Geothermal Energy Project

CURRICULUM

USE OF GEOTHERMAL ENERGY IN FOOD DRYING

“Developing Adult Skills in the Field of Geothermal Energy”

Erasmus+ KA204, Strategic Partnerships for Adult Education Project

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INTRODUCTION

Dear Trainee,

As it is known, one of the biggest factors in the deterioration of foods is microorganisms (bacteria, yeast, mold, etc.). Microorganisms are small living things that are too small to be seen with the naked eye, and can only be seen with a microscope, and they cause spoilage by multiplying in the foods they contaminate under suitable conditions. Water has an important role in the contamination and reproduction of many microorganisms in food.

The drying process, which people have unknowingly carried out in order to preserve their products for a longer period of time, is based on the principle of removing water from food. In ancient times, people used the sun as a drying source. In nature, this method takes place on its own. An example of this is the drying of grains and legumes in the field and becoming resistant. However, since the drying source is solar energy, it has been concluded that the sun cannot always be used as a drying method, and at the same time, not every product can be dried with natural sources, and people have developed new methods for drying. With these methods, the drying process began to industrialize in the 18th century.

By drying the food, it is ensured that it is preserved for a longer time without spoiling. This situation makes the products accessible even out of season, thus enabling the supply of the market both as a raw material source and as a final product.

This module has been created with researches and data on how to dry foods with geothermal energy, which is one of the renewable energy sources. The use of geothermal energy is important in terms of both protecting nature and contributing to the economy in meeting the increasing population and increasing needs.

1. DRYING FOOD

Like all living things, microorganisms, which are small creatures that can be seen with an invisible microscope, also need water in order to carry out their vital activities. Even if all vital factors are present, they cannot be active in the absence of sufficient water, thus preventing the deterioration of foodstuffs. The drying process is defined as the process of removing the water in the food content by various methods in order to prevent spoilage in the food and to preserve it for a longer time.

Since ancient times, people have benefited from solar energy as a drying method. However, this method brings with it many problems, especially contaminations (animal droppings, dust, etc.). The fact that it is not possible to dry by using the sun's heat everywhere and at all times, exposure to external factors (dust, insects, etc.), fermentation (fermentation) risks that may occur with drying have led people to research artificial drying techniques. Providing drying process in a shorter time with artificial drying and allowing homogeneous drying of all parts of the product encouraged the use of solar and hot air dryers.

2. DRYING METHODS

2.1. Natural Drying

In natural drying, the source of drying food is usually the sun and it is also called solar drying. This method, which has been used since ancient times, has been used in the drying of fish, meat, grains and legumes, and high quality products have been obtained. In many regions of our country, natural methods are still used for drying vegetables such as tomatoes and peppers.

The natural drying method is a cheap, easy and common method among its advantages. However, the slow drying rate and the risk of exposure to external factors such as dust, sand and insect residues can be shown as disadvantages of this method.

Picture 1.2: Drying of food with solar energy

2.2. Mechanical Drying

Mechanical drying is drying systems created to eliminate or minimize the problems encountered in drying foods with natural methods. With these systems, food is dried more quickly, independently of weather conditions, hygienically and homogeneously, and it remains away from contamination such as dust, sand and insect residues.

2.2. Mechanical Drying Systems

2.2.1. Cabinet Dryers

The product to be dried is placed on "kerevets", which is a kind of tray with a grid-shaped bottom, and the baskets are stacked on top of each other and first the car is brought into the shape of a wagon consisting of these cars and taken to the drying cabinet. During drying, the crayfish are immobile. Hot air enters from the side walls of the cabinet, which is in the form of louvers, and circulates between the trays and reaches the heater by exiting the side walls in the same way.

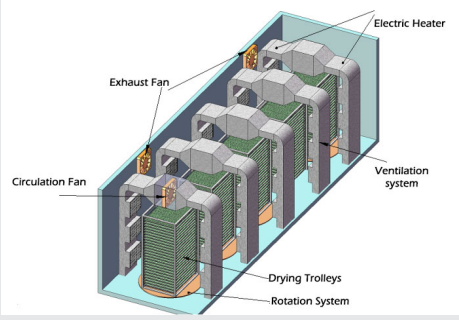


Figure 1: Cabinet Dryer

The most important problem of cabin dryers is that the air temperature, speed and humidity cannot be kept at the same rate all over the decks, so the drying speed cannot be provided equally everywhere. Another problem is that the first wagon that enters the drying cell dries earlier and the others dry slower. To prevent this, the air circulation fan is changed from time to time or a double fan is used. Drying time is around 10-20 hours depending on the product and desired final moisture level.

2.2.2. Tunnel Dryers

It can be thought of as a more advanced form of cabinet dryers. The difference from cabin dryers is that the trolleys consisting of carriage stacks move on a rail along a tunnel. In this way, while a car carrying fresh products is taken into the tunnel, another car that has been dried is taken from the other end, so that each car moves through the tunnel from time to time and dries up.

There are various types of tunnel dryers according to the product flow direction and air flow direction. Drying is carried out depending on the principles such as hot air and cars moving in the same direction or moving in the opposite direction. The most common method of drying fruits and vegetables is parallel or counter flow tunnels. In parallel drying, wet food encounters the first hot air and the air temperature decreases towards the end of the tunnel. As a result, less wrinkling occurs due to early crusting, while cavities and cracking are observed on the inner surface.

2.2.3. Conveyor Dryers

They are called continuous belt dryers. The working principle of the system is not much different from tunnel dryers. The carriages and wagons in tunnel dryers have been replaced by a continuously running belt. While the products are moving on this sieve-shaped belt made of stainless steel, drying is carried out with the principle of supplying hot air from the bottom. They are generally suitable for drying the same product in large quantities during a season. It is used for drying diced, minced, piece foods such as apples, carrots, onions and beans. These dryers are made suitable for a two-stage operation.

2.2.4. Fluid Bed Dryers

Fluid bed dryers are an improved form of belt dryers. The product to be dried almost hangs in the air with the hot air given from the bottom at high speed, and it is in a fluid bed. The fact that the product does not remain stable during drying helps to increase the heat transfer coefficient, to provide a good mixture and to achieve a uniform drying process. In order for the dried products to remain in the fluidized bed state, the air velocity and temperature must be chosen correctly.

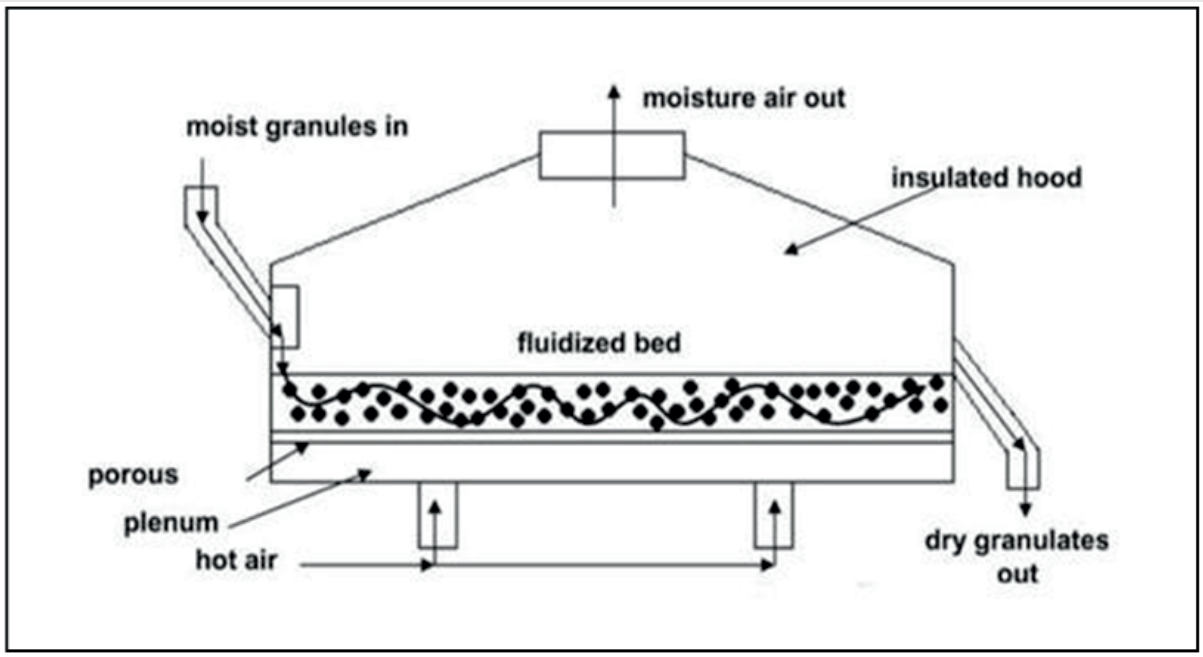


Figure 2: Fluid Bed Dryer

2.2.5. Crate Dryers

Box type dryers are drying systems used in the last stage of drying, especially in vegetables. These dryers are used to reduce the moisture content in tunnel or continuous belt dried vegetables to the desired final level. Crate dryers allow economical drying of the dried product up to a certain water content to the desired humidity. At the same time, the products that come out wet or dry from the first dryer become completely balanced in the crate dryers. They are economical, take up little space, can be mobile or fixed. On average, the operating temperature is between 40-45°C.

2.2.6. Other Drying Systems

These are the methods used for drying liquid and semi-liquid products such as tomato juice, tomato paste, fruit juice or mashed potatoes obtained from fruits and vegetables. Various systems such as spray dryers, roller dryers, vacuum dryers, puff and foam dryers can be counted among these.

Spray dryers: It is used for drying foods such as puree. Hot air is sprayed on the wet product from one side, and the product is taken dry on the other hand.

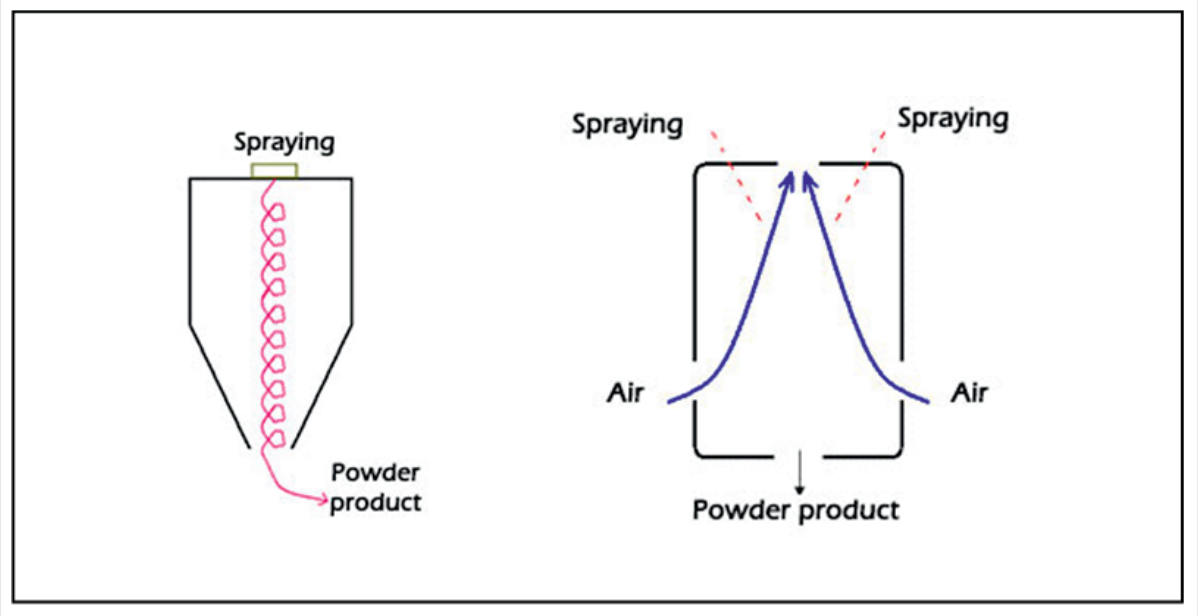


Figure 3: Spray Drying Examples

Roller dryers: In these dryers, the liquid or flaky product, which spreads in a thin layer on the hot surface of an internally heated cylinder, dries on the surface with the rotation of the cylinder of approximately 300 degrees and is dried according to the principle of scraping. With this system, vegetable purees such as mashed potatoes and tomato paste are dried. Again, this method is used in the production of powder soups.

Vacuum dryers: In this drying method, drying takes place under vacuum at low temperatures. Its basic principle is the removal of water under vacuum. The fact that there is almost no air in the environment where the drying process takes place limits the possibility of oxidation in the product. Foods in solid and liquid form can be dried with this method. However, due to both the installation cost and the high operating cost, this method is mostly used for drying foods that are very sensitive to heat or for products that need to be reduced to very low levels without damaging the moisture content. Pharmaceutical and chemical industry can be given as examples for other usage areas.

Drying takes place faster with the lowering of the boiling point of water at low atmospheric pressure. There are many types of vacuum dryers, but all of them have a vacuum chamber, a heating device, a vacuum generation and vacuum maintenance system, and a device that collects the steam generated during drying.

Picture 4: **Vacuum dryer**

Foam drying: It is the drying of liquid or pureed foods by turning them into foam. A vacuum dryer or a belt dryer operated under atmospheric conditions are used for drying. It is superior to traditional dried products in terms of qualities such as color and aroma. It is prone to oxidation as a spongy structure is formed at the end of drying. Fruit powders are produced by this method.

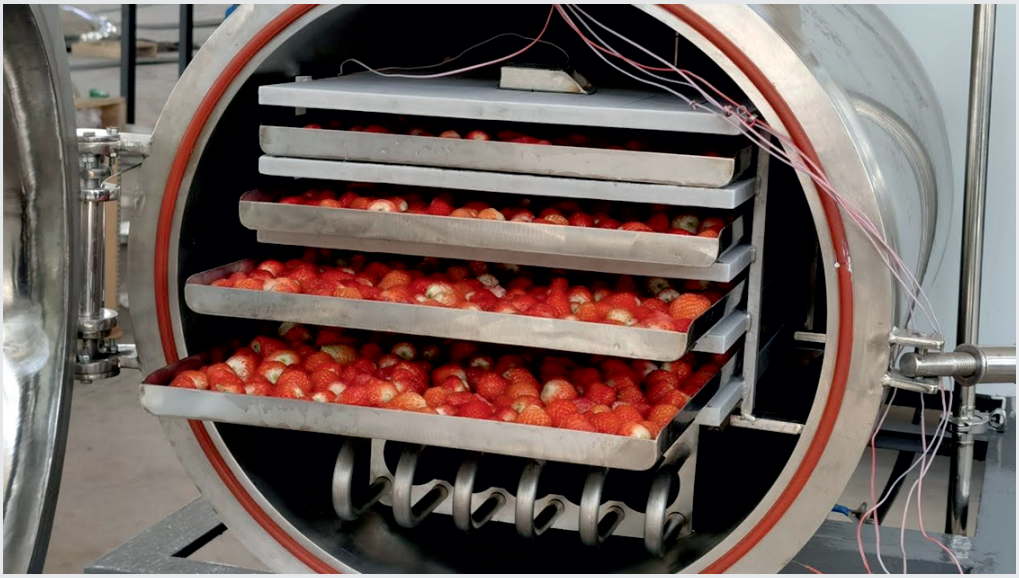
2.2.7. Microwave Drying

Microwave is a drying technique that provides heating to food from all sides. Microwave drying is a common method used by consumers today, as it is a practical and easy-to-apply method. Compared to traditional drying methods, rapid moisture movement ensures better preservation of the nutritional values of foods. However, not all products are suitable for microwave drying. At the same time, the selected wavelength and frequency range are very important in determining the quality of the final product. The high initial investment cost, capacity problems and the need for trained manpower increase the cost of the product. However, microwave is an important method for drying economically valuable products that cannot be dried in different dryers. It is a fast drying technique that can be applied to fruits and vegetables.

In addition, when combined with different dryers, product quality is positively affected and energy efficiency is increased. For example, vacuum assisted microwave drying is very suitable for the use of delicate fruits and similar products, and with this method, higher quality products can be obtained at low cost. Another combination is with fluidized bed drying. These two methods eliminate the disadvantages of each other and are effective in the quality of the desired target product.

2.2.8. Freeze Drying

Considering the quality of the final product, it is one of the best drying methods. Freeze drying; It consists of freezing, vacuum, sublimation and condensation stages. This method is carried out with the principle of freezing the product with certain refrigerants, reducing the pressure and transforming the water from the ice form directly into water vapor without melting, that is, without turning into water. With this method, the hardness of the product is preserved, so there is not much shrinkage after drying and it regains its original form when it is kept in water. In addition, the loss of taste and aroma in foods dried by this process is very low. Compared to other drying methods, it has advantages such as rapid water loss, less aroma loss, less chemical changes, as well as disadvantages such as high cost and complex technique. Instant coffees, powdered milk and some breakfast cereals are produced by this method.



Picture 3: Freeze Dryer

3. TYPES OF DRYER

In the industrial sense, drying is the drying process provided by the use of electrical energy and heat treatment. The actual energy needed is linked to achieving the appropriate temperature to get the energy needed to initiate the evaporation process and remove a certain percentage of moisture. The temperature used is achieved by direct contact of the air-dried product (vegetables, fruits, cereals, etc.) at a relatively low temperature (35-80°C). In line with this information, low-temperature geothermal resources can be considered as an energy source for drying agricultural products.

3.1. Using Air in the Drying Process

In the drying process, air is used in stages such as carrying the heat needed for the evaporation of moisture, removing the evaporated water from the facility and cooling the dried product.

The temperature of the drying air varies according to the food to be dried. For example, the highest temperature for drying grains is usually 43°. Accordingly, the duration of the drying process will also vary depending on the highest temperature determined. In short, the higher the drying temperature, the shorter the drying time will be.

Selecting the temperature too high in the drying process may cause physical and chemical damage to the food. For example, high temperature can cause cracks in grains. As a result of high temperature applied in fruits and vegetables, color loss, quality loss, structure and aroma disorders may be encountered. To avoid these results;

- Drying temperature should be selected low.
- After drying, the cooling process should be carried out slowly.
- Evaporation should be provided up to the moisture content required for each product.
- Air with a certain humidity and temperature should be used.

The principle of air systems in general; It is in the form of providing the evaporation of water by passing the hot air over and between the products. This method is a common method used in industrial establishments. The drying system created with this system;

- It does not cause dangers such as environmental pollution, explosion, burning and poisoning.
- It provides hygienic drying in a short time.
- There is no decay, explosion or change in taste in the products, and no odor occurs in the product other than its own smell.
- Heat pumps are easily and quickly installed and used in drying facilities.
- It is 40-80% more economical than drying facilities using fossil fuels.

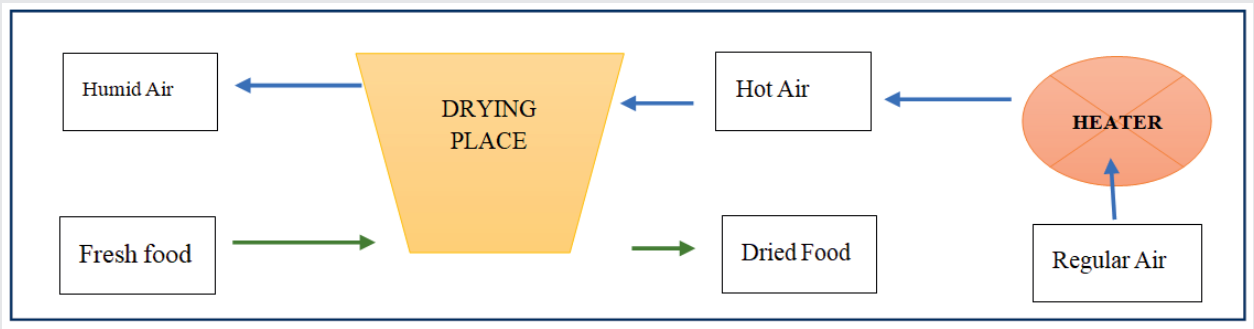


Figure 1: Hot Air Drying Scheme

Cabinet dryers, crate dryers, tunnel dryers, fluidized bed dryers and spray dryers are some applications of this method.

3.2. Geothermal Resource

As we mentioned before, it is possible to use low-temperature geothermal resources in the drying process at low temperatures. If the source to be used is a geothermal source, the following factor should be considered:

* Distance of the source to the facility
* The temperature of the geothermal source
* Geothermal source flow rate (amount of fluid flowing per hour)
* Chemical structure of the source
* Whether it can be integrated with other applications

3.3. Designing Drying Systems

Thermal calculation largely depends on how heat is applied to the product. The parameters that determine the time needed for drying in dryers operating with hot air conduction are defined by the relative humidity of the temperature, flow rate and drying rate. In the drying process, the intensity of the heat flow for the heat input paths (contact, thermal radiation, high-frequency current, etc.) is adjusted so that the material temperature does not exceed the specified limit value.

Agricultural products are usually dried by this method. The calculation of the thermal heat of drying ovens depends not only on how the heat is delivered, but also on the type and structure of the oven.

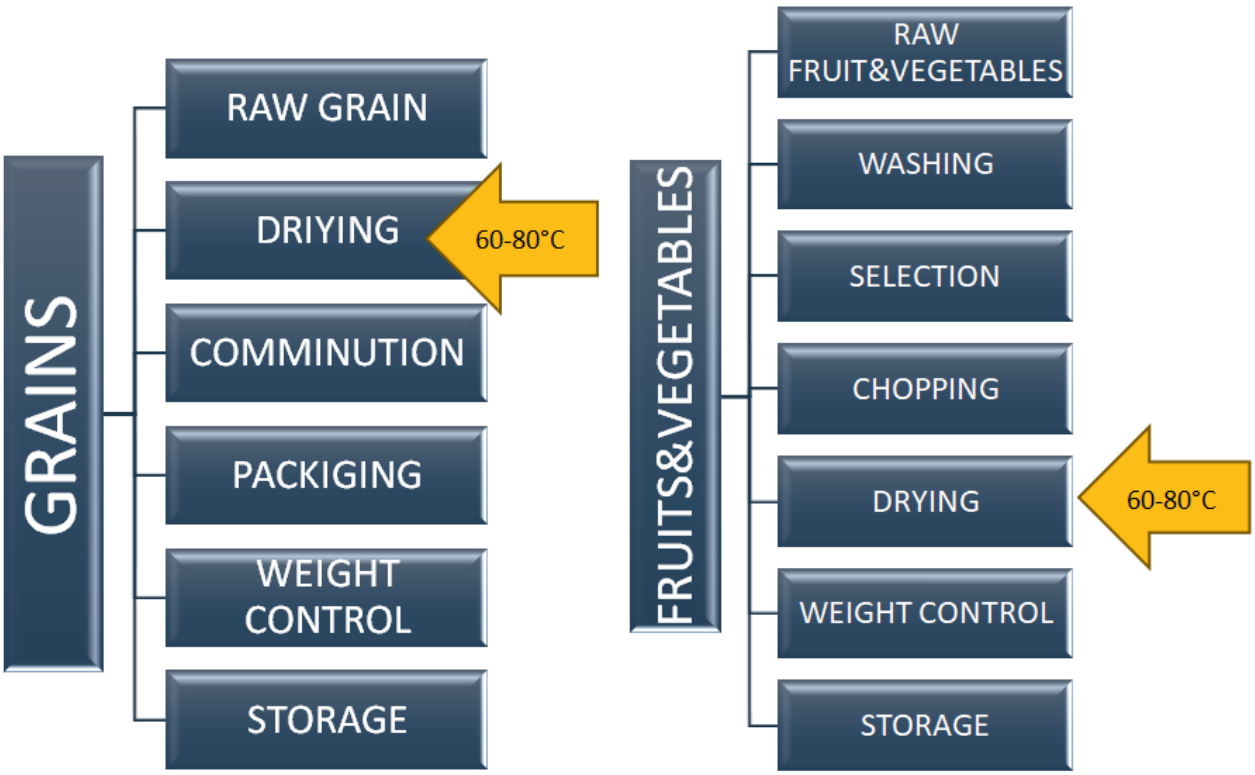


Figure 2: Stages of the Drying System

4. PROPERTIES REQUESTED IN FOODS TO BE DRIED

Picture 4.5: Dried Fruit and Vegetables

The most consumed dried foods at the international level are;

- Fruits; mango, pineapple, banana, avocado, papaya, plums and cashews.
- Vegetables; carrots, tomatoes, garlic, hot peppers.
- Herbs; aromatic foods such as coriander, parsley, celery, mint.
- Teas; Roselle flower, chamomile, orange flower, lemon tea.
- Spices; such as thyme, rosemary, bay leaf.

Many fruits and vegetables such as figs, apples, grapes, apricots, peaches, cabbage, tomatoes, sour cherries, plums, bananas, carrots, onions, eggplants, pumpkin seeds, mulberries, mushrooms, strawberries can be dried and stored without spoiling and can be consumed safely. With the drying process, many food products are dried, allowing them to benefit from nutrients even out of season. Drying of foods with high sugar content is more difficult than other food products due to their tendency to stick together during the drying process. In the products planned to be produced in powder form, agglomeration problems can be observed later.

Picture 6: Fresh Fruits and Vegetables

The features sought before drying foods are as follows;

Products must be mature. Fruits to be dried should be harvested at drying maturity. Although some foods are an exception to this situation, ripe foods are preferred at this stage because they have regained their essence in terms of taste and vitamins. In order to enjoy the taste of the first day after being saved, the color and taste of the food must be fully ripe.

Crops must be harvested by the appropriate method. The product should be harvested when it is most productive. In this way, more drying can be achieved from the same product. Food to be dried should be harvested in season and organic grown products should be used.

There should be no tissue damage and wounds on the products. No matter how much the injured products are washed during the drying phase, they are not suitable for use due to the possibility of contact with insects and pests. The foods to be used must be sound. At the same time, crushed foods are not suitable for drying because they lose their core liquids. Since rotten products harm human health, rotten products are also not suitable for drying. The products to be dried are straw, garbage, leaves, stones, etc. items should be removed.

Picture 8: Rotten and Damaged Fruits

5. PRE-TREATMENTS APPLIED TO FOODS TO BE DRY

The main purpose of the drying process is to use energy as effectively as possible, as well as to obtain a quality final product. A single drying method being both economical and successful is not sufficient for all products. For some foods, pre-treatment such as immersion in solution or boiling with steam is required before drying. As a result, apart from the drying technology, it provides a shorter drying time as well as giving better quality results for the final product with the right pre-processing method when necessary. Pre-treatments should be selected according to the type of product and the drying method to be used. For example, the product to be dried in the form of chips should be sliced in the form of rings, and the product to be produced in the form of powder should be ground. The pre-treatments applied to foods are as follows.

5.1. Pre-Treatments Applied to Fruits

These are the processes applied to the foods before drying in order to increase the drying quality. Each food product is subjected to different pre-treatments according to the drying system.
For example, small fruits such as strawberries and grapes can be dried without cutting, but large fruits such as mangoes, pineapples, apples must be sorted, washed, peeled and dried in a particular sample (cube, ring, etc.) should be cut.

Picture 9: Foods that have been sorted and chopped

As it is known, when some fruits and vegetables are cut or damaged, they turn brown in contact with air (it undergoes oxidation). The first evaluation criterion of consumers in foods is color.
In this sense, oxidation is an important problem in drying technology and can be prevented by necessary pretreatments.

Although it differs from fruit to fruit, the pre-treatments applied in general

* Washing
* Separation from foreign materials (stalk, leaves, garbage)
* Sizing
* Peeling according to the type of fruit
* Dividing, slicing, chopping
* Core extraction
* Additional pre-treatments such as boiling, immersion in alkaline (basic) solutions, sulphuring are carried out.

5.1.1. Dipping or Olive Oil Alkaline Solution

For some fruits such as grapes and plums to be dried quickly, immersing them in suitable solutions has been a method used since ancient times. While wood ash and olive oil were used for this process in the past, alkali compounds such as potassium carbonate and sodium hydroxide are used instead of wood ash today. As a pre-treatment, dipping is mostly applied to grapes. This process is applied to remove the wax layer naturally found outside the grape, to accelerate drying and to preserve its color. Cherry, plum, apple and pear are examples of other fruits with a natural wax layer on the outside. Apart from this method, light-colored raisins can be obtained even without the need for sulfur dioxide, by immersing the fresh grapes in hot water at 93°C.

5.1.2. Sulfurization Process

Depending on the enzymes in the fruit, they turn brown by showing some reactions during drying. The most common method applied to prevent this is sulphurization and sulfur dioxide (SO2) is used. The fruits are sulfurized before, during and after drying. Generally, sulphurization is done before drying apricots, peaches and pears, before the grapes are put on the market, and before and during drying for apples.

Sulfurization has advantages such as preserving color quality by preventing blackening in fruits, stopping microorganism activities, protecting vitamins A and C, providing quick drying of the product and protecting the product from pests. Apart from this, it can be shown as the disadvantages of its use that it causes abrasions on the product and equipment, the possibility of creating bad taste and aroma, and the negative effects of excess amounts on human health.

5.2. Pre-treatments on Vegetables

Pre-treatments applied in the drying of vegetables; washing, sorting, peeling, chopping, boiling, salting and cooling. The most important application among the pre-processes is boiling.

5.2.1. Washing

Washing is necessary to facilitate the heat treatment, reduce the microorganism load, and clean residues such as dust, soil and pesticides. Washing according to the type and characteristics of the product; pre-washing (softening), washing and rinsing takes place in three stages. Regardless of the selected washing process, the water used should be cold and clean.

Picture 10: Washing Machine

5.2.2. Extraction

The cleaned vegetables must be sorted before drying. Damaged, moldy and rotten products are completely discarded in the sorting unit. Sorting is usually done manually.

Picture 11: Manual selection

5.2.3. Peeling

During the drying process, the skins of the vegetables are peeled as the peel slows the drying rate of the vegetables. The peels can be done before or after boiling, depending on the nature of the vegetable. peeling process; by hand, by the application of heat, by freezing, or by chemicals.

5.2.4. Chopping

In order to accelerate the drying of vegetables, the vegetables can be divided into two, sliced or chopped into a certain shape. The way of chopping is determined according to the type of vegetables and the desired end product.

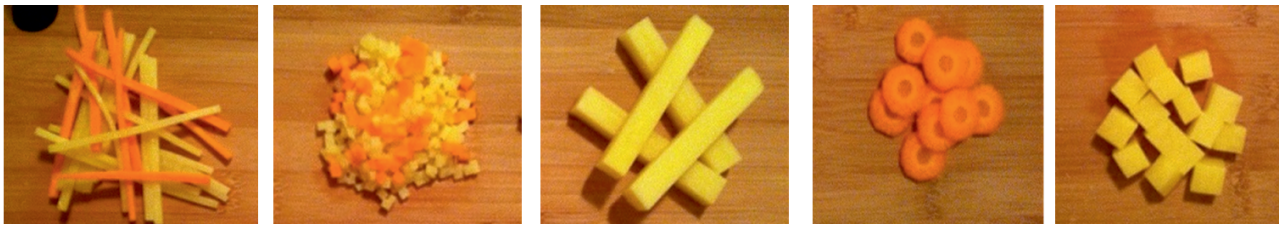


Figure 12: Vegetable Chop Shapes

5.2.5. Boiling

Boiling is one of the most important pre-processes for drying vegetables. The most important problems encountered in the storage and drying of vegetables are loss of color, taste and browning. The reason for these problems is the continuation of the enzyme activity in the food content. This factor is eliminated by boiling. In addition, since the tissues formed in the vegetable cell membranes become more permeable, drying takes place faster.

Vegetabel	Beans	Carrot	Pea	Root Celery	Red Cabbage	Green Cabbage	White cabbage
Boiling Time	2-3 minutes	6-8 minutes	3-4 minutes	2 minutes	1,5 – 2 minutes	1 minutes	1,5 – 2 minutes

Figure 3: Boiling Time of Some Vegetables

Each product is boiled at different times. Some vegetables such as onions, mushrooms and peppers cannot be boiled. With the boiling process, the microbial load on the vegetables is reduced. The boiling process causes a decrease in water-soluble vitamins, to prevent this, bisulfate can be added to the water to protect it. Boiling is done in two ways. Steaming is done by keeping vegetables in boiling water or by hanging vegetables in wire boxes or strainers around boiling water.

5.2.6. Salting

Salting is done before drying in order to prevent mold growth during the post-drying storage phase. Because many bacteria cannot perform their vital activities at a salt content of more than 6%. Salting is done by sprinkling or immersing in saline solutions. Salt application should be done immediately after harvest. The color is darker in the salty product. Mostly Italy and some European countries consume salty products. Since it tends to absorb moisture in storage conditions, mold and fermentation may occur. It is widely used in tomato drying.

Picture 13:Dried tomato

6. DETERMINING THE DRYING TEMPERATURE AND TIME TO APPLY TO FOODS

Since the primitive ages, people have reached the most appropriate method through trial and error in all their studies. In the same way, researchers have demonstrated with their research that not every product can be dried at the same temperature and in the same type of dryers. It is very difficult to always reach the same standard for the foods used as raw materials (eg tomato, mint, goji berry, fish) due to both climate change and environmental pollution. Therefore, determining the temperature and determining the dryer type are not always the same. In addition, it is not possible to reach a certain standard content in the sources. However, approximate values can be mentioned. The following tables provide information about temperature for some foods.

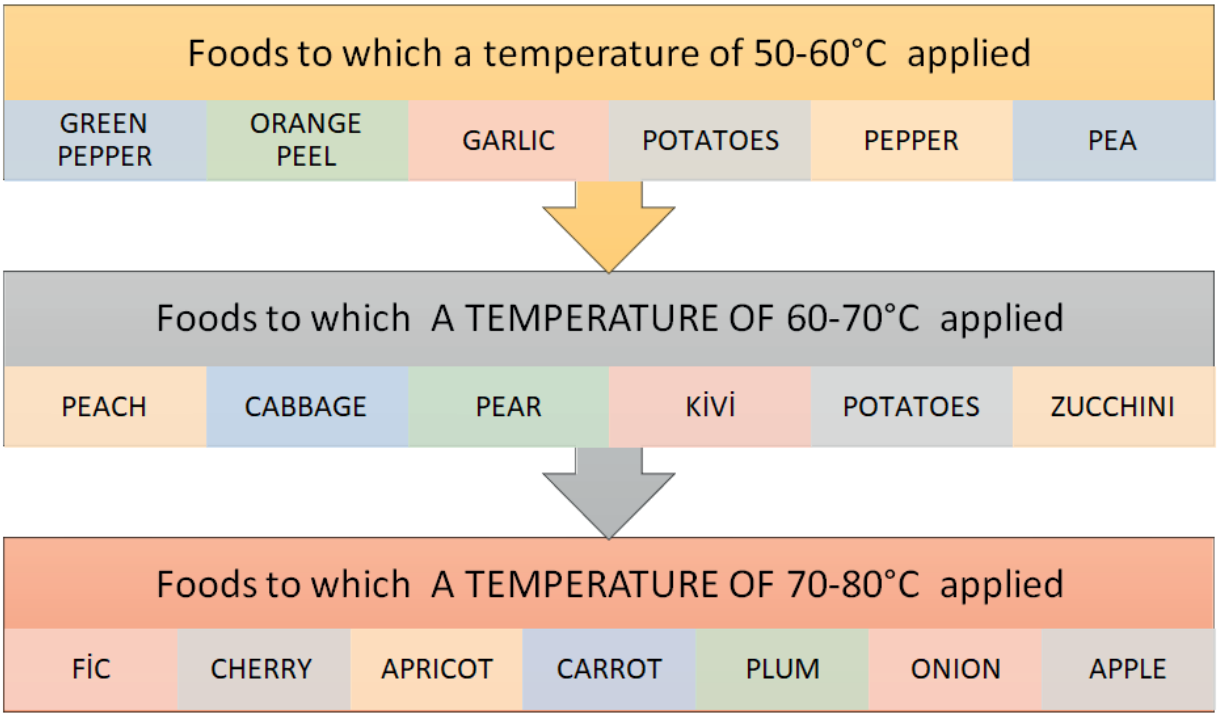


Figure 4: Temperatures Applied to Some Foods

Some foods are dried at low temperatures. Due to the slow drying rate, deterioration may occur in the product. In order to prevent this, the relative humidity of the hot air (the amount of moisture that the air can carry at a certain temperature) is reduced, thereby increasing the dehumidification capacity of the hot air and increasing the drying speed.

Conversely, high temperatures are needed to dehydrate some foods. High temperature drying has many advantages as well as disadvantages. Especially in thin layer products, burning at high temperatures and consequently loss of nutritional value are observed.

While defining the temperature and time in the drying process, the pre-treatments before drying are also important. As a result of R&D studies, pretreatment and food drying temperatures and times for some food products are shown below.

BANANA

- Sliced 3-5 mm thick
- Drying process is applied for 10-12 hours at 50°C

APPLE

- Sliced 4-5 mm thick
- If blackening is not desired, it is dipped in lemon juice.
- Drying process is applied for 10-12 hours at 50°C

PINEAPPLE

- Sliced into cubes or rounds
- Drying process is applied at 60°C for 10-14 hours.

PLUM

- Splits in two
- Drying process is applied for 10-12 hours at 50°C

APRICOT

- The core is removed.
- Drying process is applied for 22-24 hours at 60°C

ORANGE

- Sliced 5mm thick
- It is dried at 65 oC in 14-16 hours.

STRAWBERRY

- Splits in two.
- It is dried at 40 oC for 10-12 hours.

Figure 5: Pretreatment, Temperatures and Times of Some Foods

As we mentioned before, it is not possible to specify a precise temperature and time for each product. In the above study, approximately general values are given. In the R&D studies, the operating temperature of 45-51 oC was found suitable for the drying systems made with geothermal energy. It was determined that the vitamin content of the foods was preserved at these temperature values.

7. FINISHINGS APPLIED TO DRIED FOODS

7.1. Cooling Dried Vegetables

The purpose of the drying process is to remove water and to preserve the food for a longer period of time. In accordance with this purpose, after drying, the food should be stored in environments where there is no humidity so that it does not absorb moisture.

The dried food must be cooled before packaging. If the products coming out of the dryer are packaged immediately, the shelf life of the product will decrease, as the evaporation that will occur depending on the temperature of the product coming out of the package may cause humidity, and as a result, the drying process will not reach its purpose. In order to avoid these problems, the product coming out of the dryer should be cooled to a certain temperature level.

The cooling process is carried out in two ways:

1. With special fans placed inside the oven
2. Transport to the appropriate environment determined by special containers.

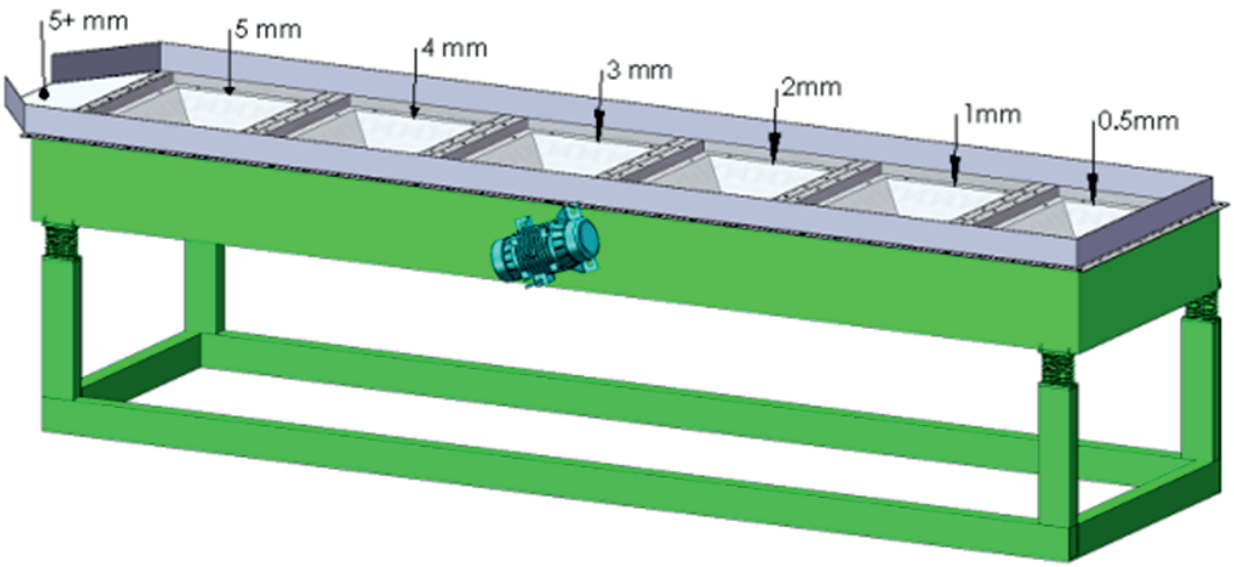
Humidity rate varies according to the characteristics of the product. Humidity should be brought to a certain level so that it is homogeneous everywhere. The moisture content of each vegetable varies when it dries. In general, the moisture content of dry food should be 8-10%.

Picture14-15: Fresh Tomatoes in Drying Benches and Tomatoes During Drying

7.2. Sizing of the Dried Product

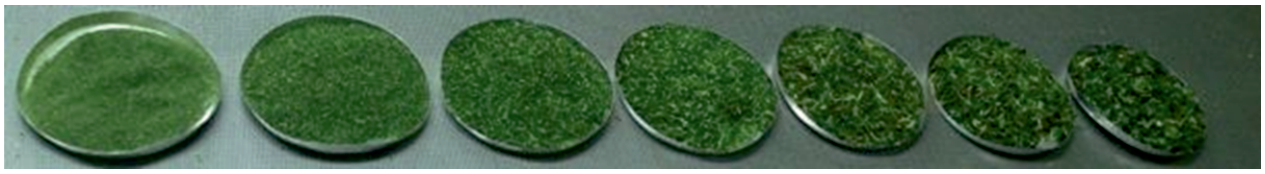
Dried products should be classified according to their end product size after passing through a sieve system. In this way, a homogeneous image is obtained in the packaging.

Picture 16: Calibration Sieve



Picture 17: Simple Diagram of Calibration Sieve

Picture 18: Dried Tomatoes Separated According to Their Sizes from the Calibration Sieve



Picture 19: Dried Spinach Separated from Calibration Sieve According to Size

Below are the images of different types of sieving machines. .The system works the same in all. The products are sized by passing over the sieves of certain sizes by creating vibration on the system and moving on the band.

Picture 19: Vibrating Sieve Picture **Picture 20:** Pulses Sieving Machine

Particles formed in the form of crumbs during drying should definitely be separated by a vibrating sieve. Also stems, bark, leaves, etc. foreign products should also be sorted out. All these processes, including packaging, must be carried out in a low humidity environment.

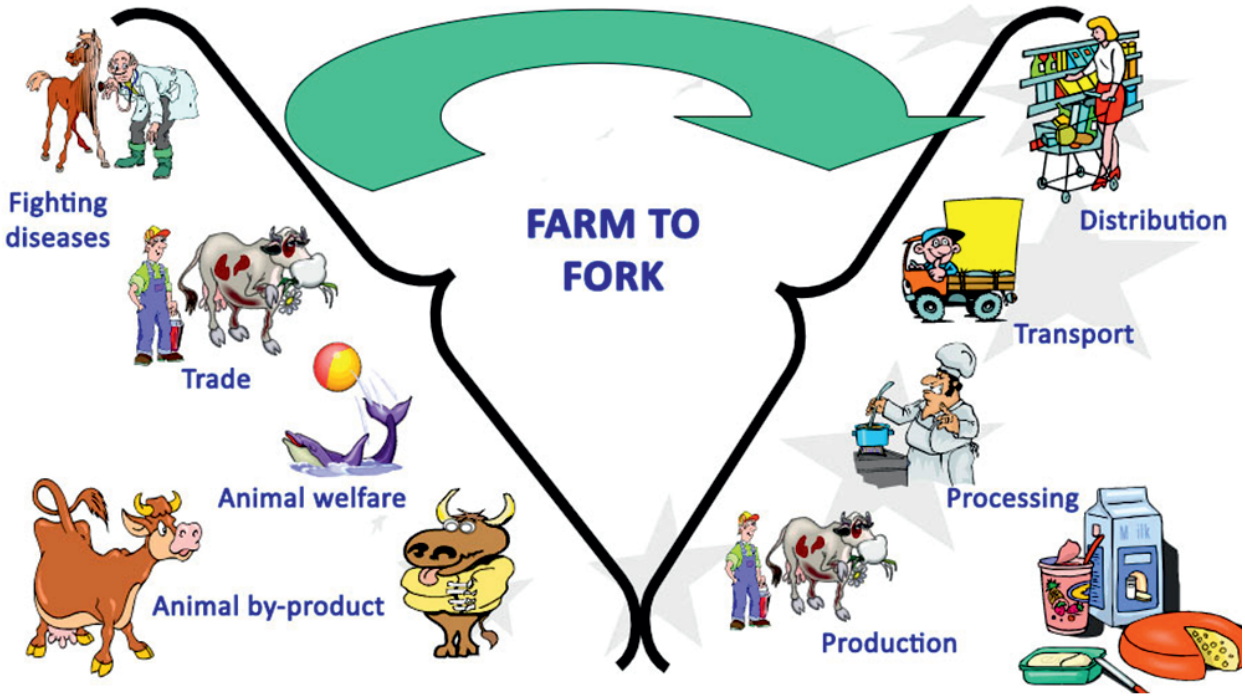
7.3. Packaging

Another stage that has an important place in the quality of dried foods is packaging. Packaging should be done in accordance with the characteristics of the food. Care should be taken to ensure that the packaging is cool, airy, dim and protected. The products in the form of containers, covers or wraps made of special materials such as metal, glass, paper, plastic that protect food from external factors and facilitate its marketing and consumption are called food packaging. According to Turkish Food Codex Regulation “foodstuffs; wrapping and/or placing in containers using packaging material for containment, protection and informational purposes”.

Characteristics of packaging materials:

- It should not pass heat and light
- It should protect the product from moisture
- It should be suitable for storage
- It must be of such a quality that it will not be damaged during shipment.

The European Union takes a holistic approach to food safety with the slogan "From Field to Fork". Aim; is to ensure food safety, animal health, animal welfare and plant health at the highest level. In all primary production, processing, packaging, transportation, storage and sales purposes, it is aimed to ensure food safety with food control, monitoring. In addition, the European Union has worked to ensure that packaging wastes are recyclable products in order not to cause environmental pollution. It has carried out studies on the contact of packaging products with food in certain standards and has made some changes in packaging such as plastic.



Picture 20: European Union Food Safety Approach

When evaluating EU or Turkish legislation, one should pay attention to exactly which packaging products the relevant regulation covers. For example, regulations on packaging and packaging waste cover all packaging, including paper or plastic containers or disposable plates and cups that are filled in at the point of sale, Regulations for prepackaged products cover only packaging products that are packaged in the absence of the seller, the quantity is predetermined, and cannot be changed without opening or deforming the packaging.

Storage times of dry products vary according to the packaging material used. Water vapor and gas permeability is not desired in the packaging system of dried foods. Depending on the gas permeability, the fatty acids in the food react with oxygen and cause oxidation, resulting in taste and color changes in the food.

Fruits dried to low moisture levels should be placed in resealable packages. Dry foods that need to be processed later can be packaged in barrels, crates, cardboard boxes and tin boxes.

Picture 21 : Packaging (Resealable Packages)

Picture 22: Vacuum Packaging

In addition, edible films, which are used in the protection of foods by coating method, are packaging that do not cause environmental pollution since they are made of agricultural origin, natural or biologically recyclable materials. Edible film is a thin layer that can be eaten by the consumer and is an oxygen and moisture barrier to food, enveloping the entire food or as a component between food ingredients. As it can be understood from this definition, edible films have functional properties such as protecting the food in terms of nutritional value and microbial quality during the presentation of the food to the consumer. These films are applied to foods in order to prevent moisture loss, slow down respiration, improve their mechanical properties, preserve their shape, maintain antioxidant, antimicrobial, color and aroma. Positive results were obtained in dried products sensitive to moisture loss and oxygen, such as apricots and figs.

Picture 23: Edible Film Coating

7.4. Labeling

The label should inform the consumer about the product. Company name, address, product name, batch number, shelf life, production and expiry date, net-gross amount, production permit, preparation and usage instructions, ingredients, storage and storage conditions, whether it contains allergens, nutritional values, etc. information must be available. Labels are affixed to the appropriate place on the package with automatic systems or personnel vehicles.

7.5. Storage

Storage is the preservation of the properties and quality of a product for a certain period of time without deterioration. The best storage for dried foods is done in cold, dark and dry environments. Thanks to the coolers placed in the warehouse, the cooling of the warehouse is ensured. Dried foods should be stored in dark warehouses to prevent color changes. The dryness of the warehouses prevents the product from getting damp and moldy. As a result, a cold, dark and dry warehouse gives positive results in the preservation and prolongation of the shelf life of dry foods.

Dried vegetables can be stored for one year without any signs of deterioration in 0-4o temperature warehouses with 50-60% relative humidity. For longer periods, different storage conditions should be provided and attention should be paid to the final moisture content of the product.

Warehouse maintenance and cleaning should be carried out at regular intervals. Tanks should be made using materials that are easy to clean. In addition, the humidity and temperature values of the warehouses should be monitored in terms of the continuity of the appropriate conditions.

8. MAJOR CHANGES THAT OCCUR DURING DRYING

8.1. Physical Changes

Regional dry matter accumulation: We mentioned that the drying process is the removal of water from the food. At this stage, with the movement of water in the food, some substances dissolved in water move from the inside to the food surface, and these substances accumulate on the food surface as the water moves away. Depending on this, there may be an increase in dry matter (ie other substances that make up the food other than water) in the food center or on its surface.

Encrustation: It is a situation caused by the wrong selection of drying conditions. It is the rapid drying and shrinkage of the outer surface due to the high temperature applied. Generally, during the drying of the fruits, the outer skin shrinks and a glassy texture is formed, so the drying does not occur completely in the inner layers and the amount of liquid (water) is more in the inner layers. By adjusting the drying speed, the problem of crusting can be prevented.

Changes in mass density: Fruits and vegetables tend to shrink after drying. Depending on the shrinkage, the area covered by the products changes, but the weight decreases with the removal of the water in the content. Mass density refers to the weight of these products depending on the area they cover. For example, the initial bulk density of a wet apple is the ratio of its weight to the area it occupies. With a balanced drying, a shrinkage will occur from the inside without rapid crusting on the outer surface and the product will shrink considerably compared to its initial size. As a result, mass density will increase. In the same way, when rapid drying is achieved, the product shrinks less as a crust forms on the outer surface and the inner surfaces will remain wet. It is closer in appearance to its original state and has a lower mass density. These concepts play an important role in the consumer's choice because the consumer prefers to buy the product that is close to its first appearance.

Rehydration ability of the dried product: If a dried product can take its pre-drying state when it is kept in water, that is, if it can reach the water content before drying, it is concluded that the drying process is very good.

8.2. Chemical and Other Changes

Chemical changes are irreversible changes.

These changes are manifested in the color, flavor, texture, fluidity, nutritional values and storage standards of dried foods. These changes are unique to each product and the applied drying temperature and drying time are the most important factors in affecting the level of chemical changes. The most common chemical change is browning of the dried product. Browning occurs both before drying and during drying and storage. It can be caused by the contact of some substances in the food with air. An example of this is the darkening of a peeled apple over time. Again, there are cases of browning that occur depending on the amount of sugar in the product. With the sulfurization of the product, browning is prevented.

Some nutritional values in foods are reduced by the pre-treatments carried out before the drying process. For example, in a product boiled as a pre-treatment, loss of vitamin C manifests it self. However, since the water in its content is removed, the nutritional elements per unit weight are higher, which increases the nutritional value. For example, the nutritional value of a fresh apricot is less than a dried apricot because it contains water that has no nutritional value (no calories). During the drying process, microorganisms are removed from the food by processes such as boiling and heating, which reduces the amount of microbes on the food.

9. USAGE AND IMPORTANCE OF GEOTHERMAL ENERGY IN THE PREPARATION OF DRIED FOODS

Since ancient times, humanity has developed different methods for the purpose of preserving fruits and vegetables, various animal foods for a longer time and consuming them out of season. The most common of these methods is drying, as we have mentioned before. To reiterate the definition of drying, briefly, it is the removal of water from foods by certain methods.

Picture 24: Dried Foods

Picture 25: Dried Meats

Picture 26: Dried Seafood

As can be seen from the pictures above and the drying subject we mentioned before, it is possible to dry both fruits and vegetables, meat products and seafood. While the shelf life of a fresh fruit varies between 3-10 days, the product can be preserved for months after drying. In the drying process, natural resources and mechanical resources developed by humanity with various methods are used. The oldest natural drying method is the use of the sun. However, the drying process in the open air has disadvantages such as the fact that the temperature is not constant and that it is adversely affected by external factors. Modern drying methods have been found to carry out the drying process in a short time and to ensure the desired end product quality. Depending on the system used, the energy requirement also increases significantly. Therefore, it is important to use renewable energy sources as an energy source in the drying process. Geothermal energy is one of the energy sources used in drying applications. Geothermal energy is a continuous energy source that is not affected by seasonal differences.

The use of geothermal resources as an energy source in our country and in the world provides advantages both economically and strategically. Therefore, it is important to expand the use of geothermal resources. Geothermal energy is an alternative method when dealing with the problems encountered in solar drying systems, such as pest, dust contamination of products. It also differs from other modern drying methods that use electricity by being less costly.

To remind again, the purposes of drying foods are as follows;

- Reducing the water level in the food,
- Reducing storage and transportation costs by reducing weight and volume,
- Transforming a food into an easier way of storing, packaging, transporting and using,
- Ensuring that the products are available throughout the year,
- To extend the shelf life of foods.

9.1. What is Geothermal?

Geothermal; It is a term formed by the combination of two words meaning "geo - ground" and "thermal - heat" in English. We can express its Turkish equivalent as ground heat or ground energy.

We can define geothermal energy as hot water, steam and dry steam formed by the storage of the heat energy accumulated in deep rocks in reservoirs by being transported with fluids.

9.2. What is Geothermal Energy?

Geothermal energy is the heat carried to the surface by means of hot water and steam under pressure, which has accumulated at different depths of the earth's crust, is above the atmospheric average temperature of the region, and may contain more dissolved minerals, various salts and gases than the normal underground and surface waters around it. Geothermal energy is generally obtained from the waters that come to the surface by using the cracks and cracks in the earth's crust or from specially drilled boreholes.

The source of geothermal energy can be seen as water, steam, hot rocks and magma in layers close to the earth. Geothermal energy is one of the most important sources of alternatives to fossil fuels.

Geothermal Energy;

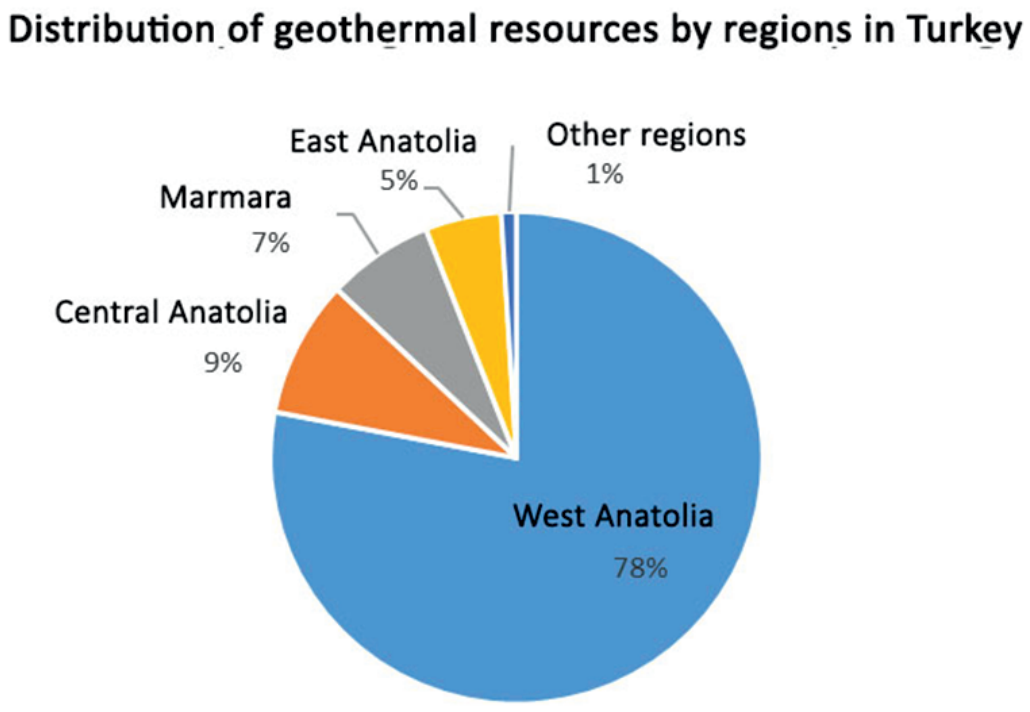
* Renewable
* Sustainable
* Cheap and reliable
* Environmentally friendly
* It is a local and green energy.

With geothermal resources;

- Electricity generation
- Central heating, cooling, greenhouse heating, etc.
- Industrial use, process heat supply, drying, etc.
- Chemical and mineral production, carbon dioxide, fertilizer, lithium, heavy water, hydrogen, etc.
- Use for spa purposes
- Aquaculture at low temperatures (30 °C)
- It is used by drinking as mineral water.

9.3. Geothermal Energy Use in Turkey

Turkey is located in an active technotic belt due to its geographical location and geological location. Therefore, it is a geothermal rich country. It ranks fourth in geothermal energy resources in Europe. There are approximately 1,000 natural outflows of geothermal resources at different temperatures. According to the data of the Ministry of Energy and Natural Resources (MENR), the geothermal power plant with 1,283 MW installed power ranks first among European countries.



Graphic 1: Geothermal Energy Resources by Regions in Turkey

In Turkey, geothermal energy source is used for residential heating, greenhouse heating, thermal and health facilities heating, thermal water heating, agricultural drying, heat pumps and cooling. According to the latest data, approximately 3,495 MW of energy use is mentioned. Drying facilities established by utilizing geothermal energy in Turkey were established in the provinces of Kırşehir, Denizli (Sarayköy), Aydın, Afyonkarahisar, Balıkesir (Sındırgı), Ankara (Kızılcahamam), Manisa (Alaşehir).

9.4. Geothermal Energy in the World

When the general distribution of geothermal energy in the world is examined, especially the regions with plate boundaries come to the fore. The Alpine-Himalayan Belt, South and Southeast Asia (Pacific Ring of Fire) and the Americas are the prominent regions in this regard. Just like in our country, other world countries also use geothermal energy, electricity generation, cooling, drying, heating and so on. uses for purposes. It is preferred especially in electricity production because it is a renewable and sustainable source. The top five countries in terms of electrical energy production are as follows; USA, Indonesia, Philippines, Turkey and New Zealand.

Some developed countries in the cold belt use geothermal energy to heat roads, pavements and runways.

COUNTRY	AMOUNT OF RESOURCES (%)	COUNTRY	AMOUNT OF RESOURCES (%)
USA	%25	**MEXICO**	%7
INDONESIA	%14	**ITALY**	%6
PHILIPPINES	%13	**ICELAND**	%5
TURKEY	%8	**KENYA**	%5
NEW ZELAND	%7	**JAPAN**	% 4
		OTHER COUNTRIES	% 1

Table 1: Geothermal Energy Resource Distribution in the World

The world's largest geothermal power plants are Geysers Complex and Saltonsea in the USA, Lardello in Italy, Cerroprieto in Mexico, Hellsheide in Iceland, Malaya and Makban in the Philippines, Olkaria in Kenya, and Darajat in Indonesia.

The project of Manisa Alaşehir Municipality was awarded the first prize in the "Fruit and Vegetable Drying with Sustainable Geothermal Energy" project, which consists of 200 projects prepared by 20 countries in total, organized in the USA in 2019.

To summarize, geothermal energy is an important resource in the world and in our country as it is continuous and renewable. In the development of our country and other countries with geothermal resources in the world, especially the studies in the production of electricity should be concentrated, and the use of geothermal energy in areas such as drying food and heating greenhouses should be expanded.

9.5. Using Geothermal Energy in Drying Process

As is known, drying process is the process of reducing the amount of moisture in order to preserve the food. When high temperature is applied to some foods, the vitamin content decreases or disappears. In this case, some foods must be dried at low temperatures. It is appropriate to use low temperature geothermal fluids for this purpose. The use of geothermal energy in the drying process will also contribute to environmental protection. The use of geothermal resources offers the opportunity to develop the country's own energy resources, industries and open new job opportunities, unlike the expensive and environmentally polluting fossil fuels. Despite the many advantages of geothermal energy, its application areas are still very limited in the world. In the studies conducted by Andritsos et al. in Greece, it was stated that low enthalpy (the sum of all kinds of energy stored in the structure of the substance) geothermal waters found in some islands of Greece can be used for drying food grown tomatoes, cherries, apricots, plums, figs, asparagus. Again in the studies of Lund et al.; Seaweed in Iceland, onion in the USA, wheat and other grains in Serbia, fruit in Guatemala and Mexico, alfalfa in New Zealand, coconut in the Philippines, bananas, dates, quince, oranges in Kırşehir province in Turkey. , kiwi, pineapple, watermelon and melon are stated to be dried.

When the principle of the drying facility located in Kırşehir in Turkey is examined, a pattern will be formed regarding the use of geothermal energy source. The facility obtains the source with a depth of 147 meters, a flow rate of 12 liters per second and a temperature of 52 oC from the Karakurt1 well. The distance between the facility and the well is 500 meters, and the geothermal source is carried to the heat center via pipes and heats the mains water through heat exchangers. The heated mains water comes to the air handling unit and hot air is blown from the nose to the drying oven. In addition, the electricity produced here is used to operate the fans and pumps in drying with geothermal energy.

The most important disadvantage of geothermal plants is that the cost of installation and parts is expensive compared to fossil fuel systems. However, it is very advantageous compared to other drying methods in terms of providing uninterrupted constant heat throughout the year and cheap energy cost. In cases where the number of technical and intermediate personnel is not sufficient in the facilities where geothermal energy is used, reductions in production may occur.

10. EVALUATION OF DRYING ACTIVITIES

Today, the increasing global population and the corresponding good life expectancy puts pressure on the limited energy resources.

The main purpose in the drying process is to reach a high quality final product. While reaching this goal, it aims to use energy as effectively as possible. It is not possible for a single drying method to be sufficient for all products in terms of both economic and quality characteristics. Sometimes pre-drying pre-treatments, such as immersion in a solution or steam blanching, increase the efficiency of the drying process, reduce drying time and lower product cost. Choosing the appropriate drying method is very important for companies to survive and survive in the highly competitive market. In addition to the drying technology, it is also important to choose suitable pre-treatment methods when necessary.

Many vegetables and fruits are consumed with pleasure in dried form, and dried vegetables are also used in ready-made soup mixes and sauces. Fruit powders are widely used in pudding and pastry industry. With the reduction in volume and weight provided by the drying process, it provides convenience in the storage and shipment of vegetables and fruits, and enables the export of products with positive results such as increased shelf life. Dried products can be stored for a long time in the determined quality with appropriate packaging and storage conditions.

GENERAL MEASUREMENT AND EVALUATION

If the information given in the sentences below is true (T), write it (F) if it is false.

(…) 1. In all conditions, solar energy is used for the drying process.
(…) 2. Sorting the food before drying does not affect the quality of the final product.
(…) 3. Facilities using geothermal energy are in a very dangerous class.
(…) 4. The pre-treatments applied before drying reduce the drying time and increase the quality of the final product.
(…) 5. When drying at lower temperatures, geothermal resources can be utilized.
(…) 6. Excessive sulphurization does not pose a risk to human health.
(…) 7. Boiling method is not applied to mushrooms as a pre-treatment.
(…) 8. The decrease in the weight of the product at the end of drying is a physical change.
(…) 9. All foods are dried at the same temperature.
(…) 10. Turkey ranks 4th in terms of geothermal resources.

Tick the correct one in the following multiple choice questions

1. Which of the following is not a physical change in dried food?
A. Shelling
B. Loss of vitamin C
C. Size Reduction
D. Reduction in Weight

2. Which of the following is a feature of food packaging?
A. Protect the product from moisture
B. It should not transmit heat and light
C. It should be suitable for storage
D. All

3. Which of the following information is false?
A. Ripe fruit is used in the drying process.
B. Dried with apricot kernels.
A. Each food has its own approximate drying temperature.
D. Dried foods are considered both as a final product and as an intermediate product.

4. Which of the following is not an advantage of using geothermal energy?
A. Sustainable.
B. It is safe.
C. Renewable.
D. The initial setup cost is high.

5. Which of the following is the oldest known drying method?
A. Drying by drying oven
B. Drying with a hair dryer
C. Drying using geothermal welding
D. Natural drying with solar energy

6. Which of the following is not one of the aims of the drying process?
A. To obtain a final product that tastes like it was plucked from the branch.
B. Preserving food by reducing water activity in food
C. Extending shelf life by drying
D. Reducing the cost of packaging, storage, transportation

7. Which of the following is the most used source in the sector for the drying process?
A. The sun
B. hot weather
C. Geothermal resource
D.Wind

8. Which of the following is not important for the facility to use geothermal energy in a facility?
A. Distance to facility
B. Whether it allows residential heating
C. Welding temperature
D. Chemical structure

9. Which of the following is not a pre-treatment before drying?
A. Extraction
B. Longitudinal
C. Dehulling, slicing
D. Not removing the seeds

10. Which of the following is not an example of food dried at 70-80 °C at high temperatures?
A. Fig
B. Apricot
C. Apple
D. Peas

ANSWER KEY

Below is the answer key for the questions with True/False options.

1	F
2	F
3	T
4	T
5	T
6	F
7	T
8	T
9	F
10	T

Below is the answer key for the multiple choice questions.

1	B
2	E
3	B
4	D
5	D
6	A
7	B
8	B
9	D
10	D

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