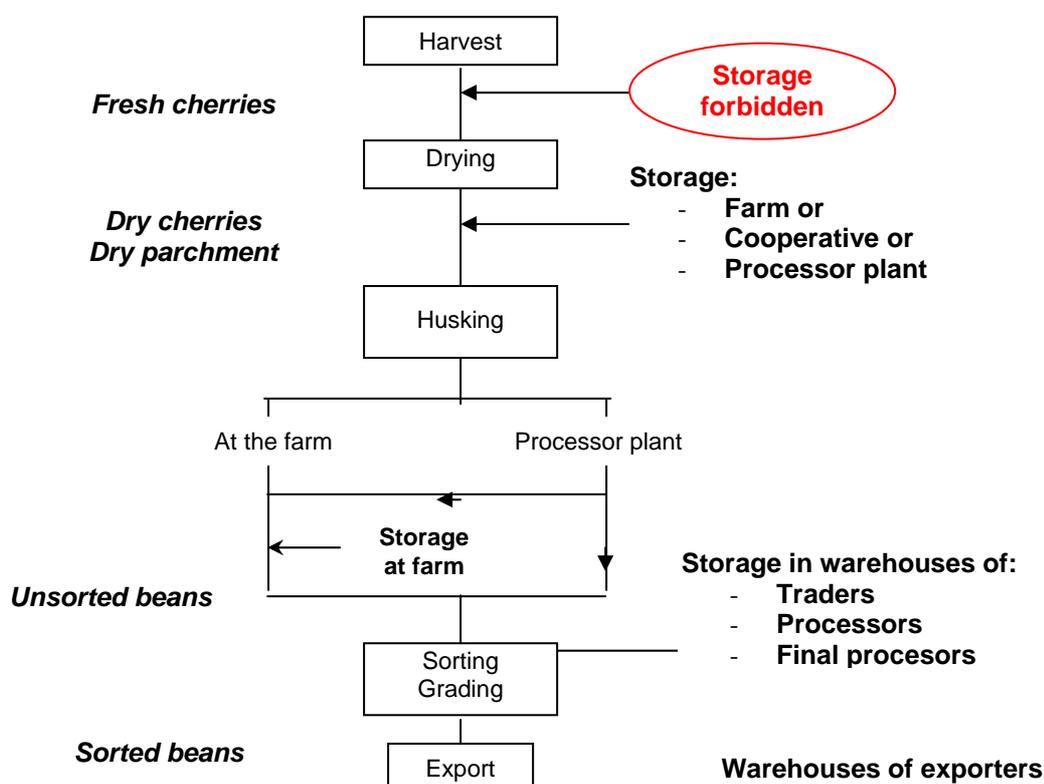


Storage of Coffee

1. Steps in the processing / marketing chain where storage occurs:

Fig. 1 - Storage steps within the coffee chain



The diagram above gives a general view of the steps when coffee is stored, and which type of coffee is stored depending of the structure of the coffee chain. Even though the actual situation varies considerably within and between countries, this diagram highlights that fact that storage often occurs at several points along the coffee chain.

Storage operations are important from the point of view of ochratoxin A (OTA) prevention and quality assurance. The 'time' element involved in storage operations provides an opportunity for microbiological and biochemical processes to lead to quality deterioration if conditions of storage – particularly temperature and relative humidity – permit.

Prevailing climatic conditions in most coffee producing countries – high temperature and humidity – mean that poor storage management is an important factor to be considered in preventing OTA contamination of coffee.

Storage conditions, including both facilities and practices, are often worse when storage occurs in upstream steps by small-scale farmers and traders. Those who are responsible for promoting safe handling of coffee throughout the chain must

be aware of where the main problems lie, and advise on realistic and holistic approaches to address them.

2. Poor Moisture Management During Storage: Implications for fungal growth and general quality loss

This section reviews a few published studies showing the impact of 'high' moisture storage on fungal development and general quality deterioration.

In one laboratory study¹, small batches of coffee were 'conditioned' at a range of relative humidities (RH) at 26°C. Once the target RH was reached, changes in selected quality factors were monitored over a period of 200 days. The coffee equilibrated at 92% RH showed a rapid increase of defects and loss of cup quality during the period of equilibration even before the actual start of the storage period. Quality losses in samples equilibrated at 72% and 82% RH, in terms of physical defects and cup quality, were also evident within 50 days of storage. Coffee stored at RH less than 70% were stable for all measured quality criteria.

Another study² reports the evolution of fungi during storage as follows:

- Fungal community (in CFU/g of beans) increased by 1700 times in 6 days at a RH of 95%, 400 times in 16 days at a RH of 90%, 6 times in 37 days at a RH of 80% and 5 times in 100 days at a RH of 75%. The community remained stable at a RH of 60 %;
- At highest relative humidities (90 and 95%), *Aspergillus versicolor* and *Aspergillus ochraceus* prevail whereas *Aspergillus niger* growth slows down.

Palacios-Carabrera et al. (2004)³ report that OTA production occurs very rapidly and large quantities of OTA were already present at the 39th day on artificially contaminated beans held at levels of RH above 80%. With un-inoculated beans, a small amount of OTA was produced after 90 days. This study concludes that the relative humidity in the overwhelmingly important factor influencing risk of OTA production in stored coffee where OTA-producers are present.

¹ Dos Santos A.C., Hahn D., Cahagnier B., Drapron R., Guilbot A., Lefebvre J., Multon J.L., Poisson J., Trentesaux E. 1971. Etude de l'évolution de plusieurs caractéristiques d'un café Arabica au cours d'un stockage expérimental effectué à cinq humidités relatives différentes. *Café Cacao Thé* vol. 15 (4), p. 329-340.

² Multon J.L., Poisson J., Cahagnier B., Hahn D., Barel M., Dos Santos A.C. 1974. Evolution de plusieurs caractéristiques d'un café Arabica au cours d'un stockage expérimental effectué à cinq humidités relatives et quatre températures différentes. *Café Cacao Thé*. vol.18 (2), p. 121-132.

³ Palacios-Cabrera H., Taniwaki M.H., Menezes H.C., Iamanaka B.T. 2004. The production of OTA by *Aspergillus ochraceus* in raw coffee at different equilibrium relative humidity and under alternating temperatures, *Elsevier Ltd*, p. 531-535.

3. Good Storage Management:

3.1. Receiving coffee into storage

An important recommendation for safe storage is to ensure that products accepted into storage are sufficiently dry (for coffee beans this is around 11-12.5% mc on a dry weight basis). In several countries regulations guide and limit the maximum moisture content of coffee in the domestic marketing chain. The moisture content of dry cherry might be slightly higher – between 12-13.5% - without supporting mould growth and ochratoxin formation (*see also: 'Relationship between moisture content and water activity (A_w) in different forms of coffee' [.pdf], found in the Support Documentation area of this Section*).

Moisture content of different forms of coffee corresponding to a A_w of 0.80		
Types of coffee	Confidence interval	
	± 5%	± 1%
Robusta in cherries	≈15,7	≈14,0
Arabica in cherries	≈15,6	≈14,7
Robusta in parchment	≈14,9	≈13,7
Arabica in parchment	≈15,0	≈13,8

Given the importance of this consideration, it is important that operators within the coffee marketing chain be able to determine whether coffee is at an acceptable level of moisture. This means that they must have access to appropriate moisture-measuring equipment and technical support to ensure that the measurements are being made correctly (*this is discussed in further detail in Chapter 14 ('Determination of moisture content') of the article 'Hygienic coffee drying' [.pdf], found in the Support Documentation area of this Section of the training resource*).

Other important factors to be checked when receiving dry coffee into storage are:

- Acceptable levels of extraneous materials: in the case of green bean storage, the presence of husk material could be an important source of OTA-producing mould that might grow and produce toxin if storage conditions allow. The initial level of mould contamination should be kept to a minimum.
- Insect infestation: apart from direct quality loss due to elevated levels of insect damaged beans, there is a risk that the activity of insects and other pests can lead to increased moisture in the storage area generally, or in localised spots, where mould growth and mycotoxin production might then be supported.



Criteria for accepting coffee into storage should be clearly defined and actions to be taken when incoming coffee does not meet requirements (rejection, cleaning, etc).

Fig. 2 - Inspection of incoming coffee before acceptance into storage

3.2. Preventing re-wetting of coffee during storage

The moisture content of foods in dry product storage is not static: there is moisture exchange between the product and the surrounding air. During storage, the coffee seeks to establish equilibrium with the air in the warehouse, so that it will take up or release water from/to the surrounding atmosphere depending of the degree of 'dryness' of the coffee and the relative humidity of the air.

This fact must be considered in establishing good storage management practices, especially seeing that many coffee-producing countries are hot and humid at least part of the year.

Apart from passive uptake from the surrounding air, re-wetting of coffee might be due to other sources such as ingress of water from rain or other sources, or from respiratory activity of insects or other pests. Studies have been undertaken to better understand the phenomena of water adsorption and desorption in coffee during storage, so as to support sound advice to various stakeholders on good storage practices.

3.2.1. Storage at farm or small trader level

These very small-scale operators generally do not have 'ideal' storage facilities. In some cases they may have access to cooperative or community storage structures, but generally they utilise simple existing structures for storage of their products. Often the facilities are poorly ventilated with no exhaust fans or any other means of controlling the relative humidity of the storage air. A study⁴ in Cameroon showed that moisture content of coffee stored in bags, initially at 13%, increased up to 15% after 3 months storage in warehouses of small traders. In a small storage trial in Côte d'Ivoire under the global coffee project, where bags of dry coffee cherry were placed in a small trader's storage room, moisture levels rose from about 12% to almost 18% within 4 months.

One strategy for minimising quality deterioration during storage at this level is to promote shorter storage times at this stage of the chain. Government policies and buying policies of downstream operators in the private sector can influence this practice. It is still necessary to provide guidance on the optimising storage on-farm or at small traders. Guidance on some key issues is given below.

Should coffee be stored in the form of dry cherry, parchment or green bean?

Storage trials that were carried out during the global coffee project did not demonstrate any differences in internal contamination with OTA-producing fungi or in levels of OTA in the coffee bean when coffee was stored as dry cherry, parchment or green bean for up to one year. The form in which the coffee is stored – if the coffee is adequately dry – does not seem to affect OTA contamination. Notably the cherry husk has been found to be highly contaminated with OTA-producing mould and pre-formed OTA. However, in the intact dried cherry, where re-wetting is prevented, the presence of contaminated husk does not lead to contamination of the bean. In fact, the presence of the

⁴ Sauda. 1957. Etude sur le stockage des cafés et cacao à Douala (Cameroun) *Café Cacao Thé* vol. 1 (1), p. 10-17.

husk or the parchment – may provide a physical barrier against contamination of the bean. A possible exception could be the storage of dried split cherry, where physical damage to the bean could increase the likelihood of contamination from the husk.

What type of bags should be used to store coffee?

Jute bags are preferred for coffee storage as they allow transmission of water vapour. Woven polythene bags are also widely used, though, while they still do allow some gaseous exchange with the external environment, it is more difficult for humid air from within the bag to escape. Impervious plastic bags should not be used to store coffee.

Apart from the question of water vapour transmission, there is also a potential problem of cross contamination associated with bags used to store coffee. Farmers and small traders often re-use bags that previously contained fertilizer, animal feeds or other farm inputs. Adequate care must be used to eliminate any opportunity for contaminating the coffee with hazardous materials.

Simple guidance on storage practice

Even with non-ideal storage structures, simple storage management practices can reduce potential problems:

- In cases where the surrounding air is at high RH, build tight-fitting stacks of coffee bags, to minimise moisture exchange with the air. If the surrounding air is dry (RH<78%) then the stacks of coffee should facilitate as much as possible passage of air;
- Bags should be piled on pallets or similar structures to prevent re-wetting from the floor and to permit better air circulation;
- Bags should be piled away from walls to avoid re-wetting by condensation;
- Storage area should be well ventilated;
- Hazardous or odorous materials should not be held in the vicinity of the coffee storage area.

3.2.2. Dedicated coffee storage facilities

Coffee storage may be in bulk or in bags. We will not be discussing exhaustively here the merits or demerits of either type of storage, but we will outline considerations for either type of storage that have an impact on the safety of and suitability for coffee.

Bulk coffee storage

In some cases, operators choose to store coffee in bulk rather than in bags. The choice of bulk storage may be based on a range of factors including: reduced storage space requirements; reduced labour costs in bagging and unbagging coffee; compatibility with systems of bulk containerization; levelling of moisture content in batches of coffee. Some consideration of bulk storage that can influence the quality and safety of coffee are discussed below.



Bulk storage in silos

Poorly designed or located silos can create quality problems. In closed, non-aerated silos that are exposed to temperature variations, movement of moisture within the mass of coffee may lead to the formation of 'wetter' zones.

One 15-month study⁵ utilised an air-tight metal silo which was placed outdoors with no insulation. The average moisture content of the coffee beans at the start of the storage period was 11.3% wb. At the end of the storage period, the upper layer of coffee beans was completely covered with mould and had a moisture content of 17.5%. This movement of moisture within the silo was due to the heating of coffee in the metal silo during the day which led to warm, moist air rising to the top of the silo. This re-distribution of moisture creates 'wet zones' within the silo where mould growth and mycotoxin formation is possible.

However, silos do offer opportunities for better control of moisture during storage:

- The surface which is exposed to surrounding atmosphere is smaller with a silo, so in humid environments, water uptake from surrounding air can be minimised;
- Ventilation systems can be installed in silos to blow air through the coffee. Silos are often equipped with fans which can blow air through the coffee at a speed of 3 to 5 m/min. If air blown through the silo is at a very high RH, it would re-humidify the coffee. In cases where coffee has been over dried, some degree of re-humidification may be intentional. More often, the concern is to limit re-uptake of water, and it is therefore important to monitor the RH of the air with a hygrometer. Only when the RH of the air is below 70%, should it be blown through the silo. When necessary, air can be heated to reduce its relative humidity before blowing it through the coffee;
- Silos can be constructed of insulating materials that protect against unwanted temperature variations or located within storage areas that protect from direct exposure with external environment.



Buchelli et al. (1998)⁶ report on changes in moisture content and water activity of green coffee beans stored in bulk silos (air-conditioned, aerated and non-aerated) or in bags over an 8-month period in Thailand. The initial moisture content of the coffee was 13%. Moisture content in the aerated silo was stable over the storage period.

Fig. 3 - Metal silos for green bean storage with aeration systems in an enclosed storage area

⁵ Wilbaux R., Richard M., Hahn D. 1971. Essai de stockage de café vert en silo métallique hermétique. *Café cacao Thé* vol. 15 (3), p. 221-234.

⁶ Bucheli, P., Meyer, I., Pittet, A., Vuataz, G., and Viani, R. 1998. Industrial storage of green robusta coffee under tropical conditions and its impact on raw materials quality and ochratoxin A content. *J. Agric. Food Chem.* 46, p. 4507-4511.

While the evolution of moisture content in the coffee stored in the non-aerated silo was similar to that in the bags. In these cases there was a significant increase in moisture to about 14.8% during the rainy period, which decreased again to about 13% thereafter.

Guidance on management of bulk stores and on the design and construction of silos for on-farm bulk storage of coffee can be found in Chapters 9 and 10 of the article 'Hygienic coffee production' [.pdf], found in the Support Documentation area of this Section of the training resource. This guidance has been developed to respond to the technical support needs of coffee farmers in Brazil, but much of the information could be wider interest.

Other structures for bulk storage



Fig. 4 - Wooden bins constructed for bulk storage of coffee

When bulk storage is effected without the use of silos, risk of moisture uptake or contamination through contact with floors and walls of storage rooms must be minimised. The Brazilian 'thula' is a good example for storage in heap. The thula is a kind of wooden bin built under a shelter or in warehouse. Wood provides good thermal insulation to avoid condensation problems. Ventilated wooden storage bins have also been used by other producer countries.

Whatever the material used in the construction of the storage area, it is essential that the structure prevent entry of rain, be well ventilated so as to avoid condensation, and the floor be raised above the ground so as to improve insulation and protect against flooding. As with any storage facility, cleaning, maintenance and pest control programmes must be routinely implemented if hygienic storage conditions are to be assured. Most of the recommendations for good storage management in Section 4 below are relevant to bulk storage.



Fig. 5 - Example of bad conditions for bulk storage of dry cherry

Warehouses for bagged storage

Storage of coffee in bags is more common than bulk storage. For many coffee handlers the initial investment required to install adequate facilities for bulk storage is prohibitive.

With a good system warehouse management (marking of bags, record keeping and physical organization of store area) the use of bags allows store managers to handle different grades or types of coffee separately, and to identify eliminate small units of coffee if problems are localised in a few bags.

There is a limited capacity to manipulate the RH of air in coffee storage warehouses. Costs associated with air-conditioning or dehumidification are prohibitive for mainstream coffee marketing. It is essential that warehouses have good ventilation so as to prevent condensation of water from humid air causing localised re-wetting, or simply to remove humid air that may lead to generalised moisture uptake by coffee in storage. Apart from features of the warehouse structure (vents in roof and walls, exhaust fans, height of roofing) to facilitate ventilation, also the organization of storage area (bags held on pallets, adequate aisle spacing, spaces between stacks and walls) contributes to the free flow of air and therefore in preventing mould and mycotoxin contamination. Good storage management should include programmes for regular monitoring of RH in the storage area and moisture in stored coffee. Action in the case of high RH in the storage facility might be the turning on of extraction fans. Action in the case of unacceptable moisture levels in the stored coffee might in some cases be re-drying.

Protection against temperature fluctuations is important as has been discussed with other forms of storage. The roof of the storage facility should minimise heat transfer to the storage area. The storage area should be located away from and be totally separated from other operations (such as artificial dryers) that could lead to accumulation of hot, humid air around the stored product.

Prevention of re-wetting of bagged coffee in warehouses also involves ensuring that rain or water from other sources does not enter the facility. The roof must be regularly checked to ensure that it is in a good state of repair, other openings – such as vents and doors – must be constructed in such a way as to prevent entry of water. There should be adequate drainage around the facility to avoid any risk of flooding.

Adequate cleaning and building maintenance programmes are an essential part of preventing access and harbourage of pests which – if they are present in high numbers – can lead to increase moisture in the storage area and can act as vectors for microbiological (and chemical) contamination.

4. Overall Recommendations for Good Storage Management

For all storage systems, good store management aims to maintain the coffee within the 'safe' range of moisture content over the required duration of storage, to protect the product from damage by insects or other pests, and to prevent cross contamination or new contamination from other sources. It also facilitates identification and handling of coffee lots. An outline of key elements of good storage practice is provided below.

Physical facility

- High, insulated roofs with air vents minimise heat transfer to the storage area and facilitate good ventilation;
- Warehouses should be equipped with fans which extract the ambient air inside the warehouse as required;
- Storage area (walls and floors) should be constructed of impermeable, smooth, easily-cleaned materials;



- External surfaces should prevent entry of pests (well-fitting doors (< 0.5 cm space)); no cracks in walls; drains and vents appropriately covered;
- There should be proper lighting in the storage area with protective covering to prevent hazards from broken glass.

Organization of coffee stacks

- Store coffee on pallets and away from walls to facilitate good ventilation and avoid re-wetting through condensation;
- Storage areas should be well demarcated to facilitate identification of coffee lots and to ensure adequate spacing between aisles which contributes to the overall ventilation in the facility and ease of handling of coffee stores.

Avoiding problems of contamination and cross contamination (storage area/bags)

- Coffee husk has been shown to be an important source of OTA mould and pre-formed OTA. Storage facilities should be away from coffee hulling, grading and cleaning operations that could be sources of contamination;
- Dry cherry, parchment and green bean should be stored separately;
- Food-grade bags should be used for the storage of green coffee;
- Clean, dry, odour-free silos should be used for bulk storage of coffee;
- Fuel, pesticides, cleaning compounds and all other potentially harmful and odorous products must NOT be stored in the coffee storage area.

Monitoring of condition of storage environment

- Moisture control of stored coffee should be done on a regular basis for taking corrective actions. Moisture meters should be regularly calibrated by qualified personnel, at least once a year;
- Hygrometers should be used to monitor RH in the storage area;
- Periodic roof inspections are necessary to ensure that there is no possible of leakage or pest entry through the roof;
- Periodic facility inspection is necessary to ensure that gutters, ducts, vents, etc. are clear;
- Periodic facility inspection (internal and external) is necessary to ensure that pest entry and harbourage are under control.

Immediate environs

- The environs of the storage facility should be kept free of vegetation and garbage that could encourage pests and other contamination vectors;
- There should be periodic inspection of the immediate surrounding to ensure that any sources of contamination are under control.

General management considerations

- Coffee should not be accepted into storage unless it meets established and documented minimum criteria (moisture content, extraneous material, etc);



- Documented cleaning programmes must be routinely implemented for the storage area and storage silos and records kept. Procedures for routine cleaning in the storage area should be based on vacuum cleaning as it is dry and minimises the spread of dust-borne contamination;
- There should be a documented programme of pest control and records of related facility checks. If fumigation treatments are used, procedures must be clearly established and records rigorously kept;
- There should be a system of stock rotation, and especially when storage is in a humid area, storage time should be kept to a minimum;
- Records of facility inspections, inspection reports and corrective actions must be maintained.

