

# Quality control for stored coffee and cocoa

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**M**any commodities are harvested, stored and sold as seed but coffee and cocoa are unique in the nature of on-farm primary processing and the condition of the commodities produced. The sequential steps in on-farm processing for coffee (wet or dry processing) and cocoa (fermentation and drying) are essential for the manufacture of high quality coffee beverage and chocolate.

Fresh mucilage covered cocoa beans undergo heat-generating microbial fermentation followed by natural

or artificial drying. Most Arabica and some Robusta coffee cherry is wet processed (pulped, washed, dried and hulled) while the vast majority of Robusta coffee, together with most Brazilian Arabica coffee, is dry processed (dried and hulled). The finished on-farm products are cured cocoa beans and green coffee.

Primary processing of cocoa and coffee activates and accentuates the taste and aroma compounds which underpin market value and define consumer acceptance. The drying dimensions and storage conditions encountered along the coffee and cocoa processes are essential to the long term integrity of these commodities.

Failure to achieve and maintain bean moisture contents below established critical levels, risks a rapid loss of integrity, quality and commercial value. Damage and deterioration is due to feeding by insect pests and the metabolic activities of microbes, in particular a small and select but highly damaging group of mycotoxin producing fungal moulds.

## Pace of change

Physical and physiological integrity of freshly harvested coffee and cocoa is compromised by on farm processing. Cured cocoa beans no longer respire because the once living seeds have been killed by the heat of microbial fermentation.

Processed coffee and cocoa beans will freely furnish the taste, aroma, and other vital chemicals required in the manufacture of coffee beverage and chocolate but their now more porous structure and condition is a 'double edged sword'. What can easily exit the beans can just as easily enter and this means cured coffee and cocoa is at high risk of damage from biotic (biological) as well as abiotic (physical and chemical) agents. Being flavour dependent commodities, they are economically sensitive to any damage or deterioration. Mycotoxins as acutely toxic signature chemicals of

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Only clean and disease free ripe cherry should be harvested for processing. Mould growth and mycotoxin contamination can start as early as the unripe green coffee berry stage (Picture Dr Terry Mabbett)



Full ripe and visibly healthy pods give the best results in cured cocoa beans (fermented and dried). (Picture Dr Terry Mabbett)



*Fallen and soil contaminated coffee cherry is a major source of mould fungi and mycotoxin contamination (Picture Alan Lowes, Omex)*

specific fungal moulds, are unique in presenting chemical risks and hazards biological in origin.

Aggravating the risk to coffee and cocoa in store and transit, is the rapidity and magnitude of any change in temperature and humidity. These physical factors set the scene for conditions experienced in store and transit during movement from place of production, to point of use.

Both coffee and cocoa are tropical crops largely grown in countries with Equatorial type climates but for historical and economic reasons, are mostly manufactured and consumed in cool temperate countries. Being processed commodities, they have a much longer 'shelf-life' than cereal grains and oilseeds. As such coffee and cocoa are stored for much longer periods but the longer the storage period, the more they are at risk from damage and deterioration.

#### Interacting risk factors

Interacting groups of factors which pose a potential threat to the integrity and quality of stored coffee and cocoa beans are three fold – physical and chemical (both abiotic) and pests and pathogens (biotic). Primary physical factors, are temperature and relative humidity which cause secondary problems such as condensation and surface moisture. Examples of chemical factors that can compromise the quality of stored coffee and cocoa are:

- chemical residues of pesticides applied in the field or in store to control insect pests
- contaminating oils in jute sacks, used to pack the beans
- chemicals stored in the same area as cocoa and coffee especially if volatile with intrinsically strong odours

Biological factors including insect pests and fungal moulds are invariably present but require the interactive intervention of physical factors before they can grow into economically-damaging problems. Insect pest explosions are triggered by high temperature and humidity, while accelerated activity in mould fungi and bacteria, is encouraged by high humidity and the presence of free water as surface moisture.

Different types of deteriorative organism affecting coffee and cocoa in store require different levels of relative humidity to initiate and main-

tain normal growth and development. Bacteria, fungal moulds (including mycotoxin producers) and mites require a relative humidity level in excess of 90%, 70% and 60% respectively. Depending on class and species, insect pests require humidity within a 30-50% range.

#### Bean moisture and relative humidity

Moisture inside stored cocoa and coffee beans evaporates to establish an equilibrium relative humidity (ERH) with the air outside the container or storage structure. Excessive moisture content will generate and establish a correspondingly high ERH to encourage insect pest and fungal mould populations. Most moisture content recommendations for coffee and cocoa come in a range of values, as % w/w [weight/weight] and expressed in g/kg, but store managers should aim for a fixed figure and err on the side of caution.

For safe storage of green coffee, the bean moisture content should not exceed 11.0% w/w. A 2.0% rise to 13.0% w/w will generate an ERH approaching 75% within the storage structure, which is sufficient to support a variety of so called 'dry moulds' including mycotoxin synthesisers. ERH levels exceeding 85% (equivalent to a bean moisture content of 18.5% w/w) supports the growth of yeasts and bacteria leading to tainting and off-flavours associated with the fermentation activity of these wet-growth microbes.

Cocoa beans are most sensitive to changes in relative humidity because like table salt, they are hygroscopic [actively absorb water from the air]. The maximum moisture content of cocoa beans required to secure safe storage is just 8.0% w/w. Moisture levels much above this figure encourage mould growth and musty odours. Free fatty acid content inside the bean is elevated with serious consequences for the cocoa butter fraction and chocolate manufacture.

However, the overall exact situation regarding bean moisture content and its effect on humidity is not as cut and dried as it first seems. This is because not all the water inside the bean will be active in generating an ERH in the surrounding air. More recent consid-



*Use of visibly diseased pods may result in off flavours and taints and mycotoxin contamination in cured beans further down the chain (Picture Dr Terry Mabbett)*



Relatively high numbers of visibly diseased pods are often seen on trees. These should be discarded if quality control problems further down the line are to be avoided. (Picture Dr Terry Mabbett)

erations and calculations differentiate between bound and unbound water in coffee and cocoa beans and focus on an entity called water activity [aw.] Water activity is regarded as a more meaningful measure of ERH which determines activity at insect, fungal, bacterial and enzymatic levels.

Scale of water activity extends from 0 (bone dry) to 1.0 (pure water). ERH (equilibrium relative humidity) is obtained by multiplying [aw] by 100. Thus dried green coffee with an [aw] of 0.6 has an equivalent ERH of 60% which is below the level at which moulds including the mycotoxin producers can grow.

#### Chemical risks

Cocoa yield and production is constrained by a wide range of insect pests and pathogens. Exports of cured cocoa beans can be equally constrained by pesticide residues. The use of pesticides e.g. by farmers which are not approved by the importing country, or the too frequent and high dose application of approved pesticides, will cause this potentially serious problem. Major importing countries have lists of chemical pesticides which must not be used in cocoa cultivation and maximum residue levels (MRLs) for those pesticides which are approved.

Chemical pesticides used in the cultivation of cocoa can undermine processed products in other ways. Cocoa grown in West Africa suffers heavy attack from sucking pests called mirids (capsids). Insecticides used to control mirids will invariably have a high fumigant activity for efficient pest knockdown but this property may go hand in hand with strong odours that leave taints and off-flavours in the beans. Lindane (gamma HCH) which is now largely banned, caused taint and off flavours in cured cocoa beans.

#### Insect storage pests

A large number of different insect storage pests will nibble at cocoa and a handful at coffee but each stored commodity only suffers attack from one major insect pest, although in cocoa two distinct species of the same genus are involved. The Coffee Bean Weevil (*Araecerus fasciculatus*) is the culprit in coffee and the larvae of *Ephestia*

moths, for cocoa. *Ephestia cautella* (Cocoa Moth) is the main storage pest in tropical cocoa origin countries, while closely related *Ephestia elutella* (the Warehouse Moth) takes over as the major pest when cured cocoa reaches cool temperate destinations.

Disinfestation of coffee and cocoa in store, using chemical insecticides to kill insect pests, is a risky business because the commodities, which are now nearer to the manufacturer and consumer, are more likely to fall foul of residue regulations and restrictions. This once widely practised routine control measure, has largely been replaced with pest monitoring and pest reduction programmes using pheromone (insect attractant) loaded traps.

Many storage and transit systems employ modified atmosphere storage. An inert gas such as carbon dioxide or nitrogen is introduced into a hermetically sealed structure containing the coffee or cocoa beans. Any insects present or hatching thereafter are essentially killed by asphyxiation.

#### Moulds and mycotoxins

Mycotoxins, which are the signature chemicals of specific fungal moulds pose the single biggest threat to coffee and cocoa, with the potential to cause a wide range of acute health conditions in trace amounts [ppm (parts per million) and ppb (parts per billion)], for consumers of contaminated products. The presence of mycotoxins in concentrations exceeding the maximum allowable level stipulated by importing countries and manufacturers can completely destroy marketability.

There is a wide spectrum of different fungal moulds synthesising a correspondingly wide range of mycotoxins but just one specific mycotoxin, from two main fungal moulds, affects coffee and cocoa. Ochratoxin A [OTA] is well established as a serious problem in coffee and more recently recognised as an increasing problem for cocoa.

The two main fungal moulds with the capacity to synthesise OTA are *Aspergillus ochraceus*, which is widespread and frequent in the tropical coffee producing countries, and *Penicillium verrucosum* which predominates in temperate climates. OTA is associated with a raft of health problems showing up in test animals



Green Coffee remains at high risk of mycotoxin contamination and should be regularly tested

and including nephrotoxicity (kidney damage) and carcinogenesis (tumour formation) in pigs, dogs and rats.

Mycotoxins are difficult to destroy and will remain at detectable levels after exposure to coffee and cocoa processing including high temperature roasting. The only way to ensure coffee and cocoa remains as free as possible from OTA contamination is to exclude the moulds responsible for its production right along the chain, from the tree to the consumer. Operation of HACCP (Hazard Analysis of Critical Control Points) is now standard practice in coffee production worldwide; from ripe cherries on the tree or soil, to green coffee beans in store and awaiting manufacture. HACCP allows farmers, managers and scientists to pin-point danger zones and to take the necessary action (e.g. proper drying), to avoid or minimize mould growth and OTA synthesis.

Underpinning the success of HACCP is continual progress in the development of increasingly sensitive and accurate mycotoxin testing equipment. Such equipment is widely used on site and in the laboratory to quantify and monitor mycotoxins in ppm and ppb. OTA is perfectly capable of causing extensive damage to human metabolism in such minute amounts. Exporters, shippers, traders and importers and coffee manufacturers monitor mycotoxin concentrations in coffee and cocoa to ensure the commodity conforms to maximum allowable levels of OTA. For instance, maximum allowable limits set by the European Commission (EC) in 2004,

were 5 ppb (5µg/kg) for roast and ground coffee and 10 ppb (10µg/kg) for soluble (instant) coffee.

Stripping away OTA uncertainty What's in store for coffee and cocoa is the near certainty of even stricter and more stringent maximum allowable limits for OTA. Only way forward is even more sensitive and accurate OTA testing technology and equipment. High sensitivity of OTA testing is critical but clearly not enough. Tests must be carried out as far upstream as possible and therefore should be suitable for use by farmers and primary processors on-site, to prevent early introduction of OTA into international supply chains.

Although laboratory methods using fluorometry or HPLC with an immunoaffinity column are widely accepted and available from VICAM and other vendors, there is new technology being developed which serves the field and non-technical user and is suitable for producers and buying operations, as well as on-site laboratories: quantitative lateral flow strip tests which are now offered by test kit manufacturers. Lateral flow diagnostic tests eliminate the need for highly skilled technical users which means that accurate results may be obtained at growing, buying and processing points along the chain of custody for green and roasted coffee.

The VICAM Vertu® Lateral Flow Reader is one example of technology at the forefront of current drives to identify and quantify OTA hazards at critical control points and as far back



*Portable mycotoxin testing equipment used to monitor green coffee and cured cocoa for ochratoxin A – such as the VICAM Vertu® Lateral Flow Reader and Ochra-V™ Strip Test shown here – is quick and convenient*

along the supply chain as possible. VICAM\*\* has gone one stage further with introduction of a 7-minute on-site strip test for ochratoxin A (OTA) which accurately detects OTA over a wide range (0-100 ppb) and with sensitivity as low as 5ppb. VICAM Ochra-V™ strip test was designed for use with the Vertu® Lateral Flow Reader and may be implemented with little or no on-site training or expertise required. This novel test employs the highly sensitive and selective monoclonal antibodies required to accurately measure OTA in samples of coffee and for on-site sampling by non-scientific users.

It is innovations from technology providers like VICAM that will continue to enable producers worldwide to measure the quality and suitability of their coffee and cocoa for internal quality and export regulatory requirements now and for years to come.

Further information and details on the VICAM Vertu® Lateral Flow Reader and the VICAM Ochra-V™ strip test can be obtained from VICAM, A Waters Business, 34 Maple Street, Milford, MA 01757. [www.vicam.com](http://www.vicam.com)

\*\*VICAM, A Waters Business based in Milford, Massachusetts, USA.

