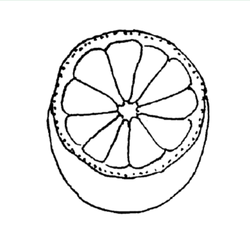
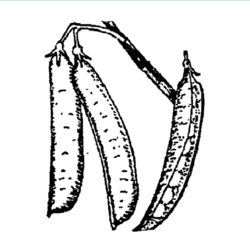
Agrodok-series No. 3

Preservation of fruit and vegetables





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Agrodok 3 - Preservation of fruit and vegetables

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Preservation of fruit and vegetables

Ife Fitz James
Bas Kuipers

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Foreword

This Agrodok is meant to be a practical manual giving a review of the simple techniques used to preserve fruits and vegetables.
In addition to information provided in the previous edition of this Agrodok, this fourth edition covers more theoretical information on food decay in general, its causes and dangerous effects, as well as preventive measures that can be taken. In our opinion this knowledge is necessary if you want to start a small-scale preserving business, to which a whole chapter is devoted in this edition.
The general introduction deals with the principles of spoilage prevention. The various methods of preserving are then explained, and the main points of spoilage specific to the method are covered. The next chapters deal with jam and juice making and attention is paid to drying vegetables and fruit, as well as salting of vegetables. Freezing is not discussed, since this technique needs facilities usually not available in many developing countries. We have tried to describe every method as practically as possible, including descriptions of the required materials and techniques.
Finally we would like to thank some people for their contributions to the realization of this Agrodok: Domien Bruinsma for writing chapter 8 and critically reading the different concepts, Jan Schreurs for text editing, Mamadi Jabbi for making some new illustrations and Willem Würdemann for critically reading the content of this Agrodok.

Ife Fitz James
Bas Kuipers

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1 Introduction

All living creatures, including humans, depend on nature for their food. Humans are not only hunters and gatherers, but also farmers. We live from hunting and fishing, agriculture and animal husbandry. Most of our food consists of agricultural products, which are usually seasonal and spoil quickly. To make food available throughout the year, humans have developed methods to prolong the storage life of products: to *preserve* them. The rotting process can be postponed by adding preservatives, optimizing storage conditions, or applying modern techniques. The last option will not be discussed in this Agrodok. This booklet focuses on the traditional preservation methods still commonly used in developing countries for fruits and vegetables.

Fruits and vegetables provide an abundant and inexpensive source of energy, body-building nutrients, vitamins and minerals. Their nutritional value is highest when they are fresh, but it is not always possible to consume them immediately. During the harvest season, fresh produce is available in abundance, but at other times it is scarce. Moreover, most fruits and vegetables are only edible for a very short time, unless they are promptly and properly preserved.

This Agrodok will focus on a few simple and relatively inexpensive preservation techniques that can be applied on a small scale by an individual or a small group (of families for example). Chapter 2 provides information on food spoilage in general, its causes and dangerous effects, as well as measures that can be taken to prevent it. Specific knowledge is needed to apply the right preservation methods. Fruits and vegetables have to be specially prepared, for example, before they can be preserved. How this is done is explained in Chapter 3. Chapters 4 to 7 describe the various preservation methods: heating, drying, and the use of additives such as salt and sugar. In times of scarcity, preserved food can be sold for a good price. It can even be worthwhile to start a small preserving business. Chapter 8 explains what this would involve. More information can be found through the addresses and literature listed in Chapter 9 and in the appendixes that follow, which provide specific information on how to prepare and preserve the various types of fruits and vegetables. Various terms that may be new to readers are defined in the glossary at the end of the booklet.

Agromisa welcomes all readers' comments that could contribute to improving the quality of our publications. A survey form is therefore included in the middle of this booklet, which can be completed and returned to us. Readers seeking more information on food preservation are also encouraged to contact Agromisa's Question and Answer Service at the address listed in the back of this booklet.

2 Food spoilage: causes, effects and prevention

2.1 What is food spoilage?

Every change in food that causes it to lose its desired quality and eventually become inedible is called food spoilage or rotting. As noted earlier, this Agrodok focuses specifically on fruits and vegetables. As long as they are not harvested, their quality remains relatively stable – if they are not damaged by disease or eaten by insects or other animals. However, the harvest cannot be postponed indefinitely: when the time is right, it is time to act. As soon as the fruits and vegetables are cut off from their natural nutrient supply, their quality begins to diminish. This is due to a natural process that starts as soon as the biological cycle is broken by harvesting. Once it is harvested, the agricultural product is edible for only a limited time, which can vary from a few days to weeks. The product then begins to spoil or 'rot'. We distinguish between various types of spoilage:

1 physical spoilage
2 physiological aging
3 spoilage due to insects or rodents
4 mechanical damage
5 chemical and enzyme spoilage
6 microbial spoilage

Physical spoilage is caused for example by dehydration. Physiological aging occurs as soon as the biological cycle is broken through harvesting. Neither process can be prevented, but they can be delayed by storing the agricultural products in a dry and draft-free area at as low a temperature as possible.

Insects and rodents can cause a lot of damage. Not only by eating the products, but also by passing on micro-organisms through their hair and droppings. The affected parts of the plants are then especially susceptible to diseases.

Chemical and enzyme spoilage occurs especially when vegetables and fruit are damaged by falling or breaking. Such damage can release enzymes that trigger chemical reactions. Tomatoes become soft, for example, and apples and other types of fruit turn brown. The fruit can also become rancid. The same processes can also be triggered by insects: the fruit becomes damaged, which causes enzymes to be released. Enzymes can be deactivated by heating the fruit or vegetables. The same effect can be achieved by making the fruit or vegetables sour or by drying them, but the enzymes become active again as soon as the acidity is reduced or water is added.

The peel of a fruit or vegetable provides natural protection against micro-organisms. As soon as this shield is damaged by falling, crushing, cutting, peeling or cooking, the chance of spoilage increases considerably. Crushing occurs most often when fruits or vegetables are piled up too high.

To prevent harvested products from spoiling, they can be preserved: physiological aging and enzyme changes are then stopped and micro-organisms are prevented from multiplying on the product. To retain the desired quality of a product longer than if it were simply stored after harvesting, it must be preserved. To preserve food it must first be treated, with the goal of stopping physiological aging and enzyme changes and preventing the growth of micro-organisms.

Before discussing the specific treatment methods, we will first focus on the subject of micro-organisms. What are micro-organisms? Why are they dangerous? How can you prevent them from making you sick? The answers to these questions will help you understand the steps required to safely preserve food.

2.2 What are micro-organisms, and what factors affect their growth?

Micro-organisms are very small, one-celled animals. There are three types: bacteria, moulds and yeasts. Bacteria and yeasts cannot be seen with the naked eye, but moulds are often visible because they form visible thin threads (filaments) or a solid cluster. Just like humans, micro-organisms require certain minimum living conditions. They cannot survive without:

- sufficient water
- oxygen
- the right degree of acidity
- nutrients
- the right temperature

Water is necessary for maintaining many physical processes. Where there is a shortage or lack of water micro-organisms cannot grow, such as in dried legumes. Drying is therefore one way to prevent spoilage. Meat and fish do not have to be 100% dry in order to preserve them. By adding salt, the remaining water becomes unsuitable for micro-organisms. The same effect can be achieved by adding sugar to fruit. Enzymatic spoilage is also inhibited by drying.

Most micro-organisms need **oxygen**. If there is a shortage of oxygen, it is difficult for bacteria to survive, let alone multiply. But there are always a few that manage to survive. As soon as the oxygen supply is increased, these remaining bacteria will again grow and multiply. Some types of micro-organisms even thrive in an oxygen-poor environment.

Bacteria grow best in an environment that is not too **acidic**. Less acidic products are therefore especially susceptible to bacterial spoilage. Examples of such products are meat, eggs, milk and various types of vegetables. Beer, yoghurt, wine, vinegar and fruit are less sensitive because they are more acidic. Adding acidity to products slows down the process of microbial spoilage. The degree of acidity is measured as a pH level. A neutral product like milk has a pH of 7; meat has a pH of about 6, carrots have a pH of 5 and oranges about 4. The more acidic a product is, the lower the pH value will be.

Just like humans, micro-organisms also need **nutrients**: sugars, proteins, fats, minerals and vitamins. These are rarely in short supply, because they can be found in all food products.

To thrive, micro-organisms need a **temperature** of between 5 and 65°C. At temperatures above 65°C it becomes very difficult for them to survive; and they definitely die if boiled, as long as they are boiled for a certain length of time, such as 10 minutes. When heated, the micro-organisms slowly die off, but not all at the same time. Heating at temperatures lower than 100°C thus has to be sustained for a longer period. The growth of micro-organisms is also slowed down significantly at temperatures between 0 and 5°C (as in a refrigerator), which makes it possible to store the food products for a few additional days. At temperatures below 0°C microbial growth is stopped completely, but the micro-organisms themselves remain alive. They will become active again as soon as the temperature rises above 0°C.

To preserve food, it is sometimes necessary to make drastic changes to the micro-organisms' living conditions. We can remove water (drying), increase the acidity, or first heat the products (to kill the bacteria) and then store them in air-tight containers to prevent oxygen from entering (preserving/canning). These and other methods will be discussed later in this booklet.

Do micro-organisms grow differently on vegetables and fruit?

Vegetables and fruit have a lot in common. But there are also important differences, which determine the type of spoilage they are most susceptible to. Damaged fruits, which are usually somewhat acidic, are very susceptible to the growth of yeasts and moulds. Vegetables are generally less acidic, and their spoilage is usually caused by bacteria. Though not visible to the naked eye, bacteria can still be present in large numbers.

What types of micro-organisms grow on what products?

- *Moulds* can be found on almost all food products. They are often very visible and can significantly alter the taste of the products. They grow the best in low temperatures in an acidic environment and on dry products such as grains and bread. Some moulds produce poisonous substances, especially in moist seeds such as peanuts, corn and soy beans.
- *Yeasts* can also cause food to spoil. They prefer low temperatures and acidic products.
- *Bacteria* can grow on almost all types of fresh food that is not too acidic: meat, fish, milk and vegetables. One type of bacteria carries a kind of seed, called a spore. Spores can survive at a temperature of 100°C, even though the bacteria themselves die. Once the temperature drops, new bacteria can grow out of the spores. To kill the spores, they must be exposed to a temperature of 121°C. This is called sterilization.

2.3 What do micro-organisms do to fruits and vegetables?

Micro-organisms take from food products the various substances they need to survive and multiply. Their secreted waste products can have either a negative or positive effect on the affected food and the humans who eat it.

Positive effects of micro-organisms in food

The waste products secreted by some micro-organisms can have a positive effect on food. Lactic acid bacteria, for example, are used to make cheese and yoghurt from milk, and sauerkraut from white cabbage. Moulds are used to make tempeh from soy beans, and yeasts are used to make beer and bread. These substances influence the taste and structure of the food products and generally increase their shelf-life. The products can be kept longer because the desired micro-organisms decrease the food's pH level or because they are present in such huge numbers that other micro-organisms have no chance to grow. This use of micro-organisms for the preparation of food is called *fermentation*. More information on this process is given in Chapter 6.

Negative effects of micro-organisms in food

Sometimes the negative effects of bacteria are clearly apparent, such as when milk has turned sour and curdled, when meat is covered in slime, when moulds and gasses have formed, and when food has a distinctly putrid smell. However, food spoilage is not always this obvious. There are bacteria whose presence in food does not always cause a change in its taste or appearance. In any case, it is important to avoid eating rotten food, because it can make a person seriously ill.

Eating rotten food can cause contamination or poisoning. A *food contamination* occurs when a person consumes a large number of living micro-organisms in a meal. These can multiply rapidly in the person's gastrointestinal tract and severely disturb the digestive system. The result is often diarrhoea and sometimes also bleeding. The symptoms appear between 3 and 24 hours after eating the rotten food. A food contamination can be prevented by frying or boiling the food thoroughly, since sufficient heating will kill the micro-organisms.

Food poisoning occurs when a person consumes food containing the poisonous waste products secreted by the bacteria. Heating the food does not help in this case: the bacteria will be killed, but the poisonous waste will remain unharmed. Both food poisoning and food contaminations can be *lethal*, but usually they only make a person sick.

How do micro-organisms come in contact with fruits and vegetables?

Spoilage caused by yeasts, moulds and bacteria develops slowly and is not always noticeable. The most important sources of microbial contaminations are sand, water, air, and pests such as insects and rodents. Food products can also be infected by people. Micro-organisms are everywhere around us. To prevent them from reaching our food in great numbers, it is important to work as hygienically as possible when handling fruits and vegetables, for example.

The following practices are therefore recommended:

- Wash your hands thoroughly with hot water and soap before beginning to prepare food.
- Make sure that kitchen utensils and appliances are well cleaned and disinfected.
- Always store food in a clean place.
- Use herbs and spices as little as possible, because they are an important source of contamination.
- Use clean and pure salt only – if the salt is not pure, heat it on a dry, metal sheet above the fire.
- Allow only clean drinking water to come in contact with fruits and vegetables.
- Never allow anyone who is sick or has open wounds to come in contact with food that is to be preserved.

3 Preparation

Fruits and vegetables should be prepared for preservation as soon as possible after harvesting, in any case within 4 to 48 hours. The likelihood of spoilage increases rapidly as time passes. This chapter discusses preparation methods used for the various preservation methods discussed in Chapters 4 to 7.

3.1 Cleaning and washing

First, the fruits or vegetables have to be thoroughly cleaned to remove any dirt or insecticide residues. The outer layers of onions also have to be removed. This cleaning process usually involves washing the products under a faucet with running drinking-water or in a bucket with clean water that is regularly refreshed. When cleaning leafy vegetables, it is best to first remove the stems. Some types of fruit, such as cherries, strawberries and mushrooms are *not* washed, because this would actually increase the spread of micro-organisms. It is also not advisable to wash cucumbers, because this shortens their shelf-life.

Dried beans and nuts are soaked in water for 16-20 hours before being processed further. To prevent the beans and nuts from turning black, a stainless steel pan or bowl, or other galvanized material, should be used. The temperature of the soaking water should remain constant.

3.2 Lye dip

Some products, such as plums and grapes, are immersed for 5-15 seconds in a pan of hot, almost boiling, lye (NaOH; 10-20g lye/litre water) to make the peel rough and to thereby speed up the general drying process. The peel then also separates more readily from the fruit, which makes it easier to remove. After such a treatment, the fruit has to be rinsed vigorously with cold water to remove the lye residues. Lemon juice can also be used to neutralize any remaining lye residues.

The preparation method described above is considered to be ecologically harmful because alkaline is transported by the waste water into the environment. Other disadvantages of using lye are that the food can become discoloured and the metal pan could become corroded. The use of too-high concentrations of lye is also unhealthy for the people working with it.

3.3 Sorting

To achieve a uniformly sized product, fruits and vegetables are sorted immediately after cleaning according to their size, shape, weight or colour. Sorting by size is especially important if the products are to be dried or heated, because their size will determine how much time will be needed for these processes.

3.4 Peeling

Many types of fruits and vegetables have to be peeled in order to be preserved. This can easily be done with a *stainless steel* knife. It is extremely important that the knife be made of stainless steel because this will prevent the discolouration of the plant tissues. It is best to first submerge citrus fruits, tomatoes and peaches, whose peels are all securely connected to the fruit, in hot water for 1 ½ to 3 minutes. The softened peel can then be removed without too much effort.

3.5 Cutting

Cutting is important because you will need approximately uniform pieces for the heating, drying and packing stages. Fruits and vegetables are usually cut into cubes, thin slices, rings or shreds. The cutting utensils have to be sharp and clean to prevent micro-organisms from entering the food. From the moment they are cut, the quality of the products decreases due to the release of enzymes and nutrients for micro-organisms. A decrease in quality is also caused by the damage done to the plant tissues. For this reason, the interval between peeling/cutting and preserving has to be as short as possible.

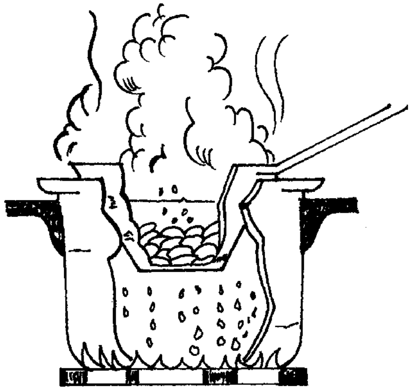
3.6 Blanching

Blanching or 'pre-cooking' is done by immersing fruits or vegetables in water at a temperature of 90-95°C. Exposing them to steam is also possible. The result is that fruits and vegetables become somewhat soft and the enzymes are inactivated. Leafy vegetables shrink in this process and some of the micro-organisms die. Blanching is done before a product is dried (see Chapter 5) in order to prevent unwanted colour and odour changes and an excessive loss of vitamins. Fruit that does not change colour generally does not need to be blanched. Onions and leek are not at all suited for blanching.

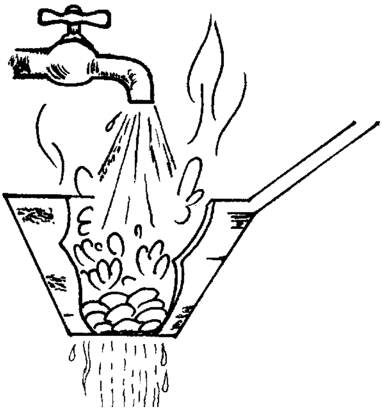
Blanching is quite simple. The only thing you need is a large pan with a lid and a metal, or in any case heat-resistant, colander (see Figure 1). Place the fruit or vegetable in the colander (a linen cloth with a cord will also do) and immerse this in a pan with sufficient nearly boiling water to cover the food completely. Leave the colander in the pan for a few minutes and turn the food occasionally to make sure that it is heated evenly. Immediately after the colander is removed from the pan the food has to be rinsed with cold, clean running water. Make sure that the extra water can run off. If no faucet is available, a container with drinking-water can also be used, as long as the water is cold and clean. During the blanching process, it is important to monitor the time and the water temperature (Appendix 4 gives an overview of recommended blanching times per vegetable).

The disadvantage of this blanching method is that many vitamins are lost in the hot water. Steaming is therefore a better alternative. Only a small amount of water has to be added to the pan and brought to the boil. Make sure that the fruit or vegetable in the colander is touched by the steam but not by the water. This blanching method is similar to the method for extracting juice described in Figure 12 and Chapter 7.

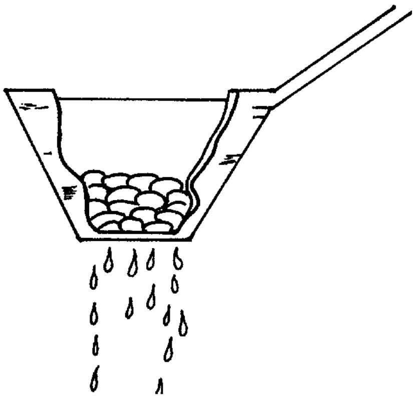
a. Pan of hot water



b. Product in colander is completely immersed in water



c. Rinsing and cooling under running water



d. Drip drying

Figure 1: Blanching

4 Preserving by heating

4.1 Introduction

One of the most common and effective ways to preserve fruits and vegetables is to prepare them and place them in air-tight containers, which are then heated. The high temperatures ensure that micro-organisms are killed and the enzymes are inactivated. Any remaining spores will not have the right conditions to grow into bacteria and microbial contamination from outside is prevented. However, it is important to remember that some micro-organisms are unfortunately less sensitive to heat: *Clostridium* and *Staphylococcus* can still multiply and spoil the food through the poisonous substances they produce. *Clostridium* can cause botulism and result in tragic deaths. This bacteria does not thrive as well in more acidic products such as fruit (pH < 4.5).

The heating method for fruit is different than for most vegetables. As noted above, fruit has a low pH level. It can be heated in boiling water (100°C), whereas most vegetables have to be heated at temperatures above 100°C, because they have a higher pH and are thus more susceptible to bacterial contamination.

This preservation method produces the best results, but only if fresh products are used and the instructions for heating are followed exactly. As with other methods, heating has advantages and disadvantages as outlined below.

Advantages

- Most micro-organisms are destroyed so there is less chance of spoilage.
- After being sterilized and stored, the food can be kept longer and more safely.

Disadvantages

- Heating requires the following investments:

- Heat-resistant storage containers (which can be difficult to obtain) such as cans or glass jars. The latter are preferred because they can be reused.
- Cooking utensils, such as a steamer
- Fuel

➢ These investment costs will have to be represented in the final cost of the product.
➢ This method is labour intensive.
➢ It requires access to abundant clean water.
➢ Preserved fruits and vegetables have a lower nutritional value and generally less taste than fresh products. However, fewer nutrients are lost using the heating method than any other preservation method.

Pasteurization and sterilization are two methods of heating food products to prevent them from rotting and to prepare them for storage in glass jars or tins. These methods will be explained later in this chapter, but first we will discuss the packing and preparation of vegetables.

4.2 Packing

Even though increasing the container volume decreases the cost per kilogram of packing a product, there are two reasons to avoid using large containers. First, the entire content of the container has to be consumed within 24 hours after opening it; and second, it will take much longer before the food in the middle of the container is heated sufficiently to kill all the bacteria. Heating the product longer will increase the energy costs. If large volumes are desired, it is best to work with flat tin containers, since the distance from the nearest edge of the container to the centre is smaller and the product will therefore heat up quicker.

Of course the packing material must be clean. The more micro-organisms that come in contact with the food, the longer the heating process will have to take. The two types of containers used to preserve food with the heating method (tins and glass) are described below.

Tins

These are iron cans, which are covered with a thin layer of tin. They are especially used for sterilizing, and are very suitable for sterilizing larger amounts. Unfortunately, they can only be used once. There are many different types available with varying volumes and shapes (cylindrical tins are long, round and narrow, while flat tins are wide and shallow). A few common volumes are: 0.58 l / 0.85 l / 0.95 l / 3.1 l.

Tins can also vary with respect to the presence or absence of a varnish layer on the inside. Unvarnished tins are often good enough. However, varnished tins must be used for special products, such as cherries, berries and plums, in order to maintain good colour and taste. In these and other products, tin triggers chemical reactions that change the product's colour and/or taste. Varnish thus avoids contact between the tin and the product.

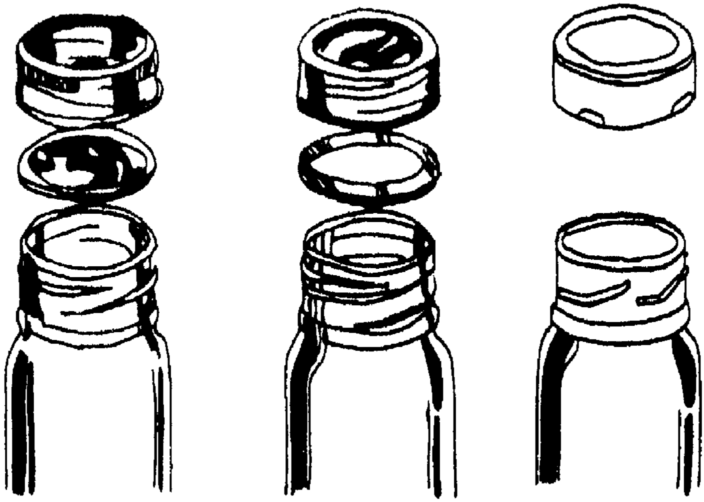
Every tin comes with a lid, which can be hermetically sealed with the help of a tin sealer. Various types are available, ranging from simple hand-operated tools to new automatic machines. The seal must be properly adjusted to prevent leakage. This can be checked by closing the tin with a little water inside and immersing it in boiling water. If, after a few minutes, steam is seen to escape, the seal must be re-adjusted.

Tins delivered from the factory are fairly clean, and do not require extra washing. Store them upside down to keep out contaminants. If they are not clean, wash them in hot soda water (1.5%), rinse with hot water and let them drip dry on a clean cloth. The lids must also be clean.

Glass

Glass bottles and jars can be used for sterilization and pasteurization and they are normally reusable. However, they are also breakable and they do not protect food from the negative effects of light. This problem can be alleviated by storing the filled bottles and jars in a dark place.

Glass bottles, those previously used for soft drinks or beer for example, are well suited for heating and storing fruit pulp, puree or juice. They have to be sealed with a metal screw cap. Their volume can vary from 0.2 to even 2 litres. These bottles and their screw caps can easily be reused.



A: Jar with divided lids *B: Jar with ceramic/rubber-lined zinc lids* *C: Jar with cap (turn and lift system; by turning the lid one quarter, it already lifts from the jar)*

Figure 2: Glass jars with different sealing mechanisms

It is important that the bottles or jars be completely hermetically sealed. This can be done by inserting a soft layer of rubber or other similar material between the bottle or jar and the cap or lid. This rubber layer can be separate or attached to the cap as shown in Figure 2. Producers of glass bottles and jars often also sell accompanying rubber rings and lids or caps. The best results are achieved when the glass containers and sealing mechanisms (rings, caps and lids) are made by the same company.

The bottles or jars and their caps or lids must first be thoroughly cleaned with soda (15 gram/litre) and hot water. Allow them to soak in the hot water until the moment they are used.

4.3 Preparation

Before a product is heated in its storage container, it must be prepared as explained in Chapter 3. Read that chapter again before proceeding, because the preparation step is very important for the success of the entire preserving process. Specific information about the appropriate ways to prepare and preserve the various types of fruits and vegetables can be found in Appendixes 1,2 and 3:

1 Pasteurization (heating up to 100°C) – for products that will be subsequently stored at temperatures below 20°C (Section 4.4.1 and Appendix 1);
2 Sterilization at 100°C – only for acidic products (Section 4.4.2 and Appendix 2);
3 Sterilization (above 100°C) in a pressure cooker or an autoclave (large pressure cooker) (Section 4.4.3 and Appendix 3).

Each appendix consists of two tables. The first table lists the recommended preparation method for each product and the content of the fluid with which the fruit or vegetable is preserved. The second table lists the temperature at which the glass container or tin should be filled and the recommended duration of heating for various sizes of glass and tins. The food to be preserved is usually heated in a large pan and then packed while still hot, before the actual heating process even begins. This is the most efficient method, because it is faster to thoroughly heat a large amount of food in a large pan by continually stirring it than to heat smaller amounts of food in individual sealed bottles or tins. It takes much more time for the heat to penetrate to the centre of the food in the jars.

4.4 Three types of heating

The previous section mentioned three types of heating (1, 2 and 3 above). Before discussing each of these in detail, we will give an example of how tins, jars and bottles should be filled. The products are first prepared as described in the appendixes. The following example demonstrates how these appendixes should be used:

To preserve white beans in 0.85 litre tins:
First peel and wash the beans and then blanch them for 3 minutes (see Chapter 3). Large beans should first be soaked in water overnight. After blanching and straining the beans, put them in the cans, which are then filled almost to the brim with boiling, salted (2%) water (see Appendix 3a). Seal the cans while the content is at a temperature of at least 60°C. Place the cans in a pressure cooker and heat them for 85 minutes at a temperature of 115°C (see Appendix 3b).

The tins or jars have to be filled up to 0.5 cm below the *sealing edge*. For leafy greens the fluid has to be poured into the tin or glass container first, followed by the vegetable. Make sure to eliminate as many air bubbles as possible. The *sealing temperature* is very important. It may never be lower than indicated in the appendix. If the temperature of the food is lower, the jars and tins must be quickly reheated in a shallow water bath until the temperature of the food in the middle of the tin is equal to or higher than the indicated temperature. Always measure the temperature in the middle of the tin. Seal quickly and apply the recommended heat treatment. Put the filled bottles or jars in the water before it boils to prevent the glass from breaking due to the sudden increase in temperature. Tins can be placed immediately in boiling water.

Important: If a sugar solution of 40% has to be used, this is not 400 grams of sugar with 1000 ml (1 l) water, but 400 grams of sugar in 600 ml water.

Pasteurization

Pasteurization is a mild heating treatment at temperatures up to 100°C (which is the boiling point of water at elevations up to 300 metres above sea level). This method causes only a slight decrease in taste and nutritional value. The enzymes are inactivated and most, but not all, bacteria are killed. Pasteurized products therefore spoil faster than sterilized products. To prevent the surviving spore-producing micro-organisms from multiplying, the products should be stored in temperatures below 20°C. To extend the shelf-life of fruit preserves, a lot of sugar is often added, which allows them to remain edible for months. Chapter 7 gives more information on preserving fruit with sugar. The more acid or sugar contained in a pasteurized product, the longer it will stay good because the remaining micro-organisms do not have a chance to develop.

A product is pasteurized by heating it for a time in a closed glass or tin container in a pan of hot water (see Figure 3). It is important that the lid of a glass jar fit well, but it should not be twisted tightly closed, because some air should be allowed to escape while it is being heated. Close the lid tightly immediately after removing the jar from the pan. As the product cools, a vacuum will develop within the container. In this way the food has no chance of coming in contact with the air and becoming contaminated.

The water in the pan has to be warm and at least the same temperature as the filled bottles and tins. Start monitoring the heating time as soon as the water has reached the recommended temperature listed in the appendix. Remove the bottles or tins as soon as the recommended time has elapsed and allow them to cool.

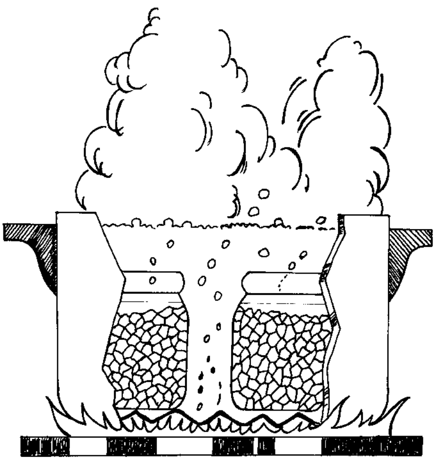


Figure 3: Jars in a pan

Remember that the boiling point of water decreases as elevation increases. In areas up to 300 metres above sea level the boiling point is 100°C. At higher elevations the heating time will have to be increased as indicated in the following table in order to compensate for the lower boiling temperatures.

Table 1: Heating time at different altitudes

Altitude in metres	Heating time in minutes	Example
0 - 300	a	a = 10 minutes
300 - 600	a + 1/5 a	total 12 minutes
600 - 900	a + 2/5 a	total 14 minutes
900 - 1200	a + 3/5 a	total 16 minutes

Since pasteurization sometimes requires heating at 100°C and the food can be kept for only a limited time, it is better not to pasteurize food (as described in App. 1) at elevations higher than 300 m, but rather to sterilize it (possibly under pressure) as explained in App. 3. Products that have to be heated at temperatures below 100°C can be made at higher elevations, as long as the required temperature can be achieved.

Fruit juices, which are not listed in the appendixes, have to be pasteurized at temperatures between 60 and 95°C. More information on fruit juices can be found in Chapter 7.

Always cook the preserved vegetables for 15 minutes before eating them. Never eat spoilt food and never eat from jars that have opened during storage.

Sterilization in a bath of boiling water

Sterilization in a boiling water bath is performed at 100°C. This process will kill all the micro-organisms present, but not the spores they produced. Under the right conditions, these spores can grow into spoilage-causing bacteria. Since the spores do not grow well in acidic conditions, acid is often added to the preserved food. Sugar has the same preventative effect. Thus by adding sugar or acid, you can ensure that even after heating at just 100°C the preserved product can be considered to be sterilized: its shelf-life is much longer than a product heated at 100°C to which no extra acid or sugar has been added. Appendix 2 provides the information you will need to sufficiently sterilize various types of fruits and vegetables.

Sterilization with a pressure cooker or autoclave

Sterilization carried out properly in an autoclave or pressure cooker (see Figure 4) will kill not only the micro-organisms but also the spores. In this way a long shelf-life can be achieved without adding extra acid or sugar.

In an *autoclave* or pressure cooker the boiling point of water is at a temperature higher than 100°C. If the atmospheric pressure (at sea level) is increased by 0.7 bar, then the water in this pan will boil at 115°C; if the pressure is increased by 1 bar the boiling point becomes 121°C. Here too, the boiling temperature is lower the higher above sea level you are. This decrease can be compensated by increasing the pressure by 0.1 bar for every 1000 metres above sea level. To sterilize canned vegetables the temperature is allowed to reach 115-121°C. In general, all foods with a high pH (which includes most vegetables) have to be preserved at a temperature above 100°C. We recommend that a pressure cooker be purchased for this purpose. Appendix 4 provides temperature and time combinations needed to sterilize foods in a pressure cooker or autoclave.

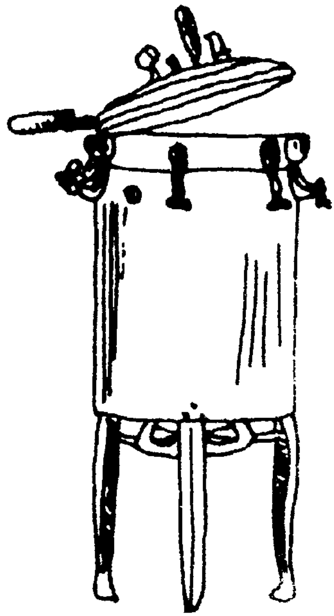


Figure 4: Autoclave

The following instructions generally apply when sterilizing foods:

- Place a rack on the bottom of the pan to ensure that the jars/bottles/tins do not come in too close contact with the heat source.
- Remember not to place the filled glass jars or bottles directly in boiling water, because they will most likely break. Heat the water in the pan up to about the same temperature as the filled jars or bottles, and then place them in the water.
- Do not screw the lids on too tightly, to ensure that some air will be able to escape (see Section 4.4.1 or Section 6.1.2).
- Do not pack the jars or bottles too tightly in the pan. Leave some space between them and between the jars/ bottles and the sides of the pan.
- The jars or bottles should be covered by at least 5 cm of water.
- The sterilization time begins at the moment the water reaches the desired temperature.
- For optimal results use jars of the same size and volume.
- Never try to open the *autoclave* or pressure cooker while the water is boiling. The high pressure in the pan and the high temperature of the water make this very dangerous!

Remember the following points when sterilizing under high pressure using tins or glass.

Tins

After the processing, let the steam escape from the pan slowly. This can be done quicker with small tins than with bigger ones, but still should be done slowly and carefully, as the tins can deform or even burst. When the pressure is again normal the lid of the pan can be opened. Remove the tins and immerse them in cold water, which should be refreshed occasionally to keep it cold. When the tins are cool dry them.

Glass jars

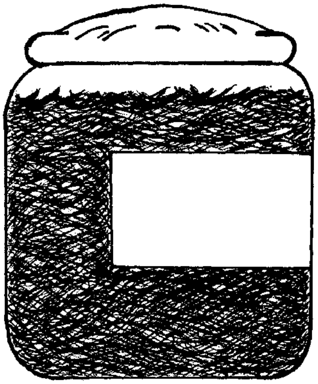
Wait until the pressure cooker cools down and the pressure inside of it has gone down before opening the lid. Remove the jars and tighten the lids immediately. The disadvantage of glass jars is that they cannot be cooled quickly. The safest way to cool them is to set them in the open air until they are lukewarm, and then put them in cold water.

The advantage of an *autoclave* over a pressure cooker is that it can be cooled down faster. On the other hand, an *autoclave* requires more water and thus more energy to heat.

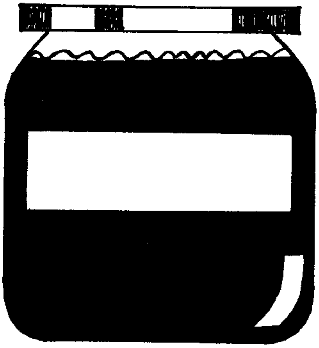
4.5 Storage and consumption

Always store the preserved food in a cool place, at a temperature preferably below 20°C. Keep glass bottles and jars out of the light. Label the containers so that you know what they contain and the date they were preserved. Always consume the older products first. The storage area has to be dry and have a consistent temperature. Moisture will make tins rust. Pay close attention when opening preserved food. A bulging lid or tin indicates gas formation by bacteria and thus food spoilage. Look carefully at the food and smell it. Heat the food if necessary and never eat anything you suspect may be spoilt.

Remember that preserving vegetables and fruit is always a risky undertaking. Always follow the rules described in this booklet and keep in mind that the heating times given in the appendixes represent the minimum time that is required. Never heat products for a shorter time than indicated. Heating food for a longer time decreases the chance of spoilage, but it also decreases the food's taste and nutritional value.

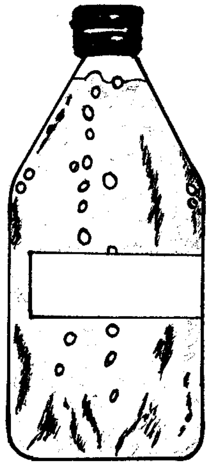


a. Bulging lid due to gas formation



b. Formation of slime coating on product

c. Mould growth



d. Formation of gas bubbles

Figure 5: Examples of products that are spoilt

5 Drying

Drying is one of the oldest preservation methods. The moisture level of agricultural products is decreased to 10-15% so that the micro-organisms present cannot thrive and the enzymes become inactive. Further dehydration is usually not desired, because the products then often become brittle. To ensure that the products do not spoil after being dried, they have to be stored in a moisture-free environment.

Drying is generally not difficult. Since the products lose water, they also become much lighter and thus easier to transport. Two disadvantages, however, are that the products also lose vitamins, and they change in appearance.

This chapter describes how vegetables and fruits are dried. More information on drying beans, grains and other products can be found in Agrodok 31: *The Storage of Tropical Agricultural Products*.

The most common drying method is exposure to air. Air can absorb water; and the warmer the air is, the more it will absorb. For optimal results, the air should be hot, dry and in motion. In a closed environment, the air has to be refreshed regularly because it will otherwise become saturated with the moisture it absorbs from the products. Good ventilation is therefore essential. For drying, the relative humidity (RH) of the air should be less than 65%. If the RH is higher than 65% the fruits and vegetables will eventually dry out, but not in the right way. When the sun is shining, the RH is usually lower than 65%, but when it is cloudy and definitely when it is raining the humidity is usually higher. Sunshine is therefore extremely important! For this reason, it is not possible to dry products in this way in every season of the year.

Before drying, the vegetables and fruits have to be thoroughly washed and cut into pieces if necessary. Sometimes extra preparation is needed to retain the product's colour and to minimize nutrient loss.

The various preparation methods are described in Chapter 3, and a list of methods required for drying each agricultural product is given in Appendix 4.

The final quality of the dried product is determined by a large number of factors, which can be divided into four groups:
1 Quality of the product to be dried
2 The preparation of the product
3 The drying method used
4 The packing and storage conditions

These four points are discussed in the following sections, followed by examples of drying potatoes, tomatoes and mango.

5.1 Quality of the fresh product

The fruits and vegetables to be dried should be of good quality. Fruit that is rotten or damaged in any way should be separated from the good fruit. To prevent the product from losing its quality, the time between harvesting and drying should be as short as possible. Of course it is possible to wait longer before drying hard fruits and root vegetables than before drying soft fruit and leafy vegetables. The time normally allowed between harvesting and consumption can also be seen as the maximum time allowable between harvesting and drying.

5.2 Preparation

Before describing the various preparation methods used specifically for drying, we would like to remind the reader that the hygiene rules described in Chapter 2 must also be followed when drying food.

Washing and cutting

Wash the fruits and vegetables thoroughly. Remove sand, rotten spots and seeds. Peeled and cut fruit dries quicker. It is important that all of the pieces are about the same size, so that they will dry at the same rate.

Tubers and roots should be cut into slices that are 3 - 6 mm long or pieces that are 4 - 8 mm thick. Leafy vegetables such as cabbage should be cut into pieces that are 3 - 6 mm thick.

Lye dip and blanching

See Chapter 3.

Osmotic drying

Some fruits can be prepared by immersing them for some time in a strong sugar solution. In fact this is not just a preparation, but already the start of the drying process because the sugar extracts water from the fruit. The fruit also adsorbs part of the sugar and is therefore allowed to retain more water at the end of drying process, which makes the product softer than if it were dried only in the air.

Normally sugar solutions of 40-60% are used. Good results are obtained by dipping the product for 18 hours in a 40% sugar solution. (An example of this is given in section 5.6.) To make such drying profitable it is necessary to have a good use for the diluted sugar solutions, such as the production of jams or syrups. More information about this treatment can be found in the FAO publication of G. Amoriggi (1998) (see "Further reading").

Preservatives

Fruit is sometimes treated with the smoke from burning sulphur or dipped in a sulphite or bisulphite-salt solution to prevent browning. Taste and vitamin C content are also better preserved with these treatments. The residual sulphite in the product can, however, be dangerous in high concentrations and can also affect the taste.

As this method needs more specific information we cannot discuss it here in detail. If you would like to know more about this, please write to Agromisa at the address given on the back cover.

5.3 Drying methods

Drying in the open air is called *natural drying*. We speak of *artificial drying* when the air is first heated to decrease the relative humidity to a desired level. Both methods are described below.

Natural drying

Drying in the open air is a simple and inexpensive process. It does not require any costly energy, just sunlight and wind. The product to be dried is placed in thin layers on trays (see Figure 6) or black plastic and exposed to direct sunlight. The trays are usually made of wood, and lined with plastic or galvanized nets. The trays should be placed 1 metre above the ground on stands set on a flat surface. This way no dirt can come in contact with the food from below and the food can receive maximum sun exposure. If necessary, the trays can be covered to protect the food from rain, dust, birds, insects and other pests. Mosquito netting probably offers the best protection from pests. To ensure that the fruits or vegetables dry uniformly, it is best to turn them regularly or at least to shake the trays. This does not apply to tomatoes, peaches or apricots, which are cut in half and arranged in a single layer on the trays.

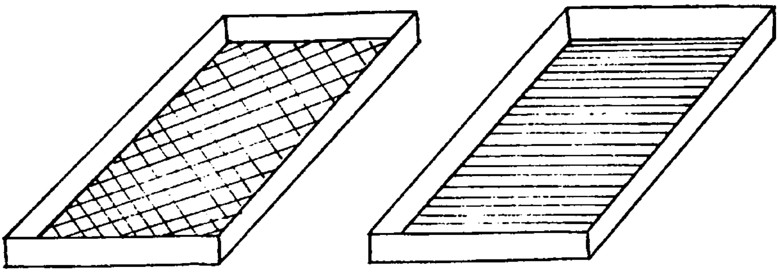


Figure 6: Drying tray

Fruit dries very well in the sun, but some products are damaged by exposure to direct sunlight and are therefore dried preferably in a shady spot. Beans and (red) peppers, for example, are bunched and hung up under some type of shelter. Of course, drying these products takes more time.

In areas with a high chance of rain, it is advisable to have an artificial dryer that can be used when it is raining or when the RH is too high. This will prevent interruption in the drying process and thus also a loss of food quality. In the event of rain, the (moveable) trays should be covered with plastic or placed under a shelter. Afterwards, they should be returned as soon as possible to the drying spot. It takes about two to four days to dry tropical vegetables.

Artificial drying

The temperature of outside air often needs to be increased only by a few degrees to make drying possible. For example, during a rain shower at 30°C the air must be heated to at least 37°C to be able to dry fruits or vegetables. Heating it further increases the speed at which the product will be dried because:

- the air can absorb more water
- the product releases water faster at higher temperatures.

The air can be heated with solar energy or by burning natural or fossil fuels. Appendix 4 gives information about preparation, drying conditions and maximum temperatures for several types of vegetables and fruit. The maximum drying temperature is important because above this temperature the quality of the dried product decreases quickly. Another reason for not drying at very high temperatures is that the product then dries quickly on the outside, but remains moist on the inside. Different types of artificial drying will be discussed below.

Improved sun drying

Products dry quicker when the trays are placed in a structure that allows the sunlight to enter through a glass cover, thereby trapping the warmth. This raises the temperature to 60-75°C. Overheating can be avoided by regulating the ventilation (see Figure 7).

Without ventilation the temperature can reach 90-100°C, especially towards the end of the drying process. The ventilation must be good enough to prevent condensation on the glass. This is a direct drying method.

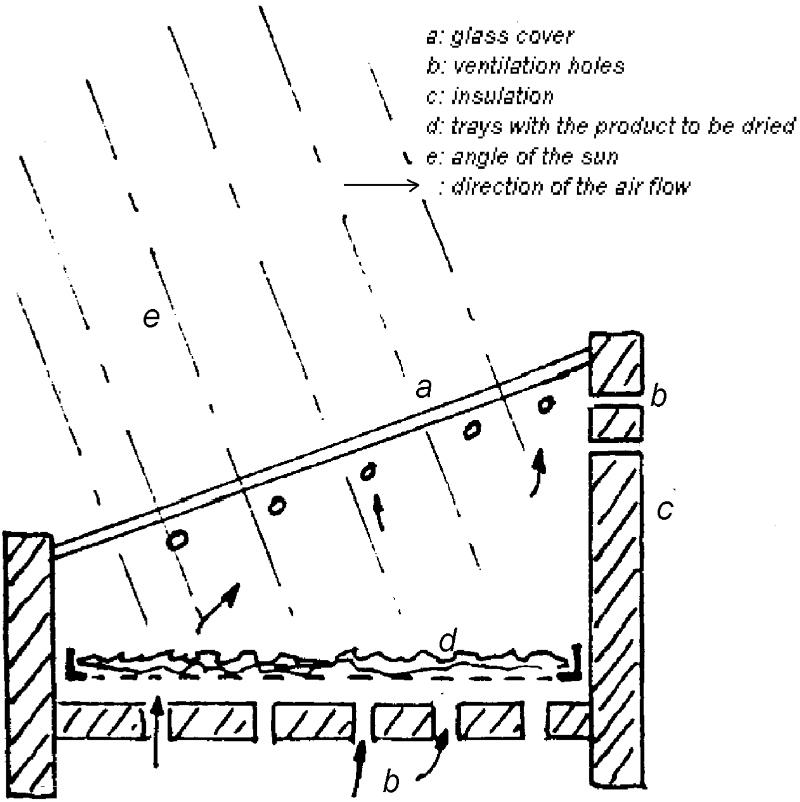


Figure 7: Improved direct sun dryer

It is also possible to heat the air in special boxes before leading it to the product (Figure 8). This method is called indirect drying, because there is no direct solar radiation on the product. These techniques will speed up the sun drying in dry areas (beware of overheating), resulting in a better product.

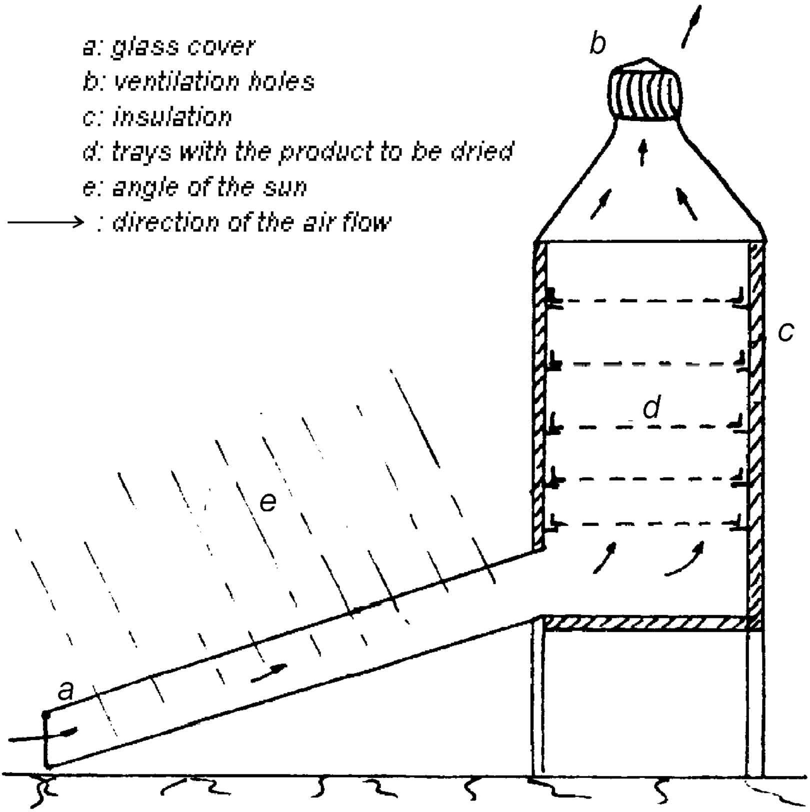


Figure 8: Improved indirect sun dryer

These techniques also make drying possible in areas with high humidity, as the relative moisture decreases with a higher temperature, as explained earlier in this chapter. An extra advantage of this technique is that the product is protected from rain. If you are interested in this method of drying, you can write to Agromisa to obtain specifications for building and using drying boxes.

Heating with fuel

In wet climates, or when large quantities (over 100 kg/day) have to be processed, one should consider heating the air, if fuel is available. Vegetables dry better with this method than in the sun, and the colour, odour and taste of the end products are better. Two methods will be briefly described to give an idea of the technique.

The bush dryer

A fire in an oven made from oil drums heats the surrounding air. The heated air rises through a thin layer of the product that is to be dried on the racks. The fire must be watched at all times, and the product has to be shaken or stirred at regular intervals. See Figure 9.

Specifications of the bush dryer:

capacity:	0.1 to 1 ton/day (24 hours)
material:	oil drums, galvanized iron sheets, netting, wire, wood, nails, one sack portland cement, sand, stones
costs:	building costs, material costs, high fuel costs and attendance
construction:	accurate work is required

Air dryers with artificial ventilation

A motor-powered ventilator can be used to blow warm air from the motor (or air warmed by a burner) through the product. Please contact Agromisa for further information about building air dryers with artificial ventilation.

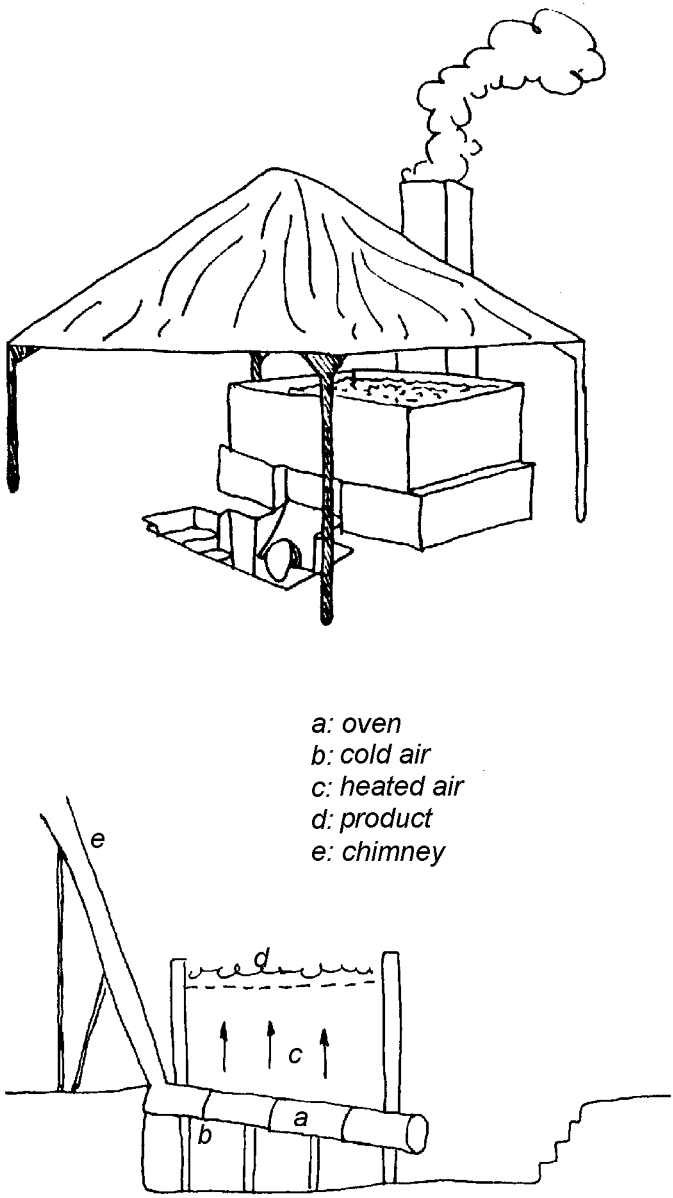


Figure 9: Bush dryer