



Hygiene Measures in Fruit and Vegetable Storage Warehouses

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There are numerous sources of contamination in storage warehouses. Perishable goods can be contaminated by fungi and bacteria during the growing season, as well as throughout the process, from harvest to storage. Containers used during harvesting and storage, processing and packaging equipment, the air and warehouse walls are other sources of contamination (Moras, 1983).

The presence of plant debris in warehouses also allows micro-organisms to multiply quickly and become a major source of contamination for stored foods. The accumulation of volatile substances originating from perishable foods provides sufficient carbon sources to support the growth of moulds and possibly of certain bacteria. Finally, the water used in the postharvest treatment or to clean warehouses can also be a source of contamination.

THE MICRO-ORGANISMS RESPONSIBLE

Different types of micro-organisms can lead to food spoilage in warehouses. However, bacteria causing rot and fungi causing moulds are the most common.

Bacteria

Bacteria, which cause rot, are single-celled micro-organisms that reproduce by division. If environmental conditions are optimal, the bacteria population can double in 20 to 30 minutes. Bacteria are generally propagated by direct contact between perishable goods or with contaminated surfaces, or else with the water used during treatment before or after storage. Some of these bacteria can be pathogenic for humans, such as *Listeria monocytogenes*, which is sometimes found on certain vegetables.

Fungi

Fungi, which cause mould, can develop on a substrate providing very few nutrients. Unlike bacteria, fungi are visible to the naked eye. They generally reproduce by forming numerous spores, which are easily disseminated by washing channels, by direct contact and particularly by the air. Fungus spores can attach themselves to storage chamber walls and to equipment used in the warehouse (Moras, 1983). The development of mould on walls or ceilings may indicate insufficient insulation or a perforated or poorly installed vapour seal. In this case, even if chemical disinfectants destroy most of the fungi, the long-term solution remains to replace or repair the defective item.



Ceiling of a cold-storage warehouse contaminated because of an accumulation of dust and condensation

Many of these organisms feed on perishable goods and organic matter. In the absence of nutrient sources, they can survive on other materials, such as wood and plastic. When they attack organic matter, bacteria and fungi can give off foul odours (ethylene and other volatile substances) that can change the taste or accelerate the maturation of stored fruit and vegetables. Although it is difficult to completely eliminate these micro-organisms, preventive measures and an appropriate clean-up plan can control their proliferation and greatly reduce the infection rate of perishable goods in storage warehouses.

CLEANING UP THE WAREHOUSE

When they are present in the warehouse, micro-organisms causing rot and mould on fruit and vegetables (Table 1) can be eliminated with an appropriate clean-up plan. The presence of any source of plant material can allow bacteria and fungus spores to survive between two storage periods. Micro-organisms can then grow and lead to major losses when perishable goods are stored. It is thus important to adhere to appropriate hygiene standards in order to reduce losses.

For a clean-up plan to be effective, it must follow certain steps in a specific order. These steps are cleaning, disinfecting, rinsing and drying. The techniques and products used to carry out each step must be adapted to



Grey mould on an onion, caused by *Botrytis cinerea*

treatment systems and storage facilities, whose main components are as follows:

- Floors, walls, ceiling, doors and structural beams;
- Components of refrigeration systems and treatment and handling systems for fruit and vegetables;
- Electrical conduits and light fixtures;
- Water and air pipes and channels and their components (drains, grates);
- Wooden and plastic containers reused for storage of fruit and vegetables;
- Pallets used to handle containers;
- Machinery used in the warehouse;
- Waste containers.

Cleaning

Cleaning is the first step in maintaining a warehouse. It eliminates the plant residues that encourage the growth of micro-organisms. These residues are a major source of contamination for stored goods. Regular elimination of this primary source of inoculum helps to reduce losses in the warehouse.

Debris on the floor can generally be eliminated simply by sweeping it up. However, vigorous brushing can be required when debris have adhered to the walls and ceilings. Thorough dusting is also required to facilitate the subsequent steps. Vacuuming or wetting the surfaces are good ways of getting dust off them without spreading it into the



Onion debris accumulated on the floor of a packing line

air. The remaining matter and dirt can be removed with water and detergent. At this stage, it is important to scour surfaces well to dislodge ground-in dirt.

High-pressure washing with a non-foaming industrial detergent is often the easiest solution. For safety reasons, electrical systems and motors that are not waterproof should be covered.

This first step is very important because the presence of organic matter impedes and can even neutralize the action of disinfectants. In addition, it removes substrates that can promote the growth of micro-organisms in the warehouse. However, many micro-organisms will not be reached by this process, and must be eliminated using disinfectants.

Disinfecting

Premises and packaging materials must be disinfected when no perishable goods are in the warehouse. It is important to cover electrical systems and metal pipes, etc, especially if you use corrosive substances (Lidster *et al.*, 1988).

Disinfecting the warehouse, warehouse equipment and treatment systems should be done with the right products using the proper methods (Table 2). Special care should be taken if there is a high rate of contamination. The disinfectant destroys micro-organisms on surfaces. However, for it to be effective, the conditions of application and contact time must be adhered to strictly.

Disinfectants are often irritating. To avoid discomfort and health problems, it is important to wear effective protective equipment and clothing when using them, including safety glasses, a breathing mask, a waterproof garment, and rubber gloves and boots.

It is also important to read labels carefully before using disinfectants that are approved for this purpose and to follow directions when using them. Special care should be taken to comply with the recommended time lapses between use of disinfectants, airing out the warehouse after disinfecting it, and the entry of new horticultural products to the warehouse. To give the storage chambers a good airing, the doors should be open and outside air forced into the warehouse. Adding an activated-carbon air filter prevents odours from developing in the storage chambers. The

literature suggests that fungicide-based paint be applied to walls to provide additional protection for a number of years (Phillips *et al.*, 1979, Lidster *et al.*, 1988).

Ozone and UV radiation are not effective in disinfecting storage chambers. In addition to being very detrimental to the health, Lidster *et al.* (1988) noted that weak concentrations of ozone (0.5 ppm) can damage perishable goods, plastic, electric wire coverings and rubber-based objects such as pressure seals.

Leaving boxes, pallets, containers and other equipment out in the sun or a strong wind will partially disinfect them.

Fumigants can be used to reach the smallest hidden corners that cannot be reached by conventional methods. However, this method is only effective when used with wet surfaces. It involves considerable health risks and the warehouse must be thoroughly ventilated for several days afterward. In order for it to be effective, great care must be used when fumigating and special precautions should be taken to avoid anyone coming into contact with these products by mistake.

Rinsing

Some disinfectants give off odours that can give an unpleasant taste to fruit and vegetables. Also, the long-acting effect of some of these products can corrode materials forming the warehouse structure and storage equipment. Proper rinsing is therefore essential when certain disinfectants are used (Table 2).

Rinsing involves thoroughly spraying all surfaces treated with disinfectants, starting with the highest ones so that the residues run down toward the floor. Any stagnant water must be eliminated. It is essential to use water of drinking quality so that the warehouse is not recontaminated.

Drying

Drying is the last important step in a warehouse clean-up plan. The goal is to eliminate humidity, which provides ideal conditions for the development of moulds and rot. If the disinfectant used does not require rinsing, drying takes place immediately after disinfecting; otherwise it comes after the rinsing stage.

Table 1. Principle Micro-organisms and Damage that They Cause to Fruit and Vegetables Stored in Warehouses

Fruit/Vegetables	Fungi	Bacteria
Carrots	<i>Alternaria</i> sp. ¹ ; <i>Rhizopus</i> sp. ² ; <i>Sclerotinia sclerotiorum</i> ⁴	<i>Erwinia</i> spp. ³
Celery	<i>Acremonium apii</i> ⁵ ; <i>Botrytis cinerea</i> ⁶	<i>Erwinia</i> spp. ³ ; <i>Pseudomonas</i> spp. ³
Crucifers	<i>Alternaria</i> sp. ¹ ; <i>Botrytis cinerea</i> ⁶	<i>Listeria monocytogenes</i> ¹³ ; <i>Aeromonas</i> sp. ⁷
Fruit in general	<i>Penicillium</i> sp. ⁸	
Vegetables in general		<i>Erwinia</i> spp. ³ ; <i>Pseudomonas</i> spp. ³ ; <i>Yersinia enterocolitica</i> ⁷ ; <i>Aeromonas</i> sp. ⁷ ; <i>Listeria monocytogenes</i> ¹³ .
Onions	<i>Aspergillus</i> sp. ⁹ ; <i>Botrytis cinerea</i> ⁶ , <i>Penicillium</i> spp. ⁸ , <i>Fusarium oxysporum</i> f.sp. <i>cepae</i> ¹⁰	<i>Erwinia</i> spp. ³ ; <i>Pseudomonas</i> spp. ³
Bell peppers	<i>Alternaria</i> sp. ¹	<i>Erwinia</i> spp. ³ ; <i>Pseudomonas</i> spp. ³
Pears	<i>Penicillium expansum</i> ⁸ ; <i>Botrytis cinerea</i> ⁶	
Apples	<i>Penicillium expansum</i> ⁸ ; <i>Botrytis cinerea</i> ⁶ ;	
Potatoes	<i>Fusarium</i> sp. ¹³ ; <i>Phoma</i> sp. ¹²	<i>Erwinia</i> spp. ³ ; <i>Listeria monocytogenes</i> ¹³
Sweet potatoes	<i>Rhizopus</i> sp. ² ; <i>Fusarium</i> sp. ¹¹	<i>Erwinia chrysanthemi</i> ³
Tomatoes	<i>Alternaria</i> sp. ¹ ; <i>Rhizopus</i> sp. ² ; <i>Botrytis cinerea</i> ⁶	<i>Erwinia</i> spp. ³ ; <i>Aeromonas</i> sp. ⁷ ; <i>Pseudomonas</i> spp. ³

1- Alternarian black rot; 2- Black rot; 3- Soft rot on perishable goods; 4- White mould ; 5- Brown stain; 6- Grey mould; 7- Diarrhea in humans; 8- Blue mould; 9- Black mould; 10- Fusarium bulb rot; 11- Fusarium rot; 12- Gangrene; 13- Listeriosis.

Drying involves removing surplus water and giving the storage chambers a good airing. If outside conditions are hot and dry, outside air can be forced inside. Maintaining a high temperature and low humidity rate can help to reduce the growth of mould and bacteria in the warehouse.

INTERVALS BETWEEN CLEAN-UP OPERATIONS

All these steps are indispensable to the warehouse clean-up process. Once the warehouse has been thoroughly cleaned, it is important not to recontaminate it with work boots and soiled protective clothing or agricultural machinery straight from the field. The intervals at which the warehouse must be cleaned depend on the type of storage.

Short-term storage

During short-term storage, such as that for strawberries or beans, hygiene measures should be ongoing. Since these products are very perishable, they promote the growth of saprophytic

micro-organisms. No accumulation of debris should be tolerated. It creates a constant source of contamination which, if not eliminated by preventive measures, can lead to large economic losses.

Long-term storage

As for long-term storage such as that for apples, potatoes and carrots, cleaning should be done immediately following the storage season. All other steps involved in cleaning up the warehouse should be carried out before each storage season begins, especially if there were losses caused by micro-organisms during the last storage period.

It is also important to determine the sources of contamination present in the warehouse, which makes it easier to establish which preventive measures to use. The control of pathogens can be greatly facilitated at the time when warehouses are designed by choosing materials that are easy to wash, eliminating inaccessible places and porous materials, allowing for easy access to ventilation ducts, and

eliminating areas where water can accumulate.

Implementing a warehouse clean-up plan will not solve all problems, but carrying out these measures will greatly reduce losses caused by micro-organisms in fruit and vegetable warehouses.



MAIL ORDERS

This fact sheet can be obtained free of charge from the following address:

Publications
Horticultural R and D Centre
430 boul. Guoin
Saint-Jean-sur-Richelieu, Quebec
CANADA J3B 3E6

Table 2: Disinfectants Approved in Canada for Cleaning of Fruit and Vegetable Warehouses (1999).

Chemical compound	Activity		Inactivated by organic matter	Corrosive	Solution	Exposure time (minutes)	Advantages	Disadvantages
	Bactericide	Fungicide						
Hypochlorides (Javex 5.25 to 6% a.m.)	+	+	Yes	Yes Very corrosive for metal	10 L / 90 L of water	10	Quick action Low cost	Discolours certain materials Odors Irritant Must be changed often Sensitive to the pH of water Can leave an odour on products Rinsing necessary
Quaternary Ammonium (10% a. m.)	++ to +	+	To a slight extent	No	8 to 24 mL / L of water	10	Effective at low temperatures Can be combined with detergents	Do not mix with other products Rinsing necessary
Phenolic compounds (hospital disinfectant)	++	++	To a slight extent	No	See label	10	Residual action	Non volatile residues Rinsing necessary
37% formaldehyde solution	++	± to +	Yes	No	4 L / 100 L of water	30	Broad-spectrum action	Noxious to humans Wear a breathing mask Irritant Air out space after treatment Toxic fumes Leaves an unpleasant odour

Legend: ++ = very effective; + = effective; ± = not very effective
Guide to pest management, 1995-96.