Guide to
Post Harvest Care of Strawberries
in Moldova

USAID
Agribusiness Development Project
Citizens Network for Foreign Affairs

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Introduction

The strawberry (*Fragaria x ananassa*) is one of the highest-valued fruit crops which can be produced in Moldova. Strawberry production is well suited to the agro-climatic conditions throughout the country, but the long-term sustainability of the industry will require continuous improvements in production and postharvest handling technologies, coupled with an extension of the harvest season by cultivar diversification and the use of protected structures.

Although current production volumes are small, excellent potential exists for expansion of the Moldovan strawberry industry to supply domestic and export markets with both fresh and processed products. Development of a strong fresh market industry and a complementary processing industry is important for maximum economic impact. Market opportunities exist both domestically and internationally for those producers who can provide consistent supplies of high quality strawberries.

Strawberries are highly perishable and require careful handling and strict adherence to appropriate postharvest management practices, in order to maintain optimal fruit quality after harvest. For maximum market life, strawberries require rapid removal of field heat coupled with low temperature storage (0 to 1º C) and maintenance of the cold chain during transport and distribution. With optimal postharvest care and the appropriate cultivar, strawberries have a 7 to 10 day market life. In order to realize this potential market life, careful attention must be given to all the details of product handling, packaging, and postharvest temperature and relative humidity management. Appropriate postharvest temperature management is the single most important factor influencing strawberry market life and fruit quality.

This strawberry postharvest care guide is written for strawberry growers in Moldova. The purpose of this guide is to provide comprehensive technical information and recommendations on all aspects of postharvest care of strawberries.

Harvesting

**Morning Harvest is Recommended**

Strawberry harvest should begin early in the morning after dew on the fruit surface has dried. Avoid harvesting strawberries in the afternoon. Strawberry fruit intended for export should not be picked when the pulp temperature exceeds 25º C. Warm fruit will sustain considerable pressure bruising during the picking and handling process. Also, fruit with a high pulp temperature will require more energy and cooling capacity to remove the field heat during the postharvest process. Strawberries should not be harvested when the fruit is wet as this will result in a greater incidence of Botrytis gray mold development.

Maintenance of fruit quality during rainy conditions is difficult due to the high incidence of gray mold development on the fruit and resultant limited shelf life. Many strawberry growers worldwide now cultivate strawberries under protected structures (greenhouses, tunnels, etc.) to avoid fruit quality problems associated with high moisture conditions.

Harvest frequency of the strawberry planting should be every other day in cooler temperate-growing areas like Moldova. However, during unusually warm periods daily harvesting of the soft-ruited cultivars may be necessary.
Harvest Maturity

Strawberries are harvested at different stages of maturity, depending on the cultivar and market preference. Maturity in strawberries is best indexed by external surface color and firmness of the fruit. Fruit of most cultivars destined for export should be harvested when the surface of the fruit is completely red, although fruit from less firm cultivars should be harvested at a lighter red color. Less firm cultivars include Senga Sengana, Polka, and Honoeye.

Firmer cultivars such as Selva and Camarosa should be harvested at a deep red color (Figure 1). The flavor of all cultivars of strawberries is more desirable and sweeter if the fruit are allowed to fully ripen on the plant. Strawberry fruit do not ripen after harvest.

Figure 1. Camarosa harvested at full color.

However, fruit should never be allowed to over-ripen. Over-ripe fruit bruises easily, deteriorates quickly, and will not be able to withstand the rigors of long distance transport. Upon arrival in the destination market, overripe fruit will be soft and have little shelf life. In addition, leakage of cell sap from bruised over-ripe fruit will stain the walls and bottom of the retail market package, and fruit may become infected with decay.

On the other hand, immature fruit will have white shoulders or tips, a whitish inner pulp and very poor flavor quality due to low sugar content (Figure 2). Immature fruit should not be harvested, since it will be low in sugar content and bland in flavor. Sweetness does not increase after harvest in strawberry fruit and white tissues do not turn red. Buyers do not accept strawberries with noticeable amounts of immature fruit and consumers avoid fruit that is not uniformly red.

Figure 2. Fruit harvested immature with white shoulders.

Harvest with Care

Strawberry fruit are very susceptible to bruising, and must be picked with great care. A significant amount of bruising can occur at harvest when the berry is detached and if the picker holds several fruits in one hand prior to transfer to the picking container.

Strawberries should always be picked with the calyx (green part) attached, but the stem may be very short. The fruit should be picked by grasping the stem between the first finger and thumb, followed by pinching the stem between the thumbnail and index finger about 0.5-1.0 cm above the calyx. The fingers should never touch the fleshy part of the fruit.
Touching the fruit will inevitably result in bruising, rendering the strawberries suitable only for juice or jam. These fruits for processing, should be harvested without stems or calyx (green part).

All fruit should be handled very delicately without squeezing. Any squeezing of the fruit will cause bruising and discoloration, with possible leakage of fluids from the impacted area. These fluids are high in soluble sugars which serve as a substrate for Botrytis gray mold development. The fruit should be carefully put into the retail container, avoiding dropping. There should be separate retail containers on the picking cart for field grading the fruit into export quality, domestic quality, processing quality, or waste.

**Field Pack**

The widespread use of transparent plastic containers, holding 250-500g has greatly improved the presentation and quality of strawberries marketed worldwide. Pickers should be properly trained to field pack and size grade the fruit directly into the final retail container at the time of harvest. This is a vital component of a strawberry export operation. Only size-graded, firm-mature fruit should be put into the retail containers designated for export. The fruit should be of equal size – large fruits should not be placed in the same container as small fruits, and the retail container must be large enough to easily hold the required weight of fruit without squashing or damaging it.

Pickers should never put over-ripe, under-ripe, diseased, or insect damaged fruit in the export containers. Grading the fruit directly into the market containers at the time of harvest will reduce the number of times a fruit is touched to only once, thereby minimizing bruising, improving quality, and minimizing costs. (Figure 4).

Figure 4. Field selecting and picking directly into the market container.

A properly trained harvest crew which is capable of field grading the fruit will avoid the necessity to repack the fruit (and handle it twice) in the packinghouse. Handling the fruit just once is the ideal situation. Monitoring of the harvesters and careful field supervision will be critical to the success of the operation and the quality of the strawberry fruit. Picker performance can be extremely variable and some workers may need to be periodically reminded to handle the fruit with greater care. Pickers should not squeeze the berries and should place them gently in the market container. Appearance of the strawberries inside the container is a very important factor influencing market demand.

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1 These small retail packs are placed and transported through the distribution chain inside cardboard or plastic outer boxes, which are specifically designed so that they contain securely, without movement, the designated number of retail containers (eg 6, 8, 12 plastic retail containers inside each box). The cardboard/plastic transport boxes must fit exactly onto the top area of a pallet – usually an international size pallet of 1m x 1.2m. There should be no danger of the boxes extending beyond the edge of the pallet; (boxes overhanging pallets are rapidly weakened and collapse damaging products and making handling impossible.)
Field Sanitation is Important

Good field sanitation is an important aspect of maintaining high percentages of market quality fruit throughout the entire harvest season. Injured, defective, over-ripe, or decayed fruit should be removed carefully from the field during each harvest. Ideally, staff removing damaged and diseased fruit should be different from those picking fruits for sale. Pickers must take care to prevent spread of disease from infected/rotting fruits to healthy fruit, and a separate container should be placed on the picking cart for diseased fruit.

In all cases, diseased or damaged fruit should not be left in the field (Figure 5). This will only serve as a source of inoculum for continued spread of the disease onto maturing healthy fruit.

Figure 5. Remove diseased fruit from the field at each harvest.

Use a Picking Cart

Picking carts should be used in the field as a harvest aid to improve harvesting efficiency (Figure 6). The cart is designed to be pushed in front of the picker and hold several cartons and, if necessary, space for unmarketable/diseased fruit. The cart typically rests on two legs and has a front wheel for ease of movement down the aisle of the row. The field cart positions the strawberry containers in a stationary horizontal position, eliminating fruit rolling.

Figure 6. A picking cart improves harvest efficiency. This cart slides on metal runners – which increases stability.

Utilization of a picking cart allows both hands of the picker to be available for harvest. Worker efficiency is improved, less fruit bruising occurs, and ultimately arrival quality of the fruit at the final market destination is better.

Figure 7. Inefficient method of picking fruit with one hand and holding field carton with the other hand.

This is in contrast to the inefficient method of picking fruit with one hand and holding the field carton with the other hand (Figure 7). Picking carts can easily and inexpensively be fabricated from locally available metal.
Take Cartons to Field Collection Area

After filling each of the plastic containers with fruit, the cartons should be taken to a sheltered shaded site in the field where they are collected for transport to a nearby cooler/cold storage facility. This field collection site may also serve as a final grading and fruit inspection site in which workers examine each container.

Where necessary, individual, poor quality fruit in some of the containers may have to be removed and replaced with good quality fruit. However, if the field workers are properly trained in field packing for market, there should be minimal replacement of individual fruit. Nevertheless, some repacking is inevitable. The cartons should be kept in the shade and protected against desiccation from wind. An efficient system should be developed for inspecting the cartons from the pickers, followed by frequent delivery of the cartons to the cooler/cold storage facility (Figure 8).

Figure 8. Field collection of harvested strawberries before taking to the coldstore/ packinghouse.

To maintain optimum quality and marketable life, the fruits should be placed within the coldstore within one hour (or less) of picking. In Molodva already, we have one efficient farm system which allows this to be carried out in 20 minutes.

Fruit Quality

Considerable differences exist between acceptable market quality strawberries in the Moldovan domestic market versus export destinations. The traditional Moldovan method of bulk-filling used vegetable cartons with variable grade strawberry fruit (Figure 9) would not be acceptable for export. Furthermore, this method of loose packing fruit results in significant postharvest damage and losses, and market life is one day at best.

Figure 9. Traditional loose-fill packing of strawberries for the Chisinau market wholesale market.

Domestic supermarkets in Chisinau require a higher quality product, packed in smaller individual plastic containers (Figure 10). A higher market price is paid to growers who supply the domestic retail supermarkets with consistently high quality fruit packed in clear plastic containers.

Figure 10. Strawberries packed in plastic containers for a Chisinau retail supermarket.
Although Moldovan supermarkets require significantly higher quality fruit than the open-air wholesale markets, this still falls short of the much higher fruit quality requirements necessary to compete in the export market.

Foreign markets require pre-cooled, firm, flavorful, uniformly red-colored fruit, without defects and diseases. The calyx must be attached, fresh, and green in color. In addition the strawberries need to be packed in strong, attractive outer containers (Figure 11). Importers have specific quality requirements that are dictated by the supermarkets they supply.

Figure 11. High quality strawberries packed for the EU export market.

Receiving the Cartons from the Field
Strawberry fruit are highly perishable and should not be left exposed to high ambient outside temperatures for very long. After final inspection in the field collection centre, cartons should be delivered rapidly to the coldstore receiving area, where the cartons are unloaded and stacked on pallets.

This receiving area should also be roofed/covered in order to shade the fruit from direct sunlight and protect against rain. The flow of product can be made more efficient by using conveyors, pallets, and hand pallet-jacks for moving the cartons from one area of the cooler/cold storage facility to another. If the individual containers were not weighed in the field packing/inspection station, they will need to be check-weighed, prior to cooling if they are destined for the export market.

Weighting
After the individual containers are inspected for quality and grading improved if necessary, they will need to be weighed if they are destined for export. Currently, the majority of E.U. importers prefer strawberries to be packed in either 250gm or 500gm clear plastic containers. A top-loading electronic balance is recommended for weighing, with a digital display that has an accuracy of plus/minus 1 or 2gm. The berries should have a net weight of between 260gm to 265gm after packing (excluding the weight of all packaging), in order to ensure they arrive at their export destination with at least 250gm net weight² (520gm to 530gm for 500gm net weight retail containers- again excluding the weight of all packaging).

Accuracy in retail container weighing is an important quality control step. Utilization of top-loading digital balances to check the container fruit weight after packing is important in order to prevent under-filling or over-filling of the containers. Weight in excess of 265gm

² All fruits and vegetables lose moisture and therefore weight after harvest, during storage and transportation. The amount of moisture/weight loss varies with the product and storage/transport conditions. The additional weight of fruit added to compensate for weight loss during the distribution process is known as tare weight, the cost of the tare weight should be included in calculations for the selling price of the strawberries.
(530 gm for 500 gm containers) is essentially giving away product for free. In addition, overfilling the containers can result in compression bruising of the fruit.

Weight less than 250gm (500gm for the larger-sized containers) upon arrival at the end customer in the EU is construed as product mislabeling, and will result in withdrawal of products from the market plus legal prosecution and stringent monetary fines.

After weighing the containers are capped with the top lid and placed in the shipping corrugated carton prior to forced-air cooling. Both 2.0kg and 2.5kg cartons containing individual plastic containers are commonly used for the market.

Figure 12. A commonly used 2.0 kg export carton with eight 250gm plastic containers. Note that cartons should have ventilation gaps to allow good air movement around the plastic containers during cooling, to facilitate rapid cooling. The export carton pictured here has low sides along it’s length, which act as long ventilation gaps when the cartons are stacked.

Figure 13 below shows the components of a 450gm plastic retail container commonly used for marketing strawberries in the EU. The components include: shallow tray cover, deep tray, bubble pad. The bubble pad is placed inside the tray, with the strawberries placed on top of the bubble pad during harvest. The plastic box must be rigid enough to resist crushing and damaging the fruit, and as explained above, the box must be large enough to easily hold the required weight of fruit without squashing or damaging it. Note also, plastic retail containers **must** have good ventilation holes on the lid, to allow natural condensation from the fruit to escape. If the condensation cannot escape, water droplets will form inside the box, and these will reduce fruit quality and encourage fast development of rots.

Figure 13: Components of a 450 plastic retail container

**Post Harvest Cooling**

Strawberries are one of the most perishable fruit crops and should be cooled immediately after harvest to maximize market life and maintain fruit quality. The cold chain should be maintained by storing, distributing and marketing fruit at 0 to 1° C. Essentially most of the strawberries produced in Moldova on small plots and marketed locally are not cooled after harvest, resulting in significant losses in fruit quality and diminished market life. Investments in forced air cooling and cold storage facilities are necessary to improve fruit quality and allow for potential exportation of this high-value berry crop. Careful attention must be given to all the details of postharvest temperature management, and maintenance of the cold chain during transport and distribution to market.
The packinghouse facility should be designed so there is a smooth and rapid flow of product, from the field to the inspection/weighing area, then to the forced-air cooler, and from the cooler to a holding or storage area at 0 to 1° C.

Forced-Air Cooling

Forced-air cooling is the ideal method of field heat removal for strawberries. The forced-air cooling process should begin within an hour after picking (sooner if possible), in order to maximize the potential market life of the fruit.

Figure 14. Delays in cooling strawberries cause rapid losses in marketable fruit.

A delay between harvest and cooling of more than one hour will result in significant losses of marketable fruit (Figure 14). Storing picked strawberries with fruit temperature of 30 degrees centigrade for four hours before cooling will result in one-third of fruit becoming unmarketable after seven days, even if the fruit are cold stored in refrigerated stores.

Strawberries are adequately cooled when the internal fruit pulp temperature reaches 1° C. Internal fruit temperature is commonly determined using a pointed tip thermometer probe.

Forced-air cooling involves placing pallets of cartons filled with strawberries in a cold room at 0 to 1° C, 90 to 98 % RH. The cartons are lined up in two parallel rows on either side of a large fan. The rows are separated by open space (usually the diameter of the fan). There should be no space between the stacks of cartons. A canvas or strong plastic cover is placed over the top of the parallel rows of cartons, centered over the open space (tunnel) between stacks of cartons (Figure 15).

Figure 15. Parallel rows of strawberry cartons centered over an open space (tunnel) between stacks of cartons.

The canvas is rolled over the top and back end of the tunnel (Figure 16). The top layer of cartons is only partially covered near the edge of the tunnel. The canvas restricts the direction of air movement. The canvas extends to the fan, which is positioned in the front middle section and centered between the parallel rows of cartons of strawberries.

Figure 16. Forced-air cooling system in operation. The fan near the wall (hidden) draws cold air through ventilation openings in the cartons of strawberries, quickly cooling the fruit.
When the fan is turned on it will pull cool air through the ventilation holes in the sides of the corrugated cartons and individual plastic containers, thereby removing the strawberry fruit field heat and cooling the product (Figure 17).

Figure 17. Diagram of airflow in a forced-air cooling system.

One of the most important, but most often overlooked requirements of a good forced-air cooler is the method used to prevent air circulating without passing over the fruit (short-circuiting of the cooling air). Air always takes the path of least resistance, so even small short circuits must be avoided. It doesn't take much of an opening to reduce airflow through the mass of fruit. Poorly designed and operated forced-air units have much of the air short-circuiting.

There are many locations for air to short-circuit, including:

- forklift openings in pallets;
- cartons that do not stack closely together; and
- between the top containers on a pallet and a loose-fitting canvas cover.

It is important that all air gaps in the cooling tunnel be blocked to avoid short-circuiting the cooling air. There should be no gaps between stacks of cartons or unblocked openings below the pallets, if the strawberry cartons are palletized. Cooling times can be extended by as much as 40% when bottom openings on pallets remain unblocked. These openings can be easily sealed by placing wooden or plastic strips around the outside base of the pallets.

At least 5% of the carton side surface area must be ventilation holes to ensure adequate cooling. The individual 250- or 500-gm containers of strawberry fruit inside the cartons must also have at least 5% of their side or top surface area perforated for ventilation. Rapid cooling can be accomplished with adequate air flow and refrigeration capacity.

### Air Flow

The recommended air flow rate for effective forced-air cooling of strawberries is 0.002 m³/sec/kg of strawberry fruit (2 liters/sec/kg). Either an axial or centrifugal fan can be used (Figure 18). The fan can be a portable unit directing the warm exhaust air toward the air return of the cold room, or it can be a permanent unit which circulates the warm air over the cooling coils of the evaporator unit before returning it to the cold room.

Figure 18. Axial fan with motor used for forced-air cooling.

The fan should be selected on the basis of airflow and static pressure. Static pressure in this case is the resistance to air movement presented by the cartons. It is recommended to use a fan that delivers at least 7.2 cubic meters per hour (cmh) per kg of strawberries against 1.25 cm of water pressure.
(7,200 liters/hr/kg). In order to calculate the total airflow required, one must use the maximum weight of strawberries that will be cooled at any given time. For example, in order to cool 1,000 kg (1 metric ton) of fruit, it will be necessary to use a fan capable of providing at least 7,200 cmh at 1.25 cm water gauge static pressure (7,200,000 liters/hr or 2,000 liters/sec).

As a rule, a one horsepower motor (0.75 kW) will provide between 1,700-2,450 liters/sec airflow at 1.25cm static pressure. Table 1 shows the approximate relationship between fan motor size and airflow rate at 12 and 25 mm (1.2 and 2.5 cm) static pressures. The static pressure can vary significantly along the length of the tunnel cooler, with the highest pressure near the fan. The cartons farthest from the fan typically take the longest to cool. The airflow rate through the cartons of strawberries can be measured using an anemometer.

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<th>Motor size kW (hp)</th>
<th>Approximate airflow, L/s (CFM) at the indicated static pressure</th>
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<tr>
<td></td>
<td>12mm (0.5 in)</td>
</tr>
<tr>
<td>0.37 (0.5)</td>
<td>1125-1225</td>
</tr>
<tr>
<td></td>
<td>(2400-2600)</td>
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<tr>
<td>0.75 (1)</td>
<td>1700-2450</td>
</tr>
<tr>
<td></td>
<td>(3600-5200)</td>
</tr>
<tr>
<td>1.1 (1.5)</td>
<td>2025-3075</td>
</tr>
<tr>
<td></td>
<td>(4300-6525)</td>
</tr>
<tr>
<td>1.5 (2)</td>
<td>2175-3550</td>
</tr>
<tr>
<td></td>
<td>(4600-7525)</td>
</tr>
<tr>
<td>2.25 (3)</td>
<td>2500-4250</td>
</tr>
<tr>
<td></td>
<td>(5300-9000)</td>
</tr>
<tr>
<td>3.75 (5)</td>
<td>3250-5200</td>
</tr>
<tr>
<td></td>
<td>(6900-11000)</td>
</tr>
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When all the strawberries have been adequately cooled, the fan is turned off and the canvas cover rolled up. It is important to have available a thermometer with a long metal probe to verify the internal fruit temperature. Several randomly selected berries inside different containers should be penetrated with the thermometer probe to determine when forced-air cooling can be stopped. It is also a good idea to control the fan with a line-voltage thermostat mounted in the air stream. The thermostat will stop the fan when the fruit has cooled to a predetermined point. Turning off the fan after the strawberries have been cooled to their optimal storage temperature (0 to 1°C) reduces energy cost and prevents fruit dehydration from excess exposure to high velocity air.

The interior of a cooling room is often damp or even wet. Fan motors should therefore be of the totally enclosed, fan-cooled type and fully grounded to prevent shock.

Placing highly perishable fresh strawberries inside a cold room without adequate fan capacity for forced-air cooling is not sufficient to allow for rapid removal of product field heat. Room cooling without adequate internal air circulation is ineffective, taking up to 24 hours to cool packed cartons of fresh strawberries. The rate of cooling is typically 5 to 10 times faster using forced-air cooling compared to room cooling without adequate air movement.

The primary function of a cooling facility is to remove the heat from the product, but an important secondary function is to provide cold storage space. Once cooled, the
strawberries should be maintained at 0 to 1°C during temporary storage, transport, and distribution to the final market destination. Any break in the cold chain will decrease fruit market life significantly. The forced-air cooling facility should be designed so there is a smooth flow of cartons from the forced-air cooler area to the temporary refrigerated storage area.

**Refrigerated Storage**

Strawberry fruit should be held in temporary short-term storage at 0 to 1° C and to 98 % RH. Strawberries should not be stored within Moldova for more than 1 day if the fruit is intended for export. The storage facility for strawberries is a vital component in the overall quality preservation of the harvested crop. There are, typically, four main components to a refrigerated storage facility:

1. The physical structure and insulation
2. The refrigeration unit and components
3. The air circulation system
4. The humidification system.

**Physical Structure and Insulation**

The materials and workmanship of the cold storage facility should be of the best possible quality. Ideally, the cooling and storage facility should be constructed on an insulated concrete slab with a reinforced, load-bearing perimeter foundation wall.

To ensure that palletized products can be moved smoothly into and around the coldstore, there should be no steps or slopes between the coldstore, or any area – interior or exterior – of the packhouse and surrounding site.

The slab should be built to ensure good drainage away from the building, particularly around doors. The coldstore floor should also be equipped with a suitable inside drain to dispose of wastewater from cleaning and condensation. The floor of large-sized refrigerated rooms should be able to support heavy loads and withstand a wet environment, but still provide adequate insulation. The slab floor should ideally be at least 10 cm thick, made of wire-mesh-reinforced concrete over 5 cm of waterproof Styrofoam insulation board. Floor insulation is beneficial and will pay for itself in a few seasons of use.

If the facility is to be used for long-term sub-freezing storage, it is essential the floor be well insulated with at least 10 cm of foam insulation board having a rating of R-20 or greater to prevent ground heave. Any framing lumber in contact with the concrete floor or standing water should be pressure treated to prevent decay.

Walls of the cold storage facility can be made of concrete block, insulated metal panels, or wood frame construction. The walls should be insulated with rigid polyurethane panels, or sprayed-on polyurethane foam (a minimum of 10-cm thickness). Polyurethane foam adheres well to metal, wood, brick, and concrete surfaces. Polyurethane expands six times its liquid volume and over application is common. The foam will dry to the touch within 60 seconds after application, and be totally solidified in five minutes. Any excess solidified foam can be simply cut or shaved off.

For best results, the polyurethane should be applied at a density of at least 32 kg/m³. It is best to begin applying polyurethane in the corners of the room and/or at the wall-ceiling
joints. When the insulation absorbs moisture, the air is replaced by water and the insulating value is greatly reduced. For this reason, insulation should be kept dry at all times.

A sealant should be applied to the outer surface of the solidified polyurethane foam to prevent moisture from penetrating through the insulation. In most types of insulation the flow of heat energy is impeded by small cells of trapped air distributed throughout the material. A fire retardant should be sprayed on the moisture sealant to minimize the flammability hazard of the highly combustible polyurethane. The finished surface should be painted with food-grade, washable paint (ideally white colored) to meet food safety/hygiene requirements, and allow cleaning which will also prevent the build up of post harvest disease spores.

All insulation materials must be used with a suitable vapor barrier. A 4-mil polyethylene sheet is normally installed on the warm side (outside) of the insulation. This placement prevents the formation of condensation on and within the insulating material. The vapor barrier sheet must be continuous from floor to ceiling. Where two sheets join, they should overlap 30 cm and be positively sealed (for example, with duct tape).

Instead of self-application of polyurethane foam, pre-fabricated polyurethane insulated panels – white plastic-coated metal panels lined with polyurethane - can also be bought from various companies and installed in sections inside the cold storage facility. These are easier to install, ideal under Food Safety requirements, and less flammable.

The size of the storage facility should be adequate to handle peak amounts of product. The floor area can be calculated by estimating the maximum volume of strawberries (and other perishable products) that will have to be stored. Allow for aisles, pallet jack or forklift maneuvering, and staging areas. The building should ideally have a floor perimeter in the shape of a square. A rectangular configuration has more wall area per square meter of floor area, resulting in a higher construction cost and higher heat exchange than a square configuration. Entrances, exits, and storage areas should be arranged so that the strawberries move in one direction through the facility.

Doors

Doors used to enter the cold-storage facility should be insulated with at least 50 mm of polyurethane and wide enough to allow the use of hand jacks or fork lifts to move palletized product. A sliding door is more efficient – it needs to be opened only as wide as necessary, minimizing the loss of cool air. This is particularly important in a small cold store, where the surface area of the door is high proportionately to the volume of cold air inside the store.

A door that does not seal properly or fails to operate, will waste costly energy, reduce productivity, and incur high maintenance costs. The door is a critical part of a cooling facility (Figure 19).

![Figure 19. Hinged insulated doors for cold storage rooms.](image)

Improperly built or maintained doors can waste large quantities of energy. Door gaskets should always provide a good seal to reduce the infiltration of warm air. Door seals can be checked
by inserting a thin sheet of paper between the door and the seal area and then closing the door. The seal is acceptable only if resistance is felt when the paper is pulled out. A large single sliding or swinging door is much easier to keep tight than a set of double swinging doors. All large doors have a tendency to sag over time unless they are diagonally braced and well supported. Only the best grade of hinges and latches should be used.

It is essential that the door can be opened from inside the coldstore, to ensure that people are not accidentally trapped inside the coldstore, and thus to prevent fatalities.

Transparent vinyl strip curtains hung on the inside of the door opening are recommended to further minimize the entrance of warm air while the door is open (Figure 20). The strips part only enough to let a person or hand jack/fork lift pass through. The balance of the strips remains closed with the parted strips falling right back into place automatically after passage, ensuring minimum loss of cooled air. They can be bought pre-cut and ready-to-hang, or bulk rolls of vinyl strip can be obtained for those who prefer to make their own strip curtains. Typical strip dimensions are 20 cm wide and 0.20 cm thick. There should be a 50% overlap of the strips when they are hung.

Figure 20. Plastic strip curtains hung on the inside of a cold storage room.

Refrigeration Unit and Components
A mechanical refrigeration system using Freon as the refrigerant should be used to cool the storage room. Ammonia is less expensive than Freon, but can injure the strawberry fruit if there is a leak in the system. Also, ammonia cannot be used with metals that contain copper. The five main elements of a mechanical refrigeration system are the evaporator, compressor, condenser, liquid receiver, and expansion valve (Figure 21).

Figure 21. Mechanical refrigeration components (left) and wall-mounted evaporator unit (right).

Refrigeration Capacity
There must be sufficient refrigeration capacity in the forced-air cooling facility to meet peak harvest volume cooling requirements. The amount of heat generated (and therefore
required to be removed) from each of the following sources must be added together to determine the total refrigeration capacity required:

1. **Field Heat**

   This is the principal source of heat and is dependent on the internal fruit temperature of the strawberries at the start of cooling. The amount of field heat (in kilocalories) necessary to be removed is determined by the following formula: weight of strawberries (kg) x 0.92 x (°C temperature difference between fruit temperature at harvest and desired storage T°). The value 0.92 in the formula is the specific heat of strawberry fruit.

   The kcal of heat required to be removed from 1 metric ton of strawberries at 27° C internal fruit temperature at harvest down to 0° C storage temperature will be 1,000 kg x 0.92 x 27° C = 24,840 kcal. To cool the fruit in 1 hour will require a refrigeration load capable of removing 24,840 kcal.

   This will be the primary source of heat, but as a rule of thumb, another 25% should be added to the total refrigeration capacity to account for heat removal from sources #2 - 5 listed below. Therefore, it will require a minimum of 31,050 kcal of refrigeration capacity to remove the field heat from 1,000 kg of strawberries and other sources. Additional refrigeration capacity will be required if more product is to be cooled, or if the room will also be used for temporary fruit storage in addition to forced-air cooling. It is recommended to always install sufficient refrigeration capacity to meet peak volume cooling needs. This peak typically coincides with maximum harvest volume.

2. **Heat of Respiration**

   After harvest, strawberries remain alive and produce heat as a natural consequence of respiration. The amount of heat they produce depends on the fruit temperature. At 0° C, 1,000 kg of strawberries will produce approximately 84 kcal per day, whereas at 27° C, 1,000 kg of strawberries will produce about 11,670 kcal.

3. **Container and Pallet Heat**

   Empty cartons and pallets have internal air space that is a source of heat that requires refrigeration to cool.

4. **Heat Leakage**

   Opening of doors, poor insulation, and cracks in the wall or ceiling are all potential sources of heat leakage, which allow warm air to enter the cold storage room. They require extra refrigeration capacity to maintain the cool temperature of the storage room.

5. **Utility Heat**

   Mechanical devices such as forklifts, lights, fans, etc., and workers entering the storage room all emit heat that has to be removed.

**Humidification System**

Strawberries are subject to rapid water loss after harvest. In order to prevent fruit shriveling and wilting or dehydration of the green calyx (cap) it is important to maintain a high relative humidity (RH) during all the postharvest handling steps. The optimum RH for strawberries is between 90 to 98%.
There are various methods available for maintaining a high RH during temporary storage. They range from wetting the floor, or open containers filled with water, (both of which are not well controlled systems, and have disadvantages related to food safety), to installation of an automatically controlled fogging or humidification system. Controlled introduction of water vapor regulated by a humidistat is the preferred method of maintaining a high RH. A simple wall-mounted or ceiling unit is recommended for strawberry storage facilities (Figure 22).

Figure 22. Humidifier unit appropriate for strawberry storage facilities.

Humidification units are easy to install and connect to a water hose and ordinary electric utilities and do not require a high pressure pump or air supply line. Units fill automatically and are equipped with water flow control. The humidifier can be connected to a cycle time controller for precise regulation of atmospheric humidity (± 3% RH). A humidifier capable of supplying 0 to 7 liters of water per hour will be adequate for storage rooms ranging in size from 50 to 175 cubic meters. Larger capacity humidifiers will be needed for large storage rooms. Storage facility operators should also obtain a good quality thermo-hygrometer for checking the storage atmosphere temperature and RH.

Maintenance of Cold Chain during Transportation

Strawberry cartons should be palletized and prepared for export shipment while they are inside the refrigerated storage room. The cartons should be removed from the cold storage facility and loaded into a pre-cooled refrigerated truck (near 0°C) without breaking the cold chain. Ideally, after cooling, the strawberries should be transported to the market destination the same day they are picked.

Strawberries that have been cooled and then allowed to re-warm will have moisture condensation on the inner surface of the plastic container and the fruit itself (Figure 23). Free moisture on the strawberry fruit surface will increase their susceptibility to fungal decay and reduce fruit market life. Even a small amount of Botrytis gray mold fungal infestation can spread rapidly from one infected fruit in the container to all adjacent healthy fruit throughout an entire carton. Low temperatures during transit are essential to minimize post harvest decay.

Figure 23. Severe moisture condensation inside non-ventilated containers due to re-warming of previously cooled strawberry fruit.
In-Transit Temperature Recording

It is also desirable to record the temperature inside the refrigerated trucks during transit. This record will be useful in case of quality claims upon arrival or due to delivery delays. Also, EU importers require accurate and detailed record keeping of the temperature during transportation and distribution.

Maintenance of the cold chain and temperature monitoring are integral parts of importer quality control requirements, hazard analysis critical control point (HACCP) plans, and EUREP GAP requirements. Temperature recorders are usually placed 1.5 m above the floor (for ease of checking) about two-thirds the way to the back of the vehicle. Temperature recorders should not be placed in a cold area such as near the air discharge of the refrigeration unit.

Thermal Blankets

Another method used to maintain the cold chain during transit is to over-wrap the stack of cartons on the pallet with a foil laminated thermal blanket (Figure 24). The external foil surface of the thermal blankets reflects ambient heat while the air pockets inside the insulation material keep out heat. Thermal blankets can maintain a temperature of 3º C within the cartons for up to 36 hours.

Figure 24. Thermal blankets used to maintain cold chain of palletized strawberries.

Palletized strawberry cartons require some type of strapping or corner strips to stabilize the pallet load and prevent load shift in transit (Figure 25). It is very important to avoid overloading the pallet. The cartons should never extend beyond the edge of the pallet, because this will cause the cartons at the base of the stack to collapse, and possibly lead to the collapse of all cartons.

Figure 25. Strawberry cartons stacked on a pallet stabilized by corner boards.
Modified Atmosphere Storage / Transport

Maintaining a high CO₂ atmosphere during storage and transport can reduce strawberry fruit respiration rate, reduce the incidence of decay, and extend market life by several days. Exposing strawberries to high atmospheric CO₂ concentrations (15 to 20 %) maintains or enhances firmness and skin brightness and reduces Botrytis gray mold. These high CO₂ atmospheres can be obtained using impermeable plastic bags or covers (125 microns thick) wrapped around the stacked cartons of strawberries, followed by a vacuum withdrawal of the atmosphere inside the plastic cover and injection of CO₂ (Figure 26).

The injection hole is sealed by tape or heat and the high CO₂ concentration is maintained for several days. Leakage from the bag must approximately balance the amount of CO₂ produced by the berries through respiration. Preparation of the cartons for CO₂ treatment should be done on already cooled strawberries inside a 0º C storage area. The cold chain must still remain intact in order for this postharvest modified atmosphere treatment to work.

The real potential for this treatment lies in over-the-road refrigerated truck transport of Moldovan strawberries to EU market destinations. The strawberry cartons need to remain sealed during the entire 2-3 day trip to obtain the benefit of the high CO₂ treatment. Pallet over-wrap systems for transporting strawberries under such conditions are available commercially. Exposure of strawberries to atmospheres containing low O₂ and 15 to 20 % CO₂ for up to 7 days has no negative effect on strawberry fruit quality. However, if oxygen concentration falls below 1 %, the fruit will lose flavor and an acid taste will develop. Also, when CO₂ reaches 30 % the berries will develop an off-flavor. The fruit will have a 10 to 14 day shelf life at 1 degree centigrade under modified atmospheres of 3-5 % oxygen and 15-20 % CO₂.

Postharvest Diseases

Postharvest decay is a major cause of poor quality, unmarketable fruit. Several different fungal diseases are responsible for the majority of the postharvest decay problems. The principal postharvest disease of strawberries is Botrytis gray mold. Diseases of lesser importance are Rhizopus soft rot and leather rot.

Figure 27. Covering the soil bed with plastic mulch significantly reduces the amount of postharvest disease problems.
Strawberry diseases involve complex interactions of causal agent, host plant, and environment. The development of a disease is influenced by the cultivar of strawberry, fruit maturity stage, physical injury, when the fruit is infected, post harvest temperature, and surface moisture.

A combination of control methods should be used to minimize the incidence and severity of postharvest diseases. These control methods include field sanitation, appropriate cultural practices (Figure 27), use of crop protectants, care in picking and handling, use of protective packaging, rapid cooling after harvest, and maintenance of the cold chain during transport and distribution to market. There are no postharvest fungicides available for use on strawberries.

In late February or early March, the dead leaves and stolons (runners) from the previous season’s growth should be removed (Figure 28). Dead plant material is a major source of gray mold spores. Manual removal of this source of inoculums before new growth emerges will significantly help in disease control. Pre-harvest applied fungicides are available for use on strawberries that afford protection against postharvest diseases. Use of the appropriate fungicide(s) in a timely manner, and in accordance with Moldovan Government and pesticide manufacturers instructions, will help to protect the strawberry fruit against disease. Postharvest disease problems also increase when plantings are too dense, making foliage and fruit slow to dry after rains and more difficult to adequately spray.

Figure 28. Dead leaves from the previous season’s growth are major sources of disease.

Gray Mold

Gray mold, caused by the fungus Botrytis cinerea, is one of the worst strawberry diseases, causing field and postharvest fruit rot. No strawberry cultivar is resistant to this disease. Gray mold spores that over-winter on dead foliage begin to germinate in early spring with the advent of warmer temperatures. Newly emerging leaves become infected, followed by the flowers, and eventually the fruit. Gray mold is generally worse in a wet spring and on crowded plants with heavy foliage and a thick canopy.

Figure 29. Advanced stages of gray mold on strawberry fruit.

It is important to maintain proper spacing between plants to allow good air circulation. This will promote rapid drying of foliage, blossoms, and fruit during periods of high humidity, and lessen the chance of Botrytis spores germinating on plant surfaces.
Heavy nitrogen applications, particularly early spring applications, also promote Botrytis development. Gray mold lesions begin as small, firm, light brown spots often occurring under the calyx. As the fruit matures, the fungal growth assumes a fuzzy, gray appearance with masses of sporulating lesions (Figure 29).

The recommended control protocol for gray mold must comply with Moldovan Government and pesticide manufacturers instructions. Ideal first steps consist of late winter plant cleaning, plus four well-timed fungicide sprays. The initial spray should be at first growth flush (after removal of the dead plant tissue), the second at initial flowering, the third at full bloom, and the fourth at late or extended bloom. If rains of 1 cm or more occur, which wash off protective fungicides, they should be re-applied as soon as possible.

Internationally, the fungicides shown to be effective against gray mold include azoxystrobin (Abound; formerly Quadris), Cabrio, Captan, Captevate (fenhexamid and captan), fenhexamid (Elevate), Pristine, Rovral, Scala, Switch, Thiram, and thiophanate-methyl (Topsin M). Growers should consult Moldovan pesticide advisers to select agrochemicals permitted for use on strawberries in Moldova; exporters should discuss with potential buyers the agrochemicals allowed on strawberries to be exported to the destination export country.

In any case, to avoid the development of fungicide resistance, the same chemical should not be applied more than four or five times per season and no more than two sequential applications should be made. Growing strawberries inside protected structures will significantly reduce the incidence and severity of gray mold.

**Rhizopus Soft Rot**

Rhizopus rot, caused by the fungus Rhizopus stolonifer, is another common postharvest disease of strawberries. Symptoms of soft rot infection generally appear as a loose cotton-like fungal growth over the fruit surface. This growth takes on a blue-black color when the spore bearing structures of the fungus form on the white whisker-like mycelium (Figure 30). Rhizopus rot affects the fruit and is most serious after harvest, but can also occur in the field. Conditions of high temperature and moisture favor its development. Infected fruits collapse and rapidly lose juice that leaks from the container.

Figure 30. Advanced stages of Rhizopus soft rot.

Soft rot control measures involve handling the fruit carefully to avoid bruising, followed by rapid cooling and maintaining the cold chain during transport and distribution to market. Rhizopus will not grow at temperatures below 5° C.
Leather Rot

Leather rot, caused by the fungus Phytophthora cactorum, is usually of minor importance as a postharvest disease. However, the leather rot organism also causes crown rot, which can be a serious pre-harvest disease. Fruits may be affected at all stages from blossom to maturity.

Infected areas of immature fruit are dark brown (Figure 31), while infected areas on ripe fruit appear bleached in color (Figure 32). Infected fruit is tough and has a bitter taste. After harvest, a white fuzzy growth may appear on fruit under moist conditions. Rainy weather promotes infection by splashing of the fungal spores along with soil particles onto flowers or fruit. Maturing fruit in contact with wet soil may also become infected. Frequent morning dew may supply adequate moisture for the spores to cause infection.

Control of leather rot is obtained by proper plant spacing and weed control for good aeration, to promote rapid drying of plant surfaces. Plastic soil mulch covering the raised bed will greatly reduce the incidence of leather rot. In addition, straw mulch should be put between the rows to prevent maturing fruit from becoming contaminated by rain-splashed soil on the surface. When conditions are very wet, and leather rot has occurred in a field, fungicide sprays may be needed. Effective fungicides for leather rot control include fosetyl-aluminum (Aliette) and metalaxyl (Ridomil).
Summary
Strawberries are one of the highest valued fruit crops which can be produced in Moldova. Considerable opportunities exists to expand domestic and export markets for fresh and processed strawberries. Utilization of proper cultural practices is important to produce consistent supplies of high quality fruit. This must be complemented with appropriate postharvest care in order to maintain the fruit quality after harvest and during transport and distribution to market. Domestic retail supermarkets and export market buyers prefer attractive, high quality strawberry fruit, of uniform appearance, packaged in the appropriate retail container.

In order to provide the market with consistent supplies of high quality strawberries, Moldovan growers and exporters will have to pay close attention to maintaining all the critical links in the strawberry postharvest cold chain, from harvest to market:

HARVEST:
- Protect the product from the Sun
- Transport quickly to the packinghouse

COOLING:
- Minimize delays before cooling
- Cool the product thoroughly as soon as possible

TEMPORARY STORAGE:
- Keep the product at optimum temperature
- Ship to market as soon as possible

TRANSPORT TO MARKET:
- Use refrigerated loading areas
- Cool truck before loading
- Avoid delays during transport
- Monitor product temperature during transport