smoking, which should also be considered.

GENERAL REMARKS ON SMOKING AND DIRECT DRYING PROCESSES

31. The formation of PAH during smoking and direct drying is dependent on a number of variables, including:
    a) Fuel (woods and other plant materials, diesel, gases, liquid/solid waste and other fuels);
    b) Smoking or drying method (direct or indirect);
    c) Smoke generation process in relation to the temperature of pyrolysis and to airflow in the case of a smoke generator (friction, smouldering, thermostated plates) or in relation with other methods such as direct smoking or regenerated smoke by atomizing smoke condensate (liquid smoke);
    d) The distance between the food and the heat source;
    e) Position of the food in relation to the heat source;
    f) Fat content of the food and what happens to it during processing;
    g) Duration of smoking and direct drying;
    h) Temperature during smoking and direct drying;
    i) Cleanliness and maintenance of equipment;
    j) Design of the smoking chamber and the equipment used for smoke/air mixture (which influences the smoke density in the smoking chamber).

32. In general, changes in processing techniques can in some cases reduce the amount of PAH formed during processing. Indirect drying or smoking processes result in lower PAH contents than direct drying or smoking. Also the use of smoke condensates, selection of fuel such as wood species and adjusting times and processing temperatures influences the PAH formation. Addition of activated carbon to coconut oil at the right dosage during the refining process can completely remove PAH contamination.

33. Application of an HACCP system in accordance with the principles and steps as recommended by Codex is one of options for reducing PAH.

SMOKING

34. Smoking techniques have been used for centuries as a method for preserving meat and fish. Smoking impregnates the high-protein food with aromatic components, which lend flavour and colour to the food, and also play a bacteriostatic and antioxidant role.

Fuel used in smoking

35. For smoking of food, woods are normally used, but other types of fuels like bagasse (plant material from sugarcane), corn cob and coconut husk and shell are used. The fuel used is an important point to consider for the potential contaminants of the food, e.g. the PAH contamination of food differs if wood or straw is used. PAH contamination of oil seed is higher when using coconut husk compared to coconut shell as fuel due to the higher lignin content of the husk.

36. The wood species used have an influence on PAH formation. However, it has not been possible to find generally accepted recommendations on the use of wood species or other plant materials. Therefore, it is recommended, that the individual species of woods and other plant materials used in smoking processes should be evaluated in relation to PAH formation before use. Also, the wood to be used in the process of smoking should preferably not be resinous.

37. The use of other fuels than wood and other plant materials for the purpose of smoking foodstuffs should be discouraged. Fuels like diesel oil, rubber (e.g. tyres) or waste oil must not be used even as a partial component, as they may lead to significantly increased PAH levels. Woods treated with chemicals such as for preserving, waterproofing, fireproofing etc. should not be used for smoking or the production of smoke condensates. Such treatments may result in tainting of the food as well as the introduction of other contaminants, e.g. dioxin from woods treated with pentachlorophenol (PCP).

Foodstuffs smoked

38. The position of the food in the smoke chamber and the distance between the food and the heat source is an important point to consider in the smoking process. As PAH are particle bound, a greater distance from the smoke source to the smoked food might reduce content of PAH in the food.

39. During direct smoking, fat dripping from the food into the source of the smoke, e.g. glowing wood or other plant materials might increase the content of PAH in the smoke and thereby in the smoked food. In order to avoid an increase in the PAH content through fat drippings into the open fire, perforated metal sheets can be installed between the food to be smoked and the heat source.

40. The microbiological quality of the final food product must be evaluated to ensure that there is no potential growth of pathogens during processing and in the final food.

41. The organoleptic properties of the final products are an essential part of their characteristics. Changes of methods might not necessarily result in organoleptically acceptable products.

Processing

42. Four types of smoking processes are generally recognized: smouldering, thermostated plates, friction processes, and smoking with smoke condensates. Friction processes allow smoke to be produced by pyrolysis of wood sawdust, wood chips, and wood logs, respectively. Smoke condensates may be used by exposing food to smoke which is reproduced or regenerated by atomizing smoke condensate (liquid smoke) in a smoking chamber.

43. Smoke is produced by pyrolysis of the fuel at temperatures of around 300-450 °C in the glow zone. To produce smoke for smoking food, flames should be avoided, including by adjusting airflow.

44. Differences in the smoking processes can lead to highly variable PAH levels in the final food product. The choice of technology for processing is very important for the final concentration of PAH. Identifying the parameters critical for PAH formation in a specific process may potentially be useful to control PAH levels. Direct smoking requires less equipment than indirect smoking but can result in higher levels of PAH in the final food product.

45. Replacing direct smoking with indirect smoking can significantly reduce contamination of smoked foods. In modern industrial kilns, an external smoke generator can be operated automatically under controlled conditions, to wash the smoke from particles before coming in contact with the food and to regulate its flow as it is brought into contact with the food. For more traditional or smaller scale operations, this may not, however, be an option.

46. Smoking processes are often divided into three groups depending on the temperatures used in the smoke chamber during processes:
    a) *Cold* smoking with temperature of approximately 18–25 °C. Used for e.g. some fish species and salami-type sausages;
    b) *Semi-warm* smoking with temperatures of approximately 30–40 °C. Used for e.g. some fish species, bacon and pork loin;
    c) *Warm (or hot) smoking* is smoking combined with heating resulting in a temperature of approximately 70–90 °C. Used for e.g. some fish species, hams, and frankfurter type sausages.

47. The type of generator used should be based on an assessment of possible reduction of the PAH content in the final food and where possible include washing of the smoke after the generator and before the smoke chamber. Good results are achieved by installing baffles after the smoke generator equipped with a device for decantation of tar. A more efficient way is to manage the pyrolysis temperature and decanting of heavy phase tanks to a cooling device with baffles. The scientific background and data to illustrate the exact influence of the use of different types of fuel, time, temperature etc. is limited and specific testing is needed for the identification of important points to consider in the individual processes. Also other methods like use of long pipes in the equipment can reduce the PAH.

48. As PAH are particulate bound, a filter may be used to remove particulate material from the smoke. This should reduce potential contamination with PAH.

49. Oxygen needs to be balanced as both too much and too little oxygen produces PAH. Adequate oxygen is needed to ensure partial/incomplete combustion of the fuel. However, too much oxygen may raise the temperature in the glow zone and lead to increased formation of PAH. A lack of oxygen may lead to the formation of more PAH in the smoke, as well as producing carbon monoxide, which may be hazardous to operators.

50. Temperature is of importance for the partial/incomplete combustion of the fuel. Generally, PAH formation increases with increasing temperature. The composition of the smoke depends on the temperature, which should be adjusted to minimize PAH formation. However, more data is needed to document which temperatures would be recommendable.

51. In principle, the smoking time should be as short as possible to minimize the exposure of the food surfaces to PAH-bearing smoke. However, in the case of hot smoking, when the product is being cooked at the same time, it will be essential to allow sufficient time for the product to be cooked thoroughly. In case hot smoke is the only heat source (traditional smoke houses), the smoking chamber should be heated before the food products are placed into the smoking chamber. Smoking time is not an important parameter as long as the source for smoke is well managed. Moreover, short smoking times may have an impact on food safety and shelf life. Clearly preventive measures cannot be taken in isolation from other considerations and it is vital that they do not adversely impact on the sensory properties and consumer acceptance of the product. Additionally, microbiological stability and nutritional properties need to remain unimpaired and care needs to be taken to ensure that other contaminants are not inadvertently introduced.

52. Because smoke condensates are produced from smoke that is subjected to fractionation and purification, products made with condensed smoke generally have lower PAH levels than products made with freshly generated smoke.

Post smoking treatment

53. There are three types of cleaning steps to be used either during processing or as post process treatment:
    a) During the process smoke may be washed before it enters the smoking chamber. This can be achieved by washing (scrubbing), using a tar condenser, cooling or filtering all of which can remove particle-bound PAH from the smoke;
    b) Post smoking treatment involves the cleaning of the smoked product itself. In this case rinsing the product or immersing it into water may remove soot and particles containing PAH on the surface of the food. This type of cleaning would not be possible to use for all types of products, e.g. not for smoked fish and fishery products;
    c) The shaving off the surface of the smoked product itself. In case of solid smoked food e.g. smoked-dried bonito (i.e. *katsuobushi*, traditional Japanese food), this can reduce PAH in the final product.

54. When possible, washing or water-cooling of smoke should be used to reduce the content of PAH in the final food. Water-cooling is already used in the meat industry. Washing the product after the process may remove PAH-containing particles from the surface of the product.

55. Washing of the product should not be used for fishery products as it could result in lower organoleptic quality and increased microbiological risk. Fish products are often smoked as the whole fish with the skin, and if the skin is not eaten, some contamination is removed together with the skin. The recommendation could be to prioritize smoking of fish with skin and, preferably, removing the skin before consumption.

IMPORTANT POINTS TO CONSIDER AND RECOMMENDATIONS ON SMOKING

56. PAH content of smoked foods can be minimized by identifying and evaluating the important points to consider mentioned below, and by taking appropriate measures. An HACCP system might be applied.

57. Fuel:
    a) The type and composition of wood used to smoke foods, including age and lignin content in the wood used. In general, conifer woods containing higher lignin contents should be avoided;
    b) Monitor the water content of the fuel. Lower water content may lead to rapid burning of fuel and higher PAH levels;
    c) When individual species of woods and other types of plant materials like bagasse (from sugarcane), corn cob and coconut husk and shell are used, their use should be evaluated in light of PAH contamination;
    d) Do not use woods treated with chemicals;
    e) The use of other fuels than woods and plant materials: Do not use diesel fuel, waste products, especially rubber tyres and waste oil which may already contain significant levels of PAH;
    f) Influence on the taste of the final food.

58. Smoke developed and used in the process:
    a) The composition of the smoke depending of e.g. the type of wood or other plant materials, the amount of oxygen present and the temperature of pyrolysis and possibly the length of time for which the plant materials are burned;
    b) The design of the smoking chamber and of the equipment used for smoke/air mixture (e.g. length of the pipe in the equipment);
    c) Filtering or cooling the smoke where possible;
    d) Washing off the smoke between a smoke generator and the smoke chamber where possible;
    e) Install baffles after the smoke generator equipped with a device for decantation of tar if possible;

59. Foodstuffs smoked:
    a) The position of the food in the smoke chamber and the distance between the food and the smoke source;
    b) Chemical properties and composition of food, e.g. the fat content of the food to be smoked;
    c) Deposits of smoke particles on the surface and the suitability of the surface for human consumption. For fish, the recommendation could be to prioritize smoking of fish with skin;
    d) The microbiological quality after processing;
    e) The organoleptic properties of the final food.

60. Smoking process:
    a) Whether the smoking process is a direct or indirect process. Replace direct smoking with indirect smoking where possible;
    b) Prior assessment of smoke generators by taking account of the resulting PAH content in the smoke;
    c) Adjusting of the airflow to avoid excessive temperatures during smoke generation;
    d) Selecting appropriate smoking chamber and device for treatment of air/smoke mixture;
    e) The accessibility of oxygen during the smoking process;
    f) Smoking time: Reducing the time that food is in contact with smoke, this should take the consequences for microbiological safety and quality into consideration;
    g) Temperatures: Temperature in the glow zone (in the smoke generation step) and temperature of the smoke in the smoking chamber;
    h) In order to avoid an increase in the PAH content through fat dripping into the heat source, perforated metal sheets can be installed between the food to be smoked and the heat source;
    i) The cleaning method and schedule applied in the processing unit;
    j) As an alternative to using freshly generated smoke, manufacturers can consider smoking with regenerated smoke from smoke condensates. They can also produce smoke-flavoured products by applying smoke condensates to foods, such as by spraying, dipping, injecting, or soaking.

61. Post smoking processes:
    The cleaning of the smoked product itself. In this case soot and particles containing PAH on the surface of the food may be removed by rinsing the product or immersing it into water. This type of cleaning would not be possible to use for all types of products, e. g. not for smoked fish and fishery products. Also, washing might lower organoleptic quality and increase microbiological risk.

DIRECT DRYING

62. One of the oldest methods of food preservation is direct drying, as it uses less equipment than indirect drying. Direct drying reduces water activity sufficiently to delay or prevent bacterial growth. Direct drying of food can be done either by sunshine or wind or using hot combustion gases. Water is usually removed by evaporation and creating a hard outer-layer, helping to stop micro-organisms from entering the food.

CONSIDERATIONS IN DEVELOPING PREVENTIVE MEASURES TO REDUCE THE PAH CONTENT OF DRIED FOODS

This section is divided in direct drying using a) sun or wind, b) other fuels.

Sun drying

63. When drying by sun or wind, the potential source of PAH is the environment. Contamination can originate from soil/dust or/and from combustion from industry and from traffic as well as forest fires and volcanic eruptions.

64. Sun-drying of foodstuffs has the advantage of using free energy from the sun or wind. However, the benefits of greater control over the drying environment and drying time, quicker drying and less contamination from dirt, grass and insect particles, coupled with a consumer demand for a cleaner and less contaminated product may make artificial drying (dehydration) more attractive.

65. A major disadvantage of sun-drying is the exposure of foodstuffs to the environment, e.g. exposure to undesirable weather conditions and to contamination agents. Weather conditions, over which the grower has no control, greatly affect the drying rate. Contamination of dried foods with foreign matter is a serious concern. Sun-dried foods are exposed to contamination by windblown dust, seeds, insects, rodent and bird droppings.

66. Sun drying of foodstuffs should not take place near industrial point sources of combustion of gas, such as roads with heavy traffic, incinerators, coal-fired power stations, cement works etc., or in the immediate proximity of roads with intense traffic. Contamination from drying in such places is expected to be a special problem for foodstuffs with a large surface area such as spices. However, covered dryers may protect foodstuffs from industrial sources to some extent.

Direct drying processes, other than sun drying

67. The drying process should begin as soon as possible after the receipt of the crops to avoid unnecessary deterioration.

Fuel used in direct drying other than sun drying

68. Different types of fuel are used in direct drying, e.g. natural gas, peat and mineral oils. For some foods, the effect of fuel choice on taste may be the important points to consider in choosing a fuel. In any event, fuels like e.g. diesel oil, rubber, tyres, or waste oil must not be used even as a partial component, as they may lead to significantly increased PAH levels.

Combustion gasses

69. Drying with combustion gases increased the contamination by 3- to 10-fold; use of coke as fuel resulted in much less contamination than use of oil. Direct contact of oil seeds or cereals with combustion products during drying processes has been found to result in contamination with PAH and should therefore be avoided. JECFA recommended that contact of food with combustion gasses be minimized.

Foodstuffs dried

70. Many types of food like meat and many fruits are usually dried. Drying is also the normal means of preservation for cereal grains.

71. Contamination of cereals and vegetable oils (including olive residue oils) with PAH usually occurs during technological processes like direct fire drying, where combustion products may come into contact with the food. Direct contact of oil seeds or cereals with combustion products during drying processes has been found to result in accumulation of PAH and should therefore be avoided.

Direct drying process

72. Dehydrators are useful for larger drying yards and growers. Dehydration allows a steady production cycle to be maintained, reduces labour costs and is an insurance against unfavourable weather conditions for sun drying. A system using a combination of initial sun drying followed by finish dehydration can have considerable advantages without loss of food quality.

73. Common direct drying/heating operations and applications include drying to remove water (and/or other solvents/chemicals) added, left or produced during processing. During direct drying, hot air is blown directly into the foodstuffs and combustion products can therefore directly enter the food.

One example of PAH contamination from direct drying is contamination of vegetable oils (including olive residue oils) in which oil has been contaminated with PAH during technological processes. Another example can be drying oil seeds prior to oil extraction.

74. Continuous flow drying, where cereals pass the drying area continuously, is a widespread grain drying method. This technique can be used for drying cereals for food. Direct drying is mainly used with temperatures up to 120 °C for feeds. For foods (cereal grains, malt, etc.), indirect drying (external heat generation) with temperatures between 65 and 80 °C are mainly used. The time span for both types of drying is between ½ and 1 hour, depending on the initial moisture content of the grain.

75. Dehydration provides a form of insurance against poor weather conditions that can handicap traditional sun- and shade-drying. Accurate control of the drying conditions (temperature, relative humidity and air movement) essential for efficient dehydration is achieved. Many kinds of fresh fruits, vegetables, herbs, meat, and fish can be dried.

76. Too high a temperature (one that causes visible burning of the product) can cause PAH formation. Where a system with a burner is being used, the temperature of the burner should be sufficient to allow complete combustion of the fuel, as incomplete combustion can lead to PAH in the drying gasses. A good homogeneity of the temperature of the air is important to avoid overheating.

77. The drying time should be as short as possible to decrease the exposure of the food to the potentially contaminating gasses as much as possible.

78. The use of active carbon is required during refining of the oil as a way to reduce the PAH content after direct drying. A monitoring system for the PAH content should be established and additional refining steps (with active carbon) must be used when the PAH level in the food is unacceptable.

79. Ensure that complete burning of the fuel has occurred, by monitoring the gases for CO, monitoring the burner (if applicable) for soot accumulation, and checking burner settings and burner or fire temperatures.

80. As drying processes could be a potential source of PAH in cereals and oil seeds, there is also a need to control the levels of PAH in agriculture crops post-harvest, with particular reference to the source of contamination, as

these crops can have a major impact on PAH intake from food. JECFA recommended avoiding fire drying of seeds, and seeking alternative drying techniques.

81. Numerous factors, including equipment cost and availability of energy sources often result in similar foods being dried in very different ways.

82. Replacing direct drying with indirect drying can significantly reduce contamination of dried foods. JECFA has recommended that direct drying be replaced with indirect drying.

IMPORTANT POINTS TO CONSIDER AND RECOMMENDATIONS ON DIRECT DRYING, EXCEPT SUN DRYING

83. PAH content of foods directly dried can be minimized by replacing direct drying with indirect drying, if possible or by identifying and evaluating the important points to consider mentioned below, and taking appropriate measures. An HACCP system might be applied.

84. Fuel:
   a) The type and composition of fuel used to dry foods affects the PAH content;
   b) Do not use woods treated with chemicals, e.g. preserved wood, painted wood;
   c) Monitor the water content of the wood. Lower water content of wood t may lead to rapid burning of the wood and higher PAH levels;
   d) Avoid the use of fuels such as diesel fuel, waste products, especially rubber tyres, olive residues and waste oil which may already contain significant levels of PAH;
   e) The fuel influences the taste of the final food.

85. Drying process:
   a) Temperature of the air should be optimal;
   b) Minimize the time that food is in contact with combustion gasses;
   c) Use of active carbon during refining of the oil;
   d) Avoid fire drying of oilseeds;
   e) Avoid direct contact of oilseeds or cereals with combustion products;
   f) Keep equipment clean and well maintained (especially driers).

Prevention and Reduction of Food and Feed Contamination

First edition

This first edition contains all the codes of practice related to the prevention and reduction of contaminants (e.g., mycotoxins, heavy metals and chemicals) in foods and/or feeds adopted by the Codex Alimentarius Commission until 2011.

The Codex Alimentarius Commission is an intergovernmental body with over 180 members established by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO).

The **CODEX** ALIMENTARIUS is the main result of the Commission's work: a set of international food standards, guidelines and codes of practice with the goal to protect the health of consumers and ensure fair practices in the food trade.

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