

A Basic Guide to Drying Fruits and Vegetables

Donald G. Mercer, Ph.D., P.Eng.
Department of Food Science
University of Guelph
Ontario, Canada

© October 2011

A Basic Guide to Drying Fruits and Vegetables

Contents

Section	Topic
1.	Introduction
2.	Why Do We Dry Mangoes?
3.	How Do We Dry Mangoes?
4.	Is Quality of the Mangoes Important? <ul style="list-style-type: none">4.1 Overall Appearance4.2 Feel4.3 Aroma4.4 Source4.5 Variety4.6 Taste
5.	What Are the Initial Preparation Steps?
6.	How Should Mangoes Be Sliced?
7.	How Do We Dry Mangoes? <ul style="list-style-type: none">7.1 The Drying Mechanism7.2 Factors Affecting Drying7.3 Basic Design of a Forced-Air Dryer7.4 Basic Design of a Solar Dryer7.5 The Role of Air Temperature7.6 The Role of Air Velocity7.7 The Effect of Thickness on Drying7.8 Case Hardening
8.	How Do Drying Methods Compare?
9.	What Do We Need to Remember for Mango Drying?
10.	How Do We Use Dried Mango Slices?
11.	Summary Comments
12.	Sources of Information

A Basic Guide to Drying Fruits and Vegetables

Donald G. Mercer, Ph.D., P.Eng.
Department of Food Science
University of Guelph
Ontario, Canada

1. Introduction:

One of the most serious problems facing growers of fruits and vegetables is how to prevent these products from spoiling and thereby becoming unfit for consumption. There are various methods of accomplishing this, such as canning or freezing. However, one of the most suitable methods of preserving most fruits and vegetables is through drying to remove most of the water content.

It is not possible to provide details about the drying of a wide variety of fruits or vegetables in a short guide such as this. Therefore, we will use mangoes as a specific example. While the drying of various products will vary to a certain degree, the basic principles are the same for mangoes as they would be for most other fruits or vegetables.

Mango trees grow naturally in many parts of Sub-Saharan Africa (Figure 1). Their sweet, fleshy fruit is quite nutritious and tasty. Sadly, when the mangoes ripen, they are often so plentiful that there is little or no significant commercial value to them. Since they cannot be sold, the mangoes may be left to rot where they have fallen from the trees.

Once harvested, there is a limited time during which the mangoes may be used before they begin to soften and spoil. There are a few ways in which the mangoes may be preserved for later use,

including, for example, mango jams and relishes.



Figure 1: A mango tree in Southern Malawi

One very convenient way to increase the useful life of mangoes is by drying them, therefore ensuring their later availability. With proper storage and handling, dried mango slices can be enjoyed several months after fresh mangoes have disappeared from the local markets.

It is the purpose of this guide to provide some instruction for the drying of mangoes. We will attempt to cover the entire process from the selection of the fruit for drying, all the way through to the steps necessary for preparing dried mangoes for consumption.

Figure 2 shows mangoes on a tree in Northern Malawi.



Figure 2: Mangoes on the tree

2. Why Do We Dry Mangoes?

Mangoes, like most fresh fruits or vegetables, consist mostly of water. Typically, a mango may contain around 85% water.

In Figure 3, we see a mango that weighs 353 grams. Since 85% of its weight is water, there will be about 300 grams of water and only 53 grams of solid material. Of these solids, some are present in the skin or peel, as well as in the stone or pit. Both the peel and stone also contain water. Of course, neither the peel nor the stone will be eaten and will be discarded.



Figure 3: A mango weighing 353 grams

Figure 4 shows just how much water there actually is in a mango. Here, we have placed 300 grams of water in a beaker. A bit of food colouring has been added to make the water more visible in the photo. When you take time to think about it, it is rather amazing how much water is present in the foods we eat.

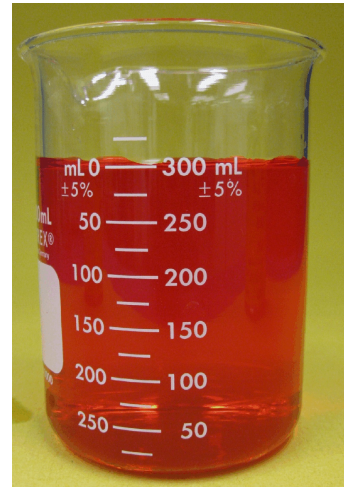


Figure 4: There are 300 grams of water in the mango shown in Figure 3

Within the ripe fleshy portion of the mango, there is a considerable amount of naturally occurring sugar. It is the sugar which gives the mango its appealing sweetness. The juice of the mango is composed of a combination of sugar dissolved in water inside the fleshy portion of the fruit. There are other compounds present which provide the distinctive flavour and aroma.

Unfortunately, the juice of the mangoes is also a convenient source of nutrients for microorganisms like molds. Once molds or other microorganisms begin to grow, they will make the flesh of the mangoes unfit for human consumption. Looking at Figure 5, we can see how unappetizing a moldy slice of mango appears. The black

spots are mold colonies. Some of these have developed to the stage where they have produced a grey fuzzy covering.

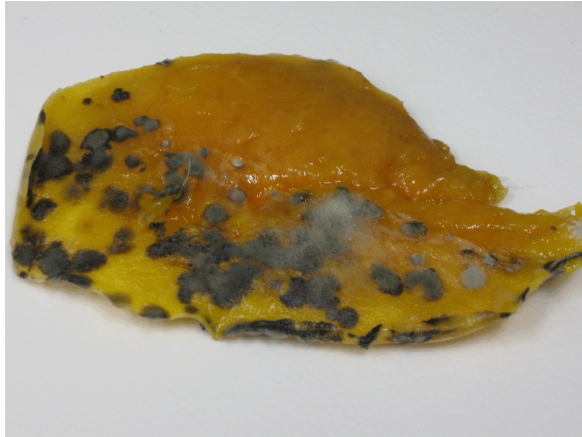


Figure 5: A moldy slice of mango

If we remove most of the water from the mangoes, there will no longer be enough moisture present to support the growth of microorganisms. As a result, the mangoes will not spoil as rapidly as they would if the water was present. This means that we will have a “shelf-stable” product that can be kept for several months without spoiling. Even though most of the water has been removed, the dried flesh of the mango will retain most of its nutritional properties.

In addition to making the mangoes last longer before they spoil, there are some additional reasons for drying them. By removing most of the water that was originally present, we are left with only the solids and a small amount of water. This makes a very large difference between the weight of the fresh mangoes and those that have been dried.

A benefit of the weight reduction is that the mangoes can be shipped at a lower cost since there is no need to transport large amounts of water. For example: 100 kg of fresh mangoes can be dried to give about 17 kg of dried mango slices. This means that we can ship only the solids portion of the mangoes and a small amount of water, thereby avoiding the expense of having to transport the added weight of the 83 kg of water that was removed.

Removing the water from mangoes causes the fleshy portion of the fruit to shrink in size. Therefore, the dried mangoes take up much less room to store or transport than fresh mangoes. Figures 6a and 6b show mango slices before and after drying. Hopefully, you can see the differences in their appearance and size.



Figure 6a: Mango slices before drying



Figure 6b: Mango slices after drying

These mangoes were dried with their peels left on as part of a drying study.

An added advantage of increasing the shelf-life of the mangoes through dehydration is that they can be shipped longer distances (possibly to foreign markets). During the considerable time it takes to reach far-off destinations, fresh mangoes could easily spoil. However, this problem can be avoided if dried mango slices are exported.

Taste and texture are two other things to consider when comparing fresh and dried mangoes. When the water is removed from the mangoes, the sugars that were dissolved in the mango juice remain in the dried mango flesh. This means that the dried mango slices will contain a high concentration of natural sugars and will have a very pleasant sweet taste and a somewhat stronger flavour than the fresh “wet” mangoes. Drying also tends to make the mango flesh take on a leathery texture which makes them a chewy snack.

We will look at how dried mangoes can be used later in this guide.

3. How Do We Dry Mangoes?

The most effective way to dry any fruits or vegetables (or even meats) is to expose them to heated air. This will remove moisture and leave behind the solids and materials which were previously dissolved in the water.

Sources of heat can include burning various fuels, or other more environmentally friendly methods such as sun-drying.

Sun-drying can be done in the open air by spreading the selected material on metal racks or mesh screens. If the air is not already saturated with moisture, the warmth of the sun and warm gentle breezes will remove moisture as the air passes across the surface of the fruits or vegetables being dried. Sun-drying can be slowed significantly if the air is humid. This reduces the “drying capacity” of the air, which is the ability of the air to remove moisture from a material.

The sun can also be used as a source of energy to heat air and dry materials that are located inside a cabinet. We refer to these enclosed devices as “solar dryers”. Although the concept is fairly simple, designing an efficient and effective solar dryer is a challenge. A great deal of research has been done to improve the design and operation of solar dryers. This has made them a very attractive alternative to dryers that rely on burning fuels (wood, oil, gas, etc.) as a source of heat.

In the remaining portions of this guide, we will look at various aspects of mango drying, with particular emphasis on solar drying.

4. Is Quality of the Mangoes Important?

The importance of selecting the proper starting materials for drying is often overlooked. Only the best quality fruit available should be used for drying. Any processing facility that is drying mangoes should have a set of standards in place to define the quality of their ideal starting material. Since this is very subjective, we cannot set out any actual standards here. We can, however, look at some of the basic attributes which need to be considered.

4.1 Overall appearance:

The mangoes need to pass a visual inspection before they can even be given additional consideration. They should be free from blemishes such as bruises and insect damage. They may need to be of a certain size or weight to make handling easier. Their colour may assist in determining the desired degree of ripeness. As mangoes ripen, their sweetness increases and their texture changes. Both of these are important factors that can be partially assessed by a preliminary visual inspection.

If there is any surface contamination, such as visible mold growth or bird droppings, these mangoes and those within the same group should be seriously considered for rejection. While bird droppings can be removed by washing, it should be remembered that fecal matter carries with it a variety of microorganisms that can be the cause of potential food-borne illnesses.

Figure 7 shows a mango purchased for some drying trials. It has a slightly different colour than the one shown in Figure 3, even though it is the same

variety. This is due to the fact that it is slightly more ripe



Figure 7: A mango selected for drying

4.2 Feel:

The mangoes being selected may need to have a certain degree of firmness that will indicate their level of ripeness. This will help verify the initial visual inspection. Mangoes that are overly ripe, or too soft, are hard to peel and slice. Their texture may not be suitable for processing. Mangoes that are too firm may not have sufficient ripeness to have developed the correct level of sweetness. While they are easy to handle and may dry satisfactorily, the taste of the final dried product may not be as sweet as desired.

Feeling the mangoes may also let you know how juicy they are. A certain level of moisture is necessary to provide a high quality mango from the point of view of texture, flavour, and sweetness.

4.3 Aroma:

It is often possible to pick the desired starting material by examining how it smells. Mangoes have a characteristic aroma that may help in assessing the quality of the starting material. In general, any fruit with an uncharacteristic or suspicious odour should be avoided, since it may be spoiled.

4.4 Source:

Mangoes for drying and other processing should be bought from trusted suppliers. The fresh mangoes entering a processing facility can bring many problems with them. As a processor, you need to know the past history of the mangoes you are using as your raw materials and will ultimately be selling to your customers.

You need to know if chemicals were used during the growth period of the mangoes. Were they sprayed with insecticides or pesticides? Were any fertilizers used, and if so, were they appropriate? What were the general conditions under which the mangoes were grown? Are there any potential health risks imposed by the growing, harvesting, or storage and handling conditions? Mangoes purchased in the market may not have a good history of how they were grown, harvested, or handled (see Figure 8).



Figure 8: We have no idea how these mangoes in the market were handled

Another very important factor is the manner in which the mangoes were obtained. Were they removed from the trees in a picking process, or were they picked up off the ground as “windfalls”?

Basically, this means that the fruit has ripened on the tree and has been knocked down by the wind. In other cases, it may simply be too heavy to be supported any longer by the stem which connects it to the tree.

Fruit that has fallen from the tree and been picked off the ground often has surface contamination. The causes of this contamination are often from being in contact with droppings of animals such as sheep, goats, or cattle that have been grazing in the areas around the trees. “Windfall” mangoes should be avoided whenever possible.

4.5 Variety:

Certain varieties of mangoes may have better properties for drying than others. Some mangoes are large and juicy with a high level of sweetness. Others may be smaller with a higher fibre content and lower sweetness level. There is also the need to understand which varieties will give you the best finished product to meet the needs of your customers. You may need to process a number of different varieties to satisfy the different preferences of the consumers.

In areas with only one variety of mango available, this factor will not be an issue.

4.6 Taste:

Since your dried mangoes will end up as a food product, it is a good idea to taste the starting material. Mangoes which are not sufficiently sweet or have an undesirable texture, or “mouth-feel”, should not be used. This is a difficult point to describe or define. However, some basic descriptions outlining examples of desirable flavour attributes can go a long way to assuring a higher quality finished product.

5. What are the Initial Preparation Steps?

Once the mangoes have been selected, the basic preparation steps can begin.

Even if the incoming mangoes have been inspected at their point of purchase, they need to be closely examined as they are coming into the processing plant facilities. This should be done before they are unloaded from the delivery vehicle. By doing this, they can be easily removed from the processing facility area if they are rejected. Had they been unloaded prior to inspection, it would be necessary to reload them onto the delivery vehicle for removal from the plant. Preliminary inspection also reduces the risks of spreading potential contaminants around the processing plant should any be found on the incoming mangoes.

All accepted fresh mangoes must be thoroughly washed before entering the main processing area. The outer peel of the mangoes can be contaminated with potentially dangerous microorganisms from a variety of sources such as birds, insects, rodents, and grazing animals (in the case of windfalls). There should be minimal delay between acceptance of the incoming mangoes and the time they go through the initial washing phase of the process. This will reduce the need to store incoming fresh mangoes before they are washed and help maintain a clean production environment.

Washing must be done with potable water. "Potable water" is water that is fit for human consumption. This will prevent the incoming fruit from being contaminated further, which would be the case if impure water was used in the washing stage.

A rinse with a chlorine solution or passage through a bath of chlorine solution would help reduce the microbial population on the surface of the mangoes. The easiest way to prepare a disinfecting solution of chlorine is by using a bleach solution. A household bleach container often has instructions on the label for preparing such a solution.

The strengths of chlorine solutions can vary depending on their application and the concentration of the initial bleach solution. A mixture of 180 mL of bleach and 4 litres of potable water may be sufficient for this application. This would need to be followed by a thorough rinse with potable water.

There is always a risk of bringing undesirable microorganisms and other contaminants into a processing facility. To minimize this risk, there needs to be a means of ensuring separation between different areas. Raw material receiving areas must be separated from the rest of the processing facility. Workers should not be allowed to travel from one area to the other without safeguards being in place to prevent contamination of one area by materials and contaminants from another area. You may want to consider the receiving area as being "dirty" and have it totally isolated from the remainder of the processing plant.

Once the mangoes have been washed, they may need to be stored for a short period of time before going on to the next processing step. This area could be considered as "clean" storage. Holding times should be minimized. The storage area must be closely monitored to ensure that the first mangoes to come into the "clean" storage area are the first ones to leave when additional fresh mangoes are

brought in.

From the “clean” storage area, the washed mangoes would go to a peeling operation. Here, the outer peel of the mangoes will be removed by using a paring knife or peeling device.

Because the inner surface of the mangoes is now exposed to the workers who are doing the peeling and other steps, these workers should be wearing proper attire for the job. This would include hairnets or other suitable head covering. Where applicable, beard nets must also be worn. Coats, smocks, or similar uniform along with proper safety equipment (e.g., proper safety shoes or other footwear, gloves, knife guards, etc.) are absolutely essential. Light-coloured uniforms, especially white, are better than darker coloured uniforms for hygienic purposes since stains and spills are more easily recognized on the lighter-coloured fabric.

Your fingers are the ten most common causes of infection and food contamination

Hand-washing stations using warm potable water and equipped with soap dispensers should be within easy access of workers. Towels for hand-drying should be clean and changed regularly. In addition, there should be adequate washroom facilities which should be maintained and cleaned according to a regular schedule. Workers should never return to their work stations without having properly washed their hands.

Workers must wash their hands:

- before and after handling foods or eating
- after using the washroom facilities
- after sneezing, coughing, or blowing their nose
- after touching a cut or open sore
- after being outside or touching any unclean surfaces

Proper hand-washing procedures include:

- wetting the hands with clean warm water
- applying soap
- rubbing the hands together to create a lather which is to be spread on the front and back of the hands, between the fingers, and under the fingernails.
- lathering should continue for at least 20 seconds
- once thoroughly lathered, the hands should be rinsed with warm potable water (i.e., water that is safe for drinking).
- a clean fresh towel should be used for drying the hands (paper towels are ideal for this purpose)
- the towel should be used to turn off the water faucet and then be discarded in a proper receptacle

Hand-washing is the most effective way to stop the spread of illness and disease

During peeling, workers will be using knives or peeling devices to remove the outer peel from the mangoes. Sufficient safety training must be provided to each worker to prevent personal injuries and to impress upon them the importance of

cleanliness within the processing facility.

**WORKER SAFETY
IS OUR #1 CONCERN**

Workers with cuts or open sores should not be allowed in the production facility where there could be a potential threat to the cleanliness of the area.

Peels from the mangoes must be removed from the area within a reasonable time period and not be allowed to accumulate. The peels may provide a risk of contamination even though they have been previously washed. Since they are biodegradable, they can be sent to a composting area. The peeled mangoes should then be sliced for drying.

Figure 9 shows peeled mangoes awaiting slicing. The slight greenish tinge is due to the fact that very little flesh was removed with the peel and that the mango may not have fully ripened.



Figure 9: Peeled mangoes

The condition of the knives and other utensils is important for worker safety. Blades should be kept sharp and free

from rust, dirt, and other sources of contamination.

All surfaces should be washed with potable water and disinfected with a chlorine in water solution of suitable concentration after each production batch or shift. All equipment should be thoroughly cleaned according to appropriate standards which are beyond the scope of this guide.

6. How Should the Mangoes Be Sliced?

Mango slicing can be difficult due to the slippery nature of the mangoes and the presence of the large stone within the mango itself.

As you can see in Figure 10, mango stones tend to be flat. The ones shown in the photo were scraped to remove most of the mango flesh. They were then dried in the sun to remove the surface moisture. When dry, you can see the fibres sticking out of the stone. These will not be as noticeable when the stone is cut away from the mango flesh and it is still wet.



Figure 10: Mango stones
(side view and flat surface view)

There are numerous ways to slice a mango. The exact procedure will depend on personal preference. If you look at the shape of the mango, it is not generally round. Instead, it is somewhat flattened. You can place the peeled mango on a cutting surface so that the longer dimension is aligned vertically. This will orient the mango so that the stone is in the up-down position as well.

The mango can then be sliced vertically from the outside until the knife hits the side of the stone. Large flat slices can generally be obtained from either side of the stone, but it will not be possible to get such large slices from the mango flesh around the stone. Here, you will get much smaller slices. Procedures on how to slice the mangoes should be established to ensure that all mangoes are sliced in a uniform manner.

The slices themselves should be about 5 to 6 mm thick (approximately $\frac{1}{4}$ inch). Thickness is a very important factor in mango drying as we will see later.

The mango slices should be placed in a clean container such as a large metal bowl. The bowl needs to be covered and kept in a cool, clean area until the slices are required for drying. It is a good idea to avoid slicing the mangoes too far in advance of when they are needed. In this way, problems with sanitation can be reduced, and there is less risk of flavour changes.

7. How Do We Dry the Mangoes?

7.1 The Drying Mechanism:

Before we go too far into the details about drying mangoes, we need to look at how moisture is removed during a typical drying process.

Most products dry because moisture (which is really water) is removed from their surfaces. If we have a sliced mango, we can see that the surface tends to be wet - especially if the mango is ripe and juicy.

It is important that the air used for drying purposes is not overly humid, or saturated with moisture. When warm dry air is blown across the surface of the wet mango slices, it picks up some of the moisture by the process of evaporation. Evaporation is the change that occurs when water goes from being a liquid to a vapour. So, the warm air now contains water vapour and carries it out of the dryer and away from the slices of mangoes.

As more and more air blows across the surface of a mango slice, moisture from inside the mango slice comes to the surface to replace the moisture that was lost. We call this process of moisture moving from the centre of the material to the outer surface "diffusion". Moisture that has diffused to the surface is then evaporated and swept away by the moving air.

At the start of the drying process, the combination of a wet surface and additional moisture coming to the surface makes the rate at which the water is removed quite high. Figure 11 shows how the drying process occurs when the moist mango slices are first placed in the