# Citrus Packhouse

## Module 5: Fruit Treatments

Learner Guide





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Citrus Growers' Association OF SOUTHERN AFRICA
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# Introduction

After fruit has been washed on entering the packhouse, they are ready to be treated with fungicides and have wax applied in preparation for packing.

# Fungicide Treatment

Blue mould and green mould are two of the most economically significant postharvest diseases in citrus. These are fungal diseases and they infect fruit through spores. Sour rot is another serious fungal disease that is responsible for significant postharvest losses, and can spread in packed boxes.

## Fungicides

Fungicides used in packhouses are aimed at controlling these significant fungal diseases. CRI publishes and regularly updates information about the registered active ingredients. On this fact sheet, you will find the name of the active ingredient and its formulation, the FRAC code, the target disease, the dosage and parts per million concentration.

CRI also publishes a protocol for fungicide treatments, updating it regularly with the latest research findings. It is critical to adhere to these recommendations. Fungicides must always be used as per their registrations, taking into account the residue levels allowed by the target market. Following the recommendation and protocols from CRI and your target market will ensure that the packhouse is compliant.

The fungicide treatment leaves a residue on fruit which protects the fruit in transit to the overseas market. If the residue is too low, the fruit will not have proper protection. If the residue is too high, the fruit may be rejected because the Maximum Residue Levels, or MRLs, of the target market will be exceeded. The residue that is loaded on fruit depends on three main factors in combination, namely the temperature of the fungicide solution, the contact time, and the fungicide concentrations. Sometimes the pH of the solution also plays a role.

In most cases, a fungicide solution at a higher temperature not only makes the fungicide treatment more effective, but also helps the water evaporate faster after the treatment, so that the fruit dries faster. A higher temperature also improves the uptake of the fungicide into fruit injuries. The optimal contact time depends on the temperature of the solution, the pH of the water, and the citrus type and cultivar. Best practice is to follow the recommendations on the CRI fact sheets. It is also important to know the maximum temperatures to use. If the fungicide solution is too hot, it can damage the fruit rind and can cause a too high fungicide residue on the fruit, possibly exceeding the MRL of the target market.

## Fungicide Treatment Systems

Two systems can be used in packhouses for fungicide treatments, namely a fungicide bath or a flooder, also called an in-line drench.

Fruit is moved into the fungicide bath on a conveyor belt, and moved through the bath at a specific rate that ensures sufficient contact time to leave the required residue. It is important for fruit to be clean and dry when it goes into the fungicide bath, otherwise the fungicide solution will become dirty sooner and will have to be replaced more often. In addition, it minimises the risk of transferring sanitising agents into the fungicide bath, with chlorine being of particular concern.

In a flooder, or in-line drench, the fruit is moved through curtains of fungicide solution that drenches the fruit, using brushes that continuously rotate the fruit. The number of curtains, the volume of fungicide solution that falls in each curtain, the temperature of the water, and the rate at which the fruit moves through the flooder are calculated to ensure sufficient coverage and contact time. The fungicide solution is in a reservoir from where it is pumped through the flooder. The reservoir can be part of the flooder, or free-standing. After the flooder, the fruit moves over rollers and doughnut sponges under fans that remove excess moisture.

It is somewhat easier to manage the pH, temperature, exposure time and fungicide concentration in flooders than in baths. They are also smaller and more energy and water efficient, with flooder tanks being roughly a third of the volume of a bath for the same size system. Fruit will also not be left in the fungicide solution for too long should the packline stop for some reason, such as a power outage.

The concentration of fungicides in the fungicide solution used in a bath or flooder must be monitored and controlled to ensure that the treatment remains consistently effective for every batch of fruit. The solution can be topped up with fungicides either manually or by using automated, integrated dosers. A manual top-up procedure is based on the volume of fungicide solution that is used, the required concentration of fungicides, and the amount of fruit that moves through the bath.

The pH of the water used in the fungicide solution has a significant impact on the efficacy of the fungicides in the solution. Some systems also have integrated pH monitors, which check, and can even correct, the pH of the fungicide solution on an ongoing basis.

It is important not to rely simply on procedures or automated systems to maintain the correct fungicide concentrations and pH. These factors must be measured and recorded regularly as part of packing process quality control. Titration is the most convenient way to accurately determine the concentration of Imazalil in the fungicide solution. Best practice is to titrate a sample from the fungicide solution in the bath or fungicide tank every second hour, and to measure the pH of the solution at the same time. Titration is discussed in detail in the next section. The findings from these tests are recorded, and corrective action is immediately implemented if the values are outside the set parameters. For accurate information on all the fungicides used, and for audit purposes, fruit samples have to be sent to diagnostic laboratories for residue testing.

## Fungicide Titration and pH Measurement

The principle of titration is based on determining the concentration of one substance by adding another substance in small increments. The two substances react to each other in a specific way and, because we can measure how much of the second substance we needed to add in order to get a specific reaction, we can calculate the concentration of the other substance.

In the case of a fungicide such as Imazalil, the concentration of the fungicide is determined by titrating the solution with a known volume of a standard solution, then using an indicator to observe a colour change. This colour change, or end-point, enables us to determine the concentration of the fungicide.

If the fungicide solution contains only one fungicide, such as Imazalil, it is easy to determine the concentration by using titration. If there is more than one fungicide in the bath it becomes more challenging, but special methods have been developed to do this. For the purpose of this module, we will do Imazalil titration as an example. Please consult your agrochemical supplier or CRI for instructions on other and more complex titration procedures.

For Imazalil titration, the following equipment is essential: a 25ml burette with 0.02ml gradation with a burette stand, a 250ml Erlenmeyer flask, an indicator dropper bottle, and flasks, cylinders or a pipette for measuring chemicals. The chemicals used for Imazalil titration are sulphuric acid, dichloromethane, an indophenol blue solution, and a reasonably fresh sodium lauryl sulphate. All solutions must be kept free of any contamination.

A sample is taken of the fungicide solution, either from the fungicide bath, or from the flooder reservoir. Carefully mark samples, noting the date and time. If there is more than one line in the packhouse, carefully mark where the sample was taken.

Before doing titration, first measure the pH of the solution, using an electronic pH meter. Record the pH along with the time and date.

Place 25ml of the fungicide solution sample in the Erlenmeyer flask. Add 10ml sulphuric acid and mix well. Then add 25ml of dichloromethane and again mix well. Add ten to fifteen drops of the indicator indophenol blue, until the solution turns blue.

The solution in the Erlenmeyer flask is now titrated using sodium lauryl sulphate. Ensure that the burette is filled with precisely 25ml sodium lauryl sulphate and secure it in its stand. Using the valve at the bottom, add the sodium lauryl sulphate drop by drop, gently swirling the solution continuously. Keep adding drops, swirling the solution, until the solution turns colourless. This is called the endpoint.

Record the volume of sodium lauryl sulphate used. Beware of making a parallax error. This volume is now used in the standard formula to calculate the Imazalil concentration in parts per million, or ppm. Consult your agrochemical supplier about the formula to use for your fungicide product. Record the results of the calculation along with the pH. Indicate what corrective actions should be taken.

Titration is not exact, and the result is subject to a 25% correction factor, which is the international standard. Therefore, if the result is 500 parts per million, it may in truth be as low as 375 or as high as 625 parts per million. For more accurate information, diagnostic laboratory tests are required.

# Wax Treatment

After the fungicide application, the fruit goes through a drying tunnel. Once the fruit has been dried, wax is applied to the fruit. Wax helps to limit moisture loss from the rind, thereby extending the shelf-life of the fruit, improving the appearance of the fruit, and helping to protect the fruit against cold damage. Fungicides can also be mixed with the wax, providing another control point for fungal spores and assisting with resistance management.

Market requirements determine what type of wax is applied to the fruit, if any at all. There are different types of citrus packing waxes of which the most common are oxidised polyethylene waxes and natural waxes. Carnauba wax is extracted from palm trees and classified as a natural wax.

Citrus packing wax products are water-based, and are carefully formulated, with a very exact combination of components, some of which are volatile. Fruit coating products consist mainly of the wax itself, emulsifiers, plasticisers and drying agents. The emulsifier interacts with the wax that is naturally on the fruit, emulsifying it with the packing wax to form a thin film on the fruit. Plasticisers ensures that the wax film remains pliant and does not crack.

It is essential to ensure that the wax remains tightly sealed in its containers until it is used. If the wax is exposed to air, the volatiles will dissipate, making the wax less effective. It is also important to constantly agitate the wax at a low speed while it is being applied to make sure that the components are evenly mixed, especially if a fungicide is added to the wax.

Wax is applied in most packhouses by automated applicators, with the fruit moving along at a set speed over brushes that constantly rotate them. The wax is sprayed onto the fruit by nozzles from above. Sensors before the wax applicators detect the number of fruit moving under the nozzles, and determine how often the nozzles must spray wax to properly cover all the fruit. Ensure that the wax manufacturer's instructions are followed rigorously.

It is important that the fruit is free of water droplets before going into the wax treatment. If the fruit is very slightly damp, it will actually help with spreading the packing wax into an even, thin film, but if there are visible water droplets, meaning if the fruit is wet, it will change the combination of the wax components and compromise its efficacy.

It is essential to maintain the brushes in the wax applicator. If the brushes are not thoroughly cleaned and maintained, the bristles become stiff with hard, clumped ends. This can easily cause fruit injuries, increasing the risk of infection and leading to cracks in the wax coating, which will compromise fruit quality. Wash the bristles every day with water and a residue-free, fruit-grade soap. Although it can be a challenge to get the wax out of the bristles, there are excellent products for this purpose, and it should not be neglected.

After the wax has been applied, the fruit again moves through a drying tunnel. Drying must not be too hot or for too long, as this can break down the wax and lead to tacky and sticky fruit.

# Fungicide Resistance

In a given population of fungal spores that have not been exposed to an appropriate fungicide before, most of the individual spores will be sensitive to the fungicide and will be killed on contact. However, due to natural genetic mutation and simply natural genetic variation, there will be a small percentage of spores that are resistant to a particular fungicide. The level of resistance varies, from spores with a resistance level only slightly higher than the general population, to a very small number of spores with a very high resistance level.

If fungicide treatments in the packhouse are not done properly, it allows for more and more of these resistant spores to survive the treatment, even those with marginal resistance. These spores can give rise to spore populations with much higher levels of natural resistance to fungicides.

The arsenal of fungicides at the disposal of the citrus industry is quite limited, and losing even one of them because of resistance can have catastrophic consequences. Increasing fungicide resistance, mostly because of poor fungicide application practices in packhouses, has been identified as a significant threat to the sustainability of the citrus industry in South Africa.

Managing fungicide resistance depends on getting the optimal fungicide residue on fruit by implementing the best application practices, and on using the best combination of fungicides at the right stage of the packhouse process.

The first factor is the residue that fungicide treatments leave on the fruit. The residue level depends on the temperature of the fungicide solution, the contact time, and the concentrations of the fungicides. If the treatment is optimal, the residue on the fruit will control all fungal spores, even those with some level of resistance. If the residue level is too low, more resistant spores will survive and multiply.

The second factor is how available fungicides are combined and used at different stages of the packing process. The first rule is to use a particular fungicide at only one point in the packhouse. Fungicides can be applied at three different stages of the packhouse process, being in the drench before de-greening, in the fungicide bath or flooder, and mixed with the wax. If a fungicide was used in the drench, that same fungicide must not be used again later, for instance in the fungicide bath or flooder. It will simply not be effective against spores that survived the first treatment, and greatly increases the risk of resistance developing.

Best practice is to use a combination of fungicides, which are able to attack fungal spores from many different directions. To enable us to do this, we need to know which fungicides can be used together, and to which ones the same spores are likely to be resistant.

FRAC codes were developed for this purpose. It can be found on the fungicide label, and is also noted on CRI's fact sheet. The FRAC code is assigned by the Fungicide Resistance Action Committee, to group together active ingredients which demonstrate potential for cross resistance. It is an easy way to know which fungicides to use together – as long as you are combining fungicides from different FRAC groups, you are safe.

# Conclusion

The fruit is now ready to be separated into grade and size categories, which is the last step before the fruit is packed for export. In the next module we will look at grading and sorting practices.