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Guidelines for the Prevention of Mould Formation in Coffee

1. The Executive Director presents his compliments and attaches a copy of a new publication: "Guidelines for the Prevention of Mould Formation in Coffee". This aims to provide coffee authorities with a technical resource for developing national guidelines or codes of practice for the reduction of Ochratoxin A (OTA) contamination in coffee.

2. The guidelines have been prepared as part of the ICO/FAO/CFC project "Enhancement of coffee quality through prevention of mould formation" and will also be included as part of a training tool which is being finalised by the FAO, as the Project Executing Agency, and which will be circulated to Members in the form of a CD-Rom.

Guidelines for the Prevention of Mould Formation in Coffee

FINAL

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1 PREFACE

In a commodity like coffee where it is important to retain diversity in flavour and where sensory quality can create value, any code of practice must respect the differing traditional production methods. Of course, practices that can be shown to compromise public health must not be permitted, but beyond this benchmark there are few if any practices without safe alternatives. However, there are restraints on acceptance of potential solutions to identified problems such as the limited capital of small farmers, remoteness from support and marketing institutions, lack of financial incentive for change and the inertia of habit borne of long tradition.

These guidelines interpret and incorporate scientific findings into practical guidance. The studies themselves can be found in the supporting documentation. There is no intention or desire to strictly codify practice into narrow limits, a futile pursuit, in any case, given the diversity of practice and the essential variety and good quality of the product of these practices.

These guidelines are not intended for the direct use of every stakeholder, rather they aim to provide concerned authorities with the basis for developing national guidelines or codes of practice specifically tuned to their respective sector.

The first objective of these guidelines is to characterise factors associated with each production step throughout the 'coffee chain' that could contribute to the problem of OTA contamination, explain their relevance in different situations and propose means for their control. Recommendations, and the contra-indications of poor practice, need to be specific enough so that the concerned authority or stakeholder can develop his own solution appropriate to his circumstances.

It is not enough for the advice to be correct and practical, and the intention to apply it solid. As much thought must be given to how it will be implemented and assured in the day-to day rush that envelops any production system at the height of the harvest period. Successful implementation is tied to understanding how to structure and manage an operation. Providing advice on a safety/quality management system to aid the implementation forms the second objective of these guidelines.

These guidelines, and national guidelines or codes of practice that should be derived from them, will form the basis of national programmes for the reduction of OTA contamination in coffee. Concerned institutions must develop effective programmes of training to support the implementation of national guidelines. Policy-makers must ensure that regulatory and other relevant policies are consistent with achieving widespread stakeholder compliance with the recommended practices.

2 INTRODUCTION

OTA is a chemical product of the growth of a few specific fungi. It occurs where certain micro-fungi capable of producing it occur in concert with the conditions they require for growth and biosynthesis of this chemical for enough time for the product to accumulate. Fungal contamination along the coffee chain can impart a smell or taste to the product. However, the specific kinds of fungi involved in these taints are not the same as those involved in OTA production, so the causes of OTA remain essentially invisible.

Compared to staple crops, coffee has some advantages. Perhaps the most significant is the limited extent to which it is subject to pest attack in storage. Birds and rodents do not eat the seeds and only one significant insect, the coffee weevil *Araecerus fasciculatus*, attacks the dry product (Hill and Waller, 1988). In fact, the bulk of the carbon in coffee seeds is in fairly refractile forms such as the poly-mannan carbohydrate storage material, cellulose and pectin and allied to the high phenolic content of coffee probably restricts the diversity and rate of fungal spoilage. Importantly, there are no significant current alternative uses for coffee aside from human consumption as a beverage or flavour in other processed products.

However, fungal and bacterial spoilage does occur and though the almost universal use of high-temperature roasting before consumption means that food poisoning bacteria present a negligible risk to public health nor are the poly-peptide enterotoxins some produce likely to be sufficiently heat-stable to persist in the roasted product. Toxins produced by fungi, however, are known to survive roasting and present a potential hazard. Ochratoxin A (OTA) and to a lesser extent aflatoxin, both produced by species of the fungus Aspergillus in coffee (M. Nakajima, *et. al.*, 1997; C. P. Levi, 1980; I. Studer-Rohr, *et. al.*, 1995; H. Tsubouchi *et. al.*, 1984), can occur in raw and roasted coffee beans.

Practices that restrict the development of certain fungi tend also to preserve quality in both sensory and safety terms. The two specific tools available are, 1) managing water availability from the beginning of drying onward, and 2) facilitating the development of competitive micro-organisms and restrictive growth conditions that are not prejudicial to quality, before this point.

There are predominantly two commercial species and some inter-specific crosses used in coffee production. *Coffea arabica* (arabica coffee) requires a wet tropical highlands climate at altitudes between 600 and 1600m. *Coffea canephora* (robusta coffee) can be grown at sea level but it too is often grown in wet tropical highlands. The vigour and disease resistance of robusta is superior to arabica.

Although the chromosome number of these two species is different, crosses can be forced, and at least one spontaneous cross is known. Such crosses are primarily used to back-cross with arabica to improve disease resistance in arabica and most commercial arabica, outside of Ethiopia, are of this type. However, two inter-specific hybrids, ‘arabusta’ and ‘congusta’ the latter a robusta and *Coffea congensis* cross, are grown and marketed to a limited extent.

Robusta’s vigour means that production costs are less than arabica, but its value is also considerably less. The bulk of robusta coffee is used in soluble coffee production but there is a small outlet in the speciality coffee market, especially for the wet-processed product.

The commercial product is the seed and these are formed, usually, two per each small cherry-like fruit which are referred to as 'cherries'. The fruit is borne in either tight (robusta) or loose (arabica) bunches at the nodes of side branches. Both commercial species are large bushes and many commercial varieties have been selected for dwarfing character to simplify harvest which is done primarily by hand.

Processing is conducted on the farm with the overall objective of stabilising the product (the seeds) by drying to a level where microbial deterioration is prevented. This may involve prior separation of the product from the fruit tissues. Once dried, the coffee can be stored and transported and will also be 'cured', a series of steps that may include sizing (grading), sorting, polishing, cleaning and sacking. The commercial value of coffee is vested in its taste characteristics so the preservation of these qualities is central to processing methods.

There are two generic systems of coffee processing: wet processing and dry or natural processing. The dried product of the first is 'parchment coffee' which is the seed enclosed in the inner integument or endocarp and the dried product of the second is the seed enclosed in the complete dried fruit tissue. Parchment coffee has a higher market value, but is more expensive to produce, and has different sensory qualities than cherry coffee. Most robusta coffee is produced as cherry coffee, most arabica coffee is produced as parchment coffee, but with important regional exceptions. There is a limited market for washed robusta in the speciality market and arabica cherry is an essential component of espresso-style blends.

In wet processing, equipment is used to split the seeds out of the fruit, generating a significant by-product, 'pulp', the skin and part of the 'mucilage' (mesocarp) of the fruit, The main product is 'parchment' coated thickly with mucilage. The parchment is traditionally fermented in order to degrade the mucilage so that it can be easily washed but it can also be removed immediately by machine. After removal of the mucilage, the parchment is dried, usually by sun drying on cement, brick terrace or tables. There are many variations and technological innovations to this generic scheme but it is beyond the scope of this treatment to describe these.

In dry or natural processing, the fruit is laid directly out to dry in the sun with or without a step to separate floating cherries from sinking ones. Bare soil, cement, brick, bamboo mat and tarpaulin are all surfaces that are commonly used for sun drying. By this method, the separation of the fruit tissues from the seeds is accomplished later, in the dry state, generating a significant by-product: dried fruit tissue or hull. The hulling step is usually done on-farm or the hull is returned to the farm.

Though sun-drying is the most common drying method for coffee, mechanical drying is important in some regions, particularly in more capitalised sectors. Even here, sun drying is normally used for a significant part of the drying period since most mechanical dryers are designed to handle coffee with an initial water content of 35 - 40% mc (wb) from initial values of 60% or more.

Although the occurrence of OTA in coffee was reported in the 1970's, it did not become a public health concern until a revision of its mode of action was mooted in the 1990's. Although not proven, there was evidence published that OTA was a genotoxic carcinogen, like aflatoxin. The practical significance of this, if true, is that any exposure to OTA, increases risk of, in the case of OTA, kidney cancer. The accepted guidance for genotoxic agents is to reduce their occurrence to a level that is 'as low as reasonably achievable (ALARA)'.

OTA is a heat-stable mould metabolite produced by a proportion of isolates of a few species in the genera of *Aspergillus* and *Penicillium*. In coffee, only *Aspergillus* species in the ochre and niger sections are involved. The toxin is produced by a growing mycelium within certain physical restrictions of water activity, nutrition and temperature and these provide the potential areas of control. Most commercial samples do not contain detectable OTA with a current detection limit of 0.1 – 0.5 µg/kg (= ppb) depending on the method in use. Of positive samples, most fall below 5ppb and anything above 20ppb is considered exceptionally high.

While these guidelines focus on reduction of OTA contamination, which is the primary food safety issue in the production of green coffee, industry food safety programmes must also effectively manage other potential hazards in the production, processing and handling of coffee.

3 DEFINITIONS

Bóia: Cherry coffee separated by virtue of it being positively buoyant in water applied to a one-pass stripping harvest system where there is abundant tree-dried cherry.

Cherry (or Coffee cherry): The complete fruit of the coffee tree, can be either fresh or dry

Conditioning: The storage of dried beans in ventilated bins to achieve an even moisture content within the bulk of the coffee.

Conditioning bin: Large wire-mesh holding bins usually of 1 x 1 x 3m (or larger) that are used for conditioning coffee. Modern designs incorporate fan ventilation.

Curing: The final stage of preparing coffee, known as 'curing', usually takes place just before the coffee is sold for export. Coffee passes through a number of operations that may include cleaning, polishing, screening, sorting and grading.

Defects: The collective name for common but undesirable particles found in bulk green coffee. Defects can include various types of beans, or parts of beans, fruit tissue and foreign matter. Numerous terms are used to describe the various defects that can be present in both green/raw and roasted coffee beans, and sometimes these are used in some producing countries and not others. In general, bean defects are caused by faulty processing, pest damage, or inclement climatic conditions leading to poor fruit development. Defects are given a weighted value to assist in the classification and grading of coffee lots under various national and international systems.

Dry processing: Treatment consisting of drying coffee cherries to give husk coffee, followed by mechanical removal of the dried pericarp to produce green coffee. The product is called 'cherry coffee', 'unwashed coffee' or 'natural coffee'.

Floats coffee: Cherry coffee separated by virtue of it being positively buoyant in water applied to selectively picked coffee the vast majority of which is ripe or immature.

Gleaning (or Sweeping): Applies to the collection of coffee fruit found lying on the ground beneath coffee bushes, having either become detached during harvest or abscised during development. 'Gleanings' is the collective term for coffee collected in this manner.

Green coffee bean: The dried seed of the coffee plant, separated from non-food tissues of the fruit. Coffee is exported in this form.

Hull: The dried endocarp of the coffee fruit.

Husk: Waste material resulting from the hulling of parchment or dry cherry coffee, made up of the dried pulp and outer covering of the parchment.

Mbuni (or Buni): Cherry coffee that has been separated from selectively harvested fruit based on visual criteria such as evidence of CBD or CBB attack or being at a non-ripe stage of maturity (**Note:** 'Bun' or 'Buni' is also the generic name for coffee in Ethiopia, and is not to be confused with 'mbuni').

Mechanical drying: Any of several drying technologies where heat is provided from combustion of a fuel.

Mechanical washing: Any of the mechanical methods for removing the mucilaginous mesocarp from the surface of the parchment, taking place after pulping without a fermentation step.

Mucilage: Common word to describe the fruit mesocarp, an intermediate layer of tissues between the epicarp and the endocarp (parchment). It consists mainly of pectinaceous mucilage and pulp.

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

Natural processing: See 'Dry processing'.

Parchment (or Parch): Common word to describe the endocarp of the coffee fruit. It lies between the fleshy part (or pulp) of the cherry and the silver skin. This is the thin, crumbly paper-like covering that is left on wet-processed coffee beans after pulping and fermentation. Subsequently removed during hulling.

Parchment coffee (or Pergamino): Wet-processed beans after pulping, dried to about 12% moisture content, but before hulling has removed their hard outer covering (the endocarp/parchment).

Processing: Steps involving the transformation of harvested coffee fruits to a dry and stable condition.

Pulp: The fleshy outer layer of the mesocarp, directly beneath and including the skin, removed with a pulping machine

Pulping: Mechanical treatment used in wet processing to remove the exocarp and as much of the mesocarp as possible

Wet process (or Wet processing): A method of processing coffee cherries into dried pergamino/parchment coffee. Treatment consists of mechanical removal of exocarp in the presence of water, removal of all the mesocarp by fermentation or other methods, and washing followed by drying to produce parchment coffee which is subsequently stripped of its parchment to produce green coffee.

4 RECOMMENDATIONS

4.1 Pre-harvest

There are serious fungal pathogens of coffee but fungi in general, and OTA-producing fungi in particular, are not responsible for plant disease. Many are or can be involved in fruit spoilage and several of these can grow and survive in viable, healthy seeds. Micro-organisms form a natural part of the plant, inside and out, and in the healthy plant there is a balance between these commensal organisms and the plant itself. There is good evidence now that infection of the seed by OTA-producing fungi can take place in the orchard and grow enough to produce OTA by the time of harvest. Further work is required to better understand the factors that lead to this contamination.

There are two documented infection routes: introduction through the flower producing no sign of this infection; introduction by casual carriage of spores into the bean on coffee berry borers (CBB) (*Hypothenemus hampei*) producing obvious signs, a hole in the cherry and one or more tunnels in the bean. More mature and dryer fruit and production by-products (husk and pulp) can contain increased levels of the spores and mycelium of OTA-producing species.

It is logical that contamination of the bean by growth of superficial mould through the fruit can occur. The relative importance of this mechanism in bean contamination in the orchard was not systematically evaluated, but mycological analysis did not demonstrate a correlation of fruit with bean contamination. If cherries become detached and reside on the ground, contamination and growth through the fruit is more likely. This process requires time but in the field, generally, the history of fallen fruit cannot be known. Fruit becomes detached through inclement weather, higher animals feeding on the fruit, disease or stress-induced abscission or accidentally through other farm activities such as weeding or spraying.

These considerations lead us to recommend practices designed to minimise spore load from OTA-producing fungi in the orchard, to minimise CBB occurrence and to ensure the vigour of the coffee trees so to minimise development of fungi residing within the tree and its fruit.

1. Use plant material from manual weeding to improve soil texture and fertility. Coffee production by-products can also be used but should first be composted until the material has reached a friable condition, requiring 3-6 months depending on temperature and moisture conditions. Avoid applying organic material during or just prior to flowering.

2. Do not use overhead irrigation around the flowering period. This could augment normal spore dispersal rates and increase the chance of infection of beans by OTA producers.

3. Clean the orchard of fallen cherries, especially in the off-season, and deploy alcohol traps for CBB control especially in the run-up to and throughout harvesting and processing. Programmes of integrated pest management (IPM) should be promoted.

4. Employ horticultural practices that contribute to vigorous trees: weeding; pruning; fertilization, pest and disease control; etc. In selecting a pruning system,

do not neglect its impact on leaf area. This should be high since self-shading and high photosynthetic potential improves vigour in coffee.

5. Do not dispose of uncomposted coffee waste, household waste, waste from staple crops that may also be produced on the farm or animal feed in or around the orchard. Deposition of seed and seed-associated material could encourage proliferation of OTA producers since many are seed-borne fungi.

4.2 Harvest

The harvesting method is dictated by a combination of the requirements of the processing method, economic considerations and availability of labour. In general, four harvesting systems can be identified: 1) multi-pass selective picking (finger picking) where the picker takes only ripe cherries; 2) multi-pass stripping where whole bearing shoots are stripped off only if bearing predominantly ripe cherry; 3) single-pass stripping where everything is stripped off as the workers get through the orchard; 4) mechanical harvesting where machines, sometimes hand-operated, use vibration to knock the fruit from the trees.

In addition to these methods of bringing in the main harvest, there are other activities before and after main harvest, some of which bring in fruit. Often a 'fly harvest' collects prematurely ripened fruit. Weeding and cleaning the orchard floor to expedite the spreading of mats or the collection of fruit that goes to ground during harvest is conducted.

Subsequent to the main harvest there is usually a collection ('gleaning' or 'sweeping') of fruit missed during main harvest, some of which is still on the trees but mostly on the ground. This is an important element of Integrated Pest Management for CBB but traditionally, this coffee joins the human food chain.

Brief contact with the ground is not problematic but becomes so if the contact period lengthens. According to some experimental findings, *in dry conditions* fungal development is not rapid and up to two weeks residence on the ground may not increase contamination with OTA producers. In wet or humid climates only collection from the ground on the same day should be considered acceptable. Measures to assure these limits are not violated must be in place if this coffee is to be used.

Irregular maturation of fruit is a problem for all farmers and processing methods because the physical properties and potential sensory quality of different maturity classes differ. If selective harvesting is used, the heterogeneity can be minimised but at the expense of higher harvesting costs. The timing of the harvest is therefore an issue of importance particularly with non-selective methods.

There is some indication that OTA can increase in the standing crop as the season passes and certainly CBB increases through the harvesting season. In early season there is a disproportionate frequency of immature cherries which have low cup quality, cannot be pulped and are not readily separated from ripe cherries by automatic means.

The proportion of over-ripe cherries increases as the season progresses and past a certain stage, they can no longer be pulped. The situation with over-mature and tree-dried cherries is complex but it appears that tree drying in regions with arid harvesting seasons is a safe practice. Tree-drying in other climates is probably less so and, in any case, has been implicated in certain cup defects such as fermented and *rioy* taste.

Coffee cherry should be processed without delay. Buffering methods such as retention of harvested cherry in sacks, holding cherries under water, removal of partly dried coffee from the drying yard to 'conditioning bins' or drying in excessively thick layers, are sometimes used to replace good planning but these are all problematic. Careful planning and anticipation is required because readiness to process depends on the completion of drying, itself usually dependent on weather conditions. The harvesting rate, along with processing performance and labour availability must be made to match drying rate.

Evidence thus far indicates that keeping fresh cherries temporarily under clean water is safe but this material rapidly becomes more difficult to pulp and wash. Indications are that retention in sacks may erratically produce high OTA levels and quality loss. Likewise, thick coffee layers during drying slow drying rates and consequently permits fungal growth and development. Tests have shown that little additional drying takes place in conditioning bins so the period in bins provides additional time in which spoilage can occur.

The coffee presented to the processing method should be uniform so that mixing different categories is avoided: wet with dry coffee in dry processing; pulpable with not pulpable in wet processing; sound fruit with other categories in all processing. The harvesting result must serve the processing intention and be evaluated by how well it does so. It is known that coffee seeds can contain OTA at harvest but the detection of these seeds is not feasible.

1. Removal of brush, fallen cherries and high weeds from the proximity of the trees is an important prelude to harvest. It improves picking efficiency, protects the pickers and is necessary to protect the main-crop from contamination by old fallen cherries that may be included when dropped cherries are retrieved from the ground.

2. Harvest should commence as soon as there are sufficient ripe cherries for the harvest to be economically viable.

3. Use picking mats beneath the trees where possible. They protect the main crop from contamination by old fallen cherries and improve harvesting efficiency. They are only practicable in flat or gently sloping terrain since the fruit rolls off the mat on steep slopes.

4. Exercise appropriate selection at the picking stage or before further processing or both to remove inferior fruit from the main production chain as is suited to the processing method.

    - Where CBD or *Phoma* commonly attack the fruit, only sorting by hand is possible. Here sorting is used to remove diseased and immature or over-mature fruit from the main harvest. Also remove immature fruit.

    - Sorting based on buoyancy in water conveniently separates fruits with one or more diseased seeds, some multi-hole CBB attacked fruits and tree-dried fruit, all of which float, from a combination of ripe and immature fruit, which sink. There are indications that the superficial microbial load is reduced by brief agitation of cherries in water though it is questionable whether this reduces the risk of OTA contamination of the coffee bean.

5. Establish clear routines for processing and handling secondary products that arise from sorting or separation procedures in your production system.

6. Coffee that had been in contact with the orchard soil for longer than specified should be collected and destroyed.

7. Assure harvested coffee can be promptly moved through the processing steps without delay. An important management function is the co-ordination of harvesting activities with processing activities. In general, coffee is better left on the tree for a few days, rather than harvested and retained awaiting processing.

4.3 Post-harvest Processing

Maturation and drying of cherries on the tree is quite distinct from drying after harvest. Coffee fruit, unlike many other fruits, has no capacity for dormancy – rapid change and senesce follow once the fruit is detached. Based on the available means of controlling processing, the post harvest period is characterised by two distinct phases joined by a transitional phase.

In the first or high moisture phase, which begins with harvest, the product is in an unstable state and spoilage can only be controlled by encouraging competitor micro-organisms, restricting oxygen and limiting the time in this state.

In the last or low moisture phase, which begins in the later part of drying and extends through to roasting, the commodity is in a stable condition and control is exerted by preventing the re-introduction or redistribution of water in the coffee bulk.

During the transition between these two phases, spoilage can only be controlled by time limitation because there is enough water for the growth of mesophilic and xerophilic spoilage organisms but not their hydrophilic competitors and aeration is an indispensable part of drying.

In wet processing the high moisture phase may be extended while being controlled with a fermentation step, but generally a process should seek to minimise the length of the high moisture phase.

The transitional phase is the least stable and most difficult to predict. During this period, certain hydrophilic microbes, known to be harmless, are replaced by mesophilic ones, some of which are known to be capable of OTA-production. It should be noted, however, that many of the harmless organisms still have the capacity to produce quality deterioration. Rapid drying is often not possible where harvest coincides with a rainy season or high prevailing humidity so measures to optimise drying under these poor conditions must be taken (see drying).

At some point during drying further growth becomes impossible as the commodity passes to the low moisture phase heralding the end of processing.

There are many claims relating good general quality to one or another aspect of processing and that partly determines market value. Usually these are not supported with evidence of objective comparison between alternatives and since they strongly influence practice, this area is in need of systematic review. A rational market needs such information to reward practices that are demonstrably beneficial either in safety terms or general quality. Resources or attention expended on non-beneficial activities at best divert effort from more important issues.

In the past, both fermentation and sun-drying were considered essential for good quality but this is now disputed as the use of mechanical washers and drying has become more widespread. Some workers recommend that parchment coffee should be protected from rapid drying in the mid-day sun at the early stages, but many origins have no such tradition.

4.3.1 Wet Processing

Wet processing has required uniformly ripe cherries, though new pulping technology has arisen that tolerates inclusion of immature cherries in the ripe cherry. Wet processing produces parchment coffee as the main product and cherry coffee as a secondary product.

This dry processed cherry coffee is derived from out-sorted cherries (floats coffee and *mbuni*) removed from the main production chain prior to pulping according to characteristic defects or incompatibility with the parchment processing technology. Typically, the low value secondary processing chain is very much neglected and this should not be the case – it too is destined for the human food chain. Analysis has shown this product, when neglected, can become highly contaminated with OTA. The out-sorted cherries are likely to contain a relatively high proportion of defects some of which, according to data from some surveys of defects, are associated with greater risk of OTA contamination than sound beans produced in the same batch.

Control of spoilage of parchment is exerted either by using a fermentation to limit oxygen availability and encourage harmless competitive micro-organisms while degrading the mucilage to permit washing followed by drying or applying mechanical removal of the mucilage to permit immediate drying. A recent innovation where the pulped parchment is immediately dried without mucilage removal (*descascado* or *cereja descascado*) provides a third alternative.

Extensive sampling has failed to show that pulping remnants strongly support the development of OTA-producers although they do support rapid growth of bacteria and yeasts the acidic by-products of which could damage the equipment. Adequate cleaning programmes are necessary to control unnecessary additional sources of contamination and also to safeguard the equipment. Likewise, recycled pulping water is safe for use for pulping. The largest reservoir of OTA-producers in wet processing is the coffee fruit, including the bean, itself.

The inclusion of skins, crushed immature cherries and un-pulped, under-sized cherries in fermentation and drying of parchment has long been considered to have serious general quality consequences. At high levels they could pose an OTA risk but the evidence for them having a significant impact on OTA accumulation, at frequencies of occurrence that are acceptable in terms of general quality, is weak.

Based on the rapidity with which naked or nipped beans become mouldy, the parch provides some tangible protection against mould contamination when wet. Although it does not automatically follow that this contamination would generally lead to OTA contamination, it is a clear cautionary point. Nipped and naked beans are much more common from low water use mechanical washers and unrefined pulpers, so special attention is required when operating these.

1. Any equipment, no matter how technologically basic, benefits from regular maintenance. Equipment failure could delay processing and compromise coffee quality and safety. In addition to regular cleaning and maintenance during harvest season:

    - In decommissioning, all processing equipment should be thoroughly cleaned and lubricated as appropriate and protected from water, dust and debris during the off-season. This is also the time to order replacement parts and conduct repairs. Check pulping surfaces for wear.

    - In re-commissioning, clean, reassemble, lubricate where appropriate and all processing equipment and inspect, installation, fittings and power and water supplies. Test for operational integrity well before use is required to provide time to retrench if faults arise.

2. Adopt acceptability criteria for each significant element of the process and unambiguously assign roles to staff to ensure that they are met. Pulping is a crucial and central activity in wet processing and you should assure it is being done as well as possible. There may be training implications for workers. A guide to these considerations follows:

    - Quality of input cherries: What is the maximum acceptable proportion of immature and over-mature / tree-dried cherries (if a siphon is not used) for your operation? How is the rate of immature and over-mature cherries estimated? Who should monitor this and how often? Prescribe remedial actions to be taken if norms are exceeded.

    - Quality of pulping I: What proportion of un-pulped cherries and, on the other side, nipped beans do you accept in your operation? How and how often do you monitor the amount of these categories? What corrective action is justified by the consequences of processing these unintended classes? Might measures to increase size uniformity of the input be cost effective? Prescribe remedial actions to be taken if norms are exceeded.

    - Quality of pulping II: Are skins being effectively separated? How and how often is monitoring required? How do you investigate the cause of poor skin separation - inadequate water supply, outflow blockage, worn pulping surfaces? Prescribe remedial actions to be taken if norms are exceeded.

    - With such a scheme established, some of the measures may prove to be ineffective, too stringent or too lax. Recording the various estimates of the monitoring, as well as the quality and safety of the product could be used to improve the efficiency of the operation.

3. Although there is no evidence that poor water quality can lead to OTA contamination, coffee is a food and clean water should be used in processing it. If

available, bore-hole or spring water should be used. Turbid water has been reported to ruin coffee sensory quality in wet processing.

4. The shortest fermentation required to loosen the mucilage sufficiently for washing is the optimal one. Establish how and when the fermentation should be sampled and assessed. Fermentation may contribute to coffee quality but its primary purpose is to enable the mucilage to be removed. The fermentation rate can vary due to variation in inoculum speciation and level (in the in-coming cherry) and ambient temperature.

5. Monitor the build-up of fruit flies and take measures to control them if their populations become extreme. In general they carry whatever micro-organisms that are present in their food but heavy infestations can unbalance fermentations.

6. Have a parallel programme for the processing of the dry-processed secondary cherry coffee and do not allow it to be controlled `by default'. Maintain separate facilities for cherry coffee drying and apply good drying practices (see below) to this product.

7. Establish criteria to judge washing efficiency and a routine to implement this control measure and whether water usage is well controlled and minimised.

    - Amount of non-coffee by-products after washing.

    - Amount of broken, nipped and naked beans after washing.

Drying and drying yard management elements are discussed below.

4.3.2 Dry Processing

In dry processing the whole cherry is dried with or without some preceding selection/separation step. Regional variations include retaining harvested coffee in sacks, heaps or thick unstirred layers before spreading to dry and the mechanical splitting of the cherry like pulping but where the parchment and skin is dried as an un-separated mass.

It should be emphasised that to get good results, cherry drying, although simple, requires the application of good practices and management as much as the more complicated wet processing method.

On a per kg of green coffee basis, almost twice as much water must be removed on the drying yard in dry processing than wet processing. At the same time, whole cherries provide a greater degree of protection for the beans. Splitting cherries is a 'low-tech' compromise to reduce drying time without increasing processing costs too much as with wet processing. If it is poorly executed, physical damage to the bean can increase opportunity for internal bean mould contamination and associated risk of OTA contamination and quality loss.

One very important variation on the usual method of presenting ripe cherries to the processing unit is to allow most of the fruit to dry on the tree. Results indicate that this method can produce safe and good quality coffee in regions where the harvest season is reliably arid. Its efficacy is to reduce the cost of harvest allowing one-pass stripping while minimising the amount of immature beans in the product.

Field surveys have revealed that it is common practice to hold harvested cherry in sacks or heaps for 3 to 7 days, especially amongst smallholders. Under these conditions, high temperatures are experienced and rapid fermentation takes place, different in kind to the fermentation employed in wet processing.

Direct studies have not produced consistent incontrovertible evidence to condemn this practice. It is clear, however, that the process is not controlled and alarming outcomes have sometimes been recorded. On this basis, it is recommended that fresh cherry should not be held beyond the day of harvest before spreading the cherry for drying. Furthermore, delays before processing often lead to substantial quality deterioration.

Wet processing operations also produce a certain amount of cherry coffee (see above) but this must not be compared to main-crop cherry coffee. Generically, this comes from, 1) 'floats coffee': where a siphon removes the ripe cherry that floats in water from the main crop and is combined with hand sortings (immature, over-mature) 2) 'mbuni': in endemic coffee berry disease (CBD) regions a siphon is not usually employed so floating cherries form a part of the main crop with visibly diseased, immature, and over-mature cherries dried as cherry.

In some regions, ripe cherry is selectively picked and dried. In most regions, especially after several years with very low prices, stripping is used in cherry coffee production, often with floatation separation. If harvesting of tree-dried coffee is common, a floatation step should be used to ensure that the tree-dried cherries are handled separately. This avoids their re-wetting on the drying yard due to mixing with fresh cherries. Even with uniformly ripe cherries, the frequency of defect beans can be reduced in the main crop by removing floats coffee. Analysis of defects have shown some of these to be associated with high levels of OTA contamination, therefore reduction of defect levels may *in some cases* be an important OTA control measure.

1. The primary equipment for the dry process is the drying equipment: the surfaces on which the coffee will be dried, mechanical dryers if used, covers and rakes as well as floatation separation facilities in some cases.

   - In decommissioning, all processing equipment should be thoroughly cleaned and lubricated as appropriate and protected from water, dust and debris during the off-season. This is also the time to order replacement parts and conduct repairs.

   - In re-commissioning, clean, reassemble, lubricate where appropriate, all processing equipment and inspect installation, fittings and power supplies if used. Test for operational integrity well before use is required to provide time to retrench if faults arise.

2. Triage or floatation should be used to remove diseased or damaged cherry from the main processing stream.

3. If unselective picking is used, use floatation to separate ripe and immature cherries from tree-dried cherries

4. Establish measures so that the harvest activities are co-ordinated with drying facility availability and that it does not become necessary to delay further processing after arrival of the cherry at the processing unit.

Drying and drying yard management elements are discussed below.

4.4 Drying Coffee

Strictly speaking, drying coffee is a part of processing but is dealt with separately here because cherry and parchment drying are more conveniently discussed together. Water relations in biological systems is a very complicated and important area in controlling the quality and safety of commodities. A great deal of effort was put into understanding all aspects of drying, control of drying and measurement of water content and a great deal of information and data is available in the supporting documentation.

World-wide, most coffee is sun-dried on some type of prepared surface such as tables covered in wire mesh, bamboo mat or sisal mat, cement or brick terraces, compacted earth, plastic sheets/tarpaulin or fish farm netting. Mechanical drying is also used after pre-drying in the sun to a moisture content of about 40%. Solar dryers are rare in the field, but the *parabolicos* and Maquesina can be found fairly commonly in some regions. The value of the former design has been found to be highly dependant on prevailing weather conditions.

Three regions of a drying time-course (m.c. vs. days) can be identified: an initial lag period, a period of maximum change and a deceleration phase. Cherry coffee has a lag period of 1 to 3 days where mc changes little compared to a lag period of 1 day or less in parchment drying. OTA-producing fungi are at a competitive disadvantage in these hydrated conditions.

The next phase is linear and its steepness depends primarily on drying conditions and secondarily on drying yard technology. Cherry and parchment, under identical conditions, dry at the same maximum rate. OTA-producers are best suited to succeed during this period.

As the coffee approaches dryness the remaining water is tightly held by the seed and water loss rates fall producing a period of slow drying. Some fungi can grow well at these moisture levels but the OTA-producing fungi are not amongst them.

For OTA to be produced, one or more of the fungi capable of producing this toxin must be able to grow. For this to happen these fungi must experience favourable conditions for a sufficient period. An essential part of these conditions is water availability: too wet (above Aw of about 0.95) and fast-growing hydrophilic fungi, including yeasts, will thrive and repress OTA-producing fungi; too dry (an Aw of less than about 0.80) and the OTA-producers are incapable of producing the toxin; dryer still (Aw below 0.78-0.76) and they are incapable of growth. The objective of control on the drying yard is to minimise the period the coffee spends in the range of water availability where OTA-producer growth is possible. Experimental results indicate that 5 days or less in this range is both generally attainable and effective in preventing OTA accumulation.

Rewetting may be more serious than slow drying. If the beans contain a level of contamination, it may have increased in biomass through the drying period so with more biomass the mycelium would be poised for rapid growth and OTA production if growth conditions become suitable.

Recent evidence confirms that the recommended maximum acceptable moisture content (12 and 13% (wb) for dry parchment and cherry coffee) protects coffee from growth of

OTA-producers and includes a substantial safety margin. This assertion is based on the study of the relationship between Aw and moisture content, including over 2,000 samples from many sources, which shows that moisture contents for robusta cherry and arabica parchment of about 18 and 16%, respectively, correspond to an average Aw of 0.76 which is the minimum requirement for growth of OTA-producers. The data indicate that, at a confidence level of 99%, this figure becomes approximately 13% for both. It should be noted that the relationship Aw vs. mc was determined only by desorption a sorption isotherm might be expected to vary slightly.

This Aw vs. m.c. relationship is supported by evidence from storage experiments where moderate re-hydration has taken place without serious consequences. However, a lot of coffee with more water in it is inherently less stable than one with less and the recommended moisture content is not difficult to attain in most producer regions.

Different climates pose different problems for drying and suitability of equipment can only be assessed in light of prevailing harvest-season climate. This fact also makes generally applicable recommendations difficult to devise. Many well-replicated studies show that differences in sun-drying equipment produce very small differences in drying rates but that drying rates vary enormously depending on how the equipment is used and the prevailing meteorological conditions at the time of the drying run. Any operation can benefit from keeping track of what has been done and the consequence. This information can be used to improve practice or to identify batches that might have experienced particularly bad drying conditions and might be considered to be at risk.

Mechanical drying is most commonly used as an adjunct to sun-drying, employed at the end of drying to rapidly generate more space in the yard. In some regions, however, it is widely used as the primary means of drying. Most of the available types of driers are controlled with two parameters: duration and inlet temperature. The main concerns with mechanical drying is excessive inlet temperature generating black beans from immature beans and over drying causing a loss of value, through weight loss, for the producer.

The objective of drying is to remove water from the seed in the most efficient way in order to stabilise the commodity and preserve its quality.

1. Site the drying yard to maximise sun and wind. In sun-drying, energy for the evaporation of water from coffee beans is provided by the sun and is expedited by air circulation. The drying yard should be located where both are maximally available, avoid shade and low areas for drying.

2. Use a surface appropriate to the climate and product you are producing.

    - In extensive side-by-side tests, different surfaces sometimes showed differences in drying rate but these are generally small and not consistent.

    - Parchment coffee taints more easily so only cleanable and easily drained surfaces can be used.

    - These tests failed to condemn the use of any particular surface but all have advantages and disadvantages. Soil would not be recommended in rainy zones and impervious surfaces such as plastic have been observed to 'sweat' below the coffee layer and promote the superficial growth of moulds. In regions with wet or showery weather, consider the practical imperative that the coffee will have to be frequently covered and re-spread, once the surface has dried.

3. Plan the harvest based on the processing/drying yard capacity and the average required residence time for drying. Plan in a contingency since poor weather can occur and increase drying yard residence time.

4. Coffee committed to the drying yard must be carefully managed to make the most of prevailing conditions, on the one hand, and to avoid adverse possibilities that could occur in any outdoor process. The principle parameters available to control this process follow:

   - Keep different categories and different day's harvests separate and use a system of labelling to prevent confusion.

   - Do not dry coffee in thick layers. As a guide, the optimal load for sun drying is about the same for parchment and cherry drying at 25 to 35 kg/m^2 when fresh. This corresponds to 3 or 5 cm layer depth, respectively.

   - Better drying conditions (low humidity, good air circulation and sun intensity), allow thicker layers: in cloudy damp, still weather the optimum layer is thinner and coffee should be spread more thinly. Different regions could apply different norms based on climatic differences

   - Once the coffee is somewhat dry, on average one full day for parchment and three for cherry, heap and cover it at night. When fully wet, there can be water loss during the night and covering would produce condensation. This protects the coffee from re-wetting from dew or showers.

   - During the day, turn the coffee layer four times per day if possible. Although it is difficult to demonstrate that raking more than once per day reduces the drying period, coffee in a static bed has been observed to become covered in mould.

   - Take measures to prevent access of farm animals to the coffee. Coffee is a foodstuff and should not be exposed to agents commonly found on and in livestock and even local introduction of water to drying coffee must be avoided.

   - Be aware and regularly monitor CBB populations on the drying yard, during cherry drying. The concentration of cherries can attract females from the surrounding area and extra damage to the crop can take place during drying. Use alcohol traps around the yard to help control them.

   - In showery weather, be prepared to protect dry or part dried coffee from rain. Persistent re-wetting can produce unfit coffee. Cherry coffee that has been on the yard for less than about three days will be little affected by some re-wetting but parchment coffee should always be protected.

   - Establish a routine, a standard approach for assessment of the dryness of coffee as it approaches full dryness (<13% or <12% (wb) for cherry and parchment, respectively). For guidance, and bearing in mind that over-drying is also undesirable from the producer's perspective, a lot should first be assessed two or three days before it is expected to be dry. Reassess at least daily, depending on subsequent drying conditions. Assemble a sample from several positions in the lot accounting for any shading across a part of the lot.

- Traditional methods, such as biting or shaking, can be effective in this assessment but stronger measures to 'verify' these measures against a reliable instrument should be undertaken than are usually in place in the field. It is imperative that if a meter is used, the person using it has been well trained and that the instrument is calibrated at least annually, preferably just prior to harvest season.

5. Organise the operations on the drying yard. Make sure the workers are trained in what they are expected to do. Have a ready reference available of what is supposed to be done. Clearly delegate responsibilities and make sure that essential tasks are recorded as completed so in the case of the absence of the designated person, the task will get covered. Most farms cannot afford to delegate a team or even a man to solely to oversee drying operations so communication between the workers should be facilitated to assure the best application that is possible.

6. Once dry, store the dry product in clean sisal sacks in appropriate storage conditions (see below). Storage of the dried cherries or the dried parchment coffee ('*en casca*' or '*en parch*') is appropriate, especially if it is intended to retain the product for some time on the farm.

7. After the harvest season, clean and protect the drying surface and equipment as appropriate. Before drying commences, inspect, repair, clean and commission the equipment, and the on-farm store or go-down. This includes easily over-looked items such as baskets, tarpaulins, rakes, barrows, sacks, stitching cord etc. – develop a checklist.

4.5 Cherry / Parchment Handling and Local Trading

Handling coffee in local trading varies a great deal in different producer countries both with respect to the chain structure and how the functions are executed. These functions include various value-added operations such as removal of remaining fruit tissues, cleaning, sorting, grading (into size classes) re-bagging, sometimes re-drying. It also includes storage and transport. In general it is in the form of green bean that coffee is traded.

Throughout this period the coffee must be protected from degradation, re-wetting, cross-contamination and, indeed should be improved through sorting and cleaning. Sale and shipment to a roaster ends this stage of the 'coffee chain'.

In storage, coffee will continue to dry if the air is drier than the coffee (a relative humidity less than about 60%) but if the air is more humid than the coffee (a relative humidity of more than about 80%) the coffee will begin to absorb water. Since storage periods can extend for a considerable length of time, even very slow changes can become problematic. Routes of re-wetting include moisture migration from damp floors and walls, leaks or wind-driven rain, dead air, and blending of dry with wet coffee. These are all controllable by following good practices in adequate facilities complemented with routine monitoring so to diagnose and act on a problem before the consequences emerge.

Moisture content is the principle parameter for predicting storability and an important part of assessing the current status of a coffee lot. Few farmers have moisture meters, used to make rapid determinations of moisture content, but they are more common amongst traders. Meters make an indirect estimate based on the electronic properties of coffee and are calibrated to one or a few samples of known (typically by the oven drying method) moisture content.

Their veracity is subject to several limitations aside from sampling, which affects all methods. Coffee can differ significantly between lots according to physiological and processing historical differences and these variations cause unexpected errors in the moisture determination by meters. In addition, the equipment drifts off calibration, could be maliciously adjusted off calibration and is subject to errors of use due to inadequate training. The use of these instruments is deceptively simple but it is not a foolproof or trivial measurement.

Aside from storage certain value-added functions will be conducted but it is impossible to generalise as to who and when the several functions are executed as coffee moves from the farm to the exporter because the various sectors differ widely. The coffee must be de-hulled or de-husked which may be done by the farmer or not, it may change hands several times, get blended with other coffees, get re-dried, get sorted in any one of several ways and graded (sorted into size classes) get cleaned polished and weighed into sacks.

Results, based on lower grades of coffee, have indicated that certain defect classes can contain highly elevated OTA content. This is by no means a universal observation and further investigation is urgently required to clarify the relationship between types of defects and OTA contamination. In the meanwhile there is a case for special handling of defects implicated in OTA risk. Tolerance for such defects in sorted green bean should be low and the out-sorted defect beans should not be re-blended into clean coffee or sold to directly to roasters unless direct OTA analysis, with a suitable sampling plan has shown them to be acceptable on public health grounds.

Between stakeholders there is, of course, a transportation step. Depending on the conditions of roads and remoteness, coffee may be transported locally from place to place moving around the highlands on motorbikes, jeeps, lorries or trains or taken directly to the harbour-based exporters. This last transfer implies a significant climatic change, which could require additional measures to avoid rewetting of coffee.

All parts of the production chain are, of course, sensitive to market forces. The local market is the part of the production chain, perhaps most sensitive to changes in demand. If there is a demand for coffee that has been handled according to hygiene recommendations, practices will be undertaken to supply it. This means the potential for influencing practices through regulatory and non-regulatory mechanisms is at its highest, a fact that should be taken under consideration by concerned authorities. Ensuring that producers reliably operate in a way that assures the safety of their product should be the overriding consideration of any intervention.

Each of the stakeholders can contribute to protection of the coffee as it passes along the chain by establishing procedures to avoid accepting suspect coffee and avoiding practices that could contribute to a downstream problem. Once dried, the coffee must be protected from re-absorbing water, whether through contact with liquid water, blending with wet lots of coffee, absorption from damp surfaces or air or through 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 forms another imperative.

1. Each operator should establish minimum requirements related to the hygienic condition of coffee presented for sale as well as a method of rapid assessment, before purchase, to assure that coffee conforms to established minimum acceptable criteria.

    - To the extent possible, develop a list of approved suppliers who adhere to recommended hygiene practice.

    - Establish a routine for rapid assessment of in-coming coffee to include, a method of sampling that presents a representative sub-sample of the in-coming lot for moisture content determination, defect levels, general physical quality assessment and signs of mouldiness (visual or smell).

    - Use a spear to remove coffee from each sack and combine into one sub-sample. The sampling method must account for the fact that a lot may be an agglomeration or a blending of different sources so each bag must be sampled. A spear is the most convenient tool for assembling a representative sample and the uniformity of the lot should be assessed by visual impression as this is made.

    - If coffee is delivered in bulk, make up the sample by removing small aliquots regularly during unloading or with a specially adapted long spear if sampling is to precede unloading.

    - Use a well maintained and calibrated moisture meter to estimate moisture content. Moisture content is a good predictor of storability but not of past handling.

    - Aside from the basic records of purchase and sale where weights and prices will be recorded, maintain a complete record of the evaluations, moisture content, location of origin, and any feed-back from downstream (e.g. reports of cup quality, curing reports, complaints) that you may become aware of.

    - Improve the criteria according to which in-coming coffee is assessed based on an annual review of the records. Match as much as possible the receiving assessments with the outcome of more detailed or specific assessments. Of course, the extent to which this is possible is limited by the need to pool batches of coffee.

2. The design and structure of the storage facilities play an important role in maintaining dryness and uniformity of the stored coffee. Storage facilities do not have to be expensive structures but they must be sound:

- The best facility has a high ceiling and ample air circulation, cement floor with a damp-course and is not subject to local flooding, even during heavy rains. Assure the roof and any windows are sound and prevent water ingress. If possible, route any water supply around the storage area so any plumbing problems that might arise do not wet the coffee.

- Stored coffee should not be exposed to direct sunlight or located where there could be local heating that could lead to temperature differentials and water migration.

- If coffee is stored in bulk, the best arrangement is purpose-built silos with elevators. Less expensive but also effective for bulk storage is the slatted wooden bin ('*tuhla*'), which are not part of the outside walls and chocked up above the floor. A door formed of removable short slats held in rails allows convenient filling and removal of the coffee.

3. The objective of operating a storage facility is to optimise the organisation of the facility so that cross contamination and the reintroduction of moisture is prevented and execution of receiving, sale and value-added operations are facilitated. The quality of the product has to be preserved until it is sold to the next stakeholder in the marketing chain.

   - Maintain records of receiving so that the initial condition and age of all stocks is known.

   - If sacks are used for storage, do not stack them directly against walls and arrange them so that air can circulate freely. Use pallets to prevent direct contact with the floor.

   - Cleaning and maintenance programmes should be implemented to ensure that storage facilities are periodically inspected, cleaned and renewed.

   - Facility inspection should include checks for evidence of the coffee weevil. These insects can only survive in coffee too wet for suitable storage so an infestation signals the presence of wet coffee. Remedial measures should include eradication of the insect and correction of high-moisture problem.

   - Many operations, including farms, will need to maintain a separation of coffee types so they should plan the storage area and labelling system to accommodate this requirement. Coffee stores, including on-farm storage areas, should not be used for the storage of non-food materials that could lead to contamination or taints.

   - If appropriate to the period of storage, institute a monthly check of moisture content measurement of the stocks and take action accordingly. Possible remedial action in case of unacceptable moisture uptake from surrounding air could include activation of extractor fans or re-drying.

4. Cleaning and sorting of coffee should not result in physical damage to coffee that could make it more susceptible to contamination/deterioration, should not

introduce new contamination and should assure reduction of undesirable materials to acceptable levels, in accordance with pre-determined criteria.

- Cleaning and maintenance programmes should be implemented to ensure that the facility and equipment are inspected, maintained and thoroughly cleaned at regular intervals.

- When cleaning and sorting coffee is combined with storage, consideration should be given to measures, such as partition walls or extractor fans, to avoid contamination of post-cured coffee with the curing by-products of dust and foreign matter.

- Remove defects from main-crop production stream. Such off-grades should either be discarded or subject to screening before inclusion into to the human food chain. OTA can occur in coffee of any class, grade or origin and no certain pattern has emerged relating its occurrence to any region, practice or circumstance. However, its distribution within the classes of beans separated from bulk coffee is not uniform and there is evidence that defect beans and husk (also considered as a defect) sometimes contain substantially more OTA than the corresponding sound beans. Likewise, silverskin can contain a disproportionate amount of OTA compared to the sound bean. National authorities should provide clear guidance on the basis of further investigations of OTA contamination of defects.

5. Transport of coffee can be considered as an extension of storage of coffee but introduces distinct practical challenges in meeting the storage strictures of avoidance of re-wetting, from whatever source, maintaining uniformity of temperature and preventing contamination by non-food foreign materials.

- Where appropriate operators should develop a list of approved transport service-providers who operate in a way that is consistent with good hygiene practices for transport of coffee.

- Inspect the vehicle for residues from previous loads and holes that could allow penetration of water or exhaust fumes to the cargo. Pay particular attention to the floor and around wheel wells since water from the road surface, even after light rains, could be channelled into the cargo bay by the wheels.

- Regular maintenance of the vehicle is particularly important since a breakdown could lead to unexpected exposure in the open.

- The longer the period in transport, the more important is the condition of the vehicle or container and the requirements of their use.

4.6 International Transportation

Coffee is only transported from producer to consumer nations in bulk, mostly in containers holding from 18 to 22 tonnes depending on whether the coffee is loaded in sacks or as bulk. Even well-dried coffee in these volumes contains a great deal of water that, as long as it remains evenly distributed, poses no problem. However, temperature fluctuations can cause condensation and local re-wetting and standing temperature gradients can cause redistribution of water and lead to fungal outgrowth.

1. Loading and off-loading areas should be covered to protect coffee from rain.

2. Assure that coffee intended for export is dried uniformly and below 12% mc (wb). Check that the coffee is free of foreign matter and excessive defect beans, according to classification.

3. Inspect the empty containers for residues from previous loads or moisture. Check for obvious structural damage that could lead to a further failure during loading onto ship. Check for evidence of minor structural damage that, never the less, could allow the entry of water.

4. Load coffee preferentially in bulk in a sealable plastic liner – taking care that the liner is well away from the roof of the container.

5. If sacks are to be used, stack them so that the stacks cross over for mutual support and empty vertical columns (chimneys) are not formed. Cover the top layer of sacks with heavy cardboard to absorb any condensation that might form despite precautions. Silica gel packages are also sometimes used to absorb moisture in the air. Their efficacy is unknown and protection against contamination of the coffee by the silica gel must be assured.

6. Coffee is best shipped in a protected location aboard ship out of direct sun because direct sun will cause local heating of the container.