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CONSERVATION BY DRYING OF PLUMS WITH SOLAR ENERGY

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Abstract: *Dehydration is one of the most common methods for preserving fruits, especially grapes and plums, vegetables and mushrooms. This technology is one of the most natural methods of preservation. There is no need for chemical treatment of food only of the energy to minimize the water content of products. To reduce costs we suggest and justify the use of solar energy and some relatively simple equipment, which in Romania can be efficient for at least 6 months per year.*

Key words: *plum, drying, solar energy, conservation.*

1. Introduction

A plum or gage is a stone fruit tree of the genus Prunus, subgenus Prunus. The subgenus is distinguished from other subgenera (peaches, cherries, bird cherries etc.) by a terminal bud in the shoots and by the solitary side buds (not clustered), the flowers in groups of one to five together on short stems, and the fruit having a groove running down one side and a smooth stone (or pit).

Mature plum fruit may have a dusty-white coating that gives them a glaucous appearance and is easily rubbed off. This is an epicuticular wax coating and is known as "wax bloom". Dried plum fruits are called dried plums or prunes, although prunes are a distinct type of plum, and may have pre-dated the fruits now commonly known as plums [8].

Dried plums (or prunes) are also sweet and juicy and contain several antioxidants. Plums and prunes are known for their laxative effect. This effect has been attributed to various compounds present in the fruits, such as dietary fiber, sorbitol, and isatin. Prunes and prune juice are often used to help regulate the functioning of the digestive system. Dried prune marketers in the United States have, in recent years, begun marketing their product as "dried plums". This is due to "prune" having negative connotations connected with elderly people suffering from constipation.

Dried, salted plums are used as a snack, sometimes known as saladito or salao. Various flavors of dried plum are available at Chinese grocers and specialty stores worldwide. They tend to be much drier than the standard prune. Cream, Ginsing, Spicy, and Salty are among the common varieties. Licorice is generally used to intensify the flavor of these plums and is used to make salty plum drinks and toppings for Shaved Ice or baobing [8].

2. Material and Method

Plums come in a wide variety of colors and sizes. Some are much firmer-fleshed than

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others and some have yellow, white, green or red flesh, with equally varying skin color.

Plum cultivars in use today include:

- Damson, or Damask Plum.
- Greengage (Firm, green flesh and skin even when ripe).
- Mirabelle (Dark yellow, predominantly grown in northeast France).
- Satsuma plum (Firm red flesh with a red skin).
- 'Victoria' (Yellow flesh with a red or mottled skin).
- Yellow gage, or Golden plum (Similar to Greengage, but yellow).

The top ten plum producers in 2009 were the countries presented in Table 1:

Table 1

Top ten plum producers in 2009		
Country	**Production (tons)**	Note
China	5,373,001	[E]
Serbia	662,631	
USA	561,366	
Romania	533,691	
Turkey	245,782	
Spain	200,100	
Italy	194,100	
Bosnia and Herzegovina	155,767	
France	150,000	[E]
Ukraine	136,700	
World	**10,679,206**	**[A]**

For the production of prunes only brownie plums are used (Prunus domestica L. ssp domestica) as well as their derivatives: Stanley, Amers, Węgierka, Dąbrowicka, empresa, Oneida, Jojo, Top, Valjevka, President and Damacha. Fruits of these varieties have the characteristics necessary for drying including a high sugar content and relatively low water content. The fruit must be healthy with no signs of rot, mechanical damage or visible damage by insects, mites or other pests. For example, for the production of smoked prunes only drying units are used, where plums can be dried and smoked with smoke and hot air. Drying Unit can not be higher than 3 meters. Fruits are placed on trays by hand. They must be arranged in such manner that the air and smoke easily reach every part of them. Depending on the size of the fruit, they are placed on trays in varying numbers of layers. A layer can be thicker than 12 cm. Prunes are dried and smoked using hot air and smoke from hardwood which are supplied by an oven placed under the tray. The mixture of hot air and smoke is passing among the trays and the fruit placed on them. For this purpose gravity circulation of air and smoke is used. Temperature in drying units is 45°C-90°C. Temperature is highest at the bottom of the drying unit and the lowest in the middle of it because of the gravitational circulation of air. The whole process of drying and smoking lasts for 48 hours, but duration may vary depending on fruit size, temperature and drying facilities maintained by the external atmospheric factors, particularly temperature and humidity. Dried fruits and smoked uniformly are gathered from the trays and sorted [6].

Equipment scheme that can be achieved drying by using solar energy is shown in Figure 1. For solar energy recovery and its use as energy source it is necessary to use photovoltaic panels. Overall scheme of the control panel is shown in Figure 2. The control panel consists of photovoltaic panel, battery, controller and connecting cables.

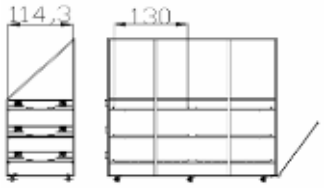

Fig. 1. *Overall scheme of the dryer*

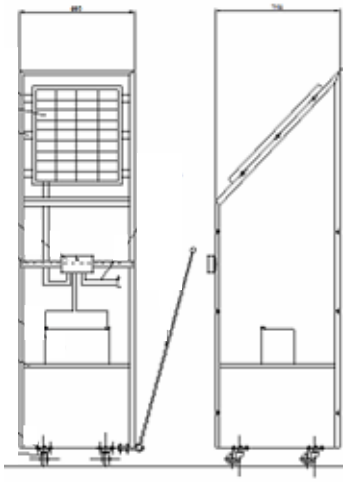

Fig. 2. *Overall scheme of the panel*

3. Water Evaporation

Removing excess water from the fruit is subjected to dehydration by evaporation under the influence of temperature and air movement. If the rate of air movement exceeds 1 m/s, all wet surfaces that are in the same air flow receive about the same amount of heat, known as wet-heat thermometer. During dehydration of fruits, the water from cell juice surfaces and evaporates due to internal diffusion. Rate of heat transfer by convection and evaporation rate is proportional to the difference between air temperature and considered surface, the difference between dry and wet thermometer temperature. This difference is called the wet thermometer depression (WTD). However, a fruit area that is exposed to dehydration is different from a free water surface. This is because the raw material subject to dehydration can receive the heat by convection from the grates that are placed, or by radiation from the surrounding environment.

When using solar energy for drying plums these will dry in the sun when temperatures remain around 30 degrees Celsius or higher and when there is good air movement, even in the form of light breeze. A single day will not be enough for proper drying and fruit should be placed in a location where they can be quickly taken inside in case of rain [2].

Romania is in a geographical area with good sun coverage, with an annual solar flux between 1000 KWh/m^2/year to 1300 kWh/m^2/year. From this amount of energy one can capture between 600 and 800 kWh/m^2/year. The level of insolation is determined by geographical location using a country-specific sunshine map (Figure 3). This map divides our country into three main areas of sunshine: Zone 0, Zone 1 and Zone 2, Zone 0 with the highest solar radiation [1].

Fig. 3. *Romanian solar map*

For fresh plums, humidity is about 81.1%. Thus, in order to preserve the fruit for a long time, dehydration should be made until the humidity reaches values of 18-20% [6].

4. Results and Discussions

Among the internal factors that influence dehydration's first factor is the nature of raw material, expressed by the chemical composition and physical structure. Pre-treatment of material, scalding or steaming (blanching) causes dehydration to be faster than in untreated ones because the first case increases the permeability of cell membranes. The degree of maturation, expressed by dry matter content and proportion of its main components, the time from collection to dehydration and storage conditions can be incorporated in the group of natural factors.

The main external factors which influence dehydration are form and degree of fragmented material or piece size. It is known that the dehydration speed of a water-rich material and therefore drying time, theoretically speaking, is inversely proportional to the square of the thickness of the pieces. A practical consequence of this finding is shortened dehydration. In case of drying with solar energy, the exploitation of this type of energy requires conversion of solar energy into electricity. It is possible to simultaneously convert solar energy into chemical energy and electricity by photo electrochemical conversion using chemical reactions of charge transfer. This conversion is currently under scrutiny [3]. A PV cell consists of two layers of silicon semiconductors doped with other elements to change their electrical properties. A layer has more electrons so it has a negative charge (N type) and the other has less (type P) than naturally. When sunlight reaches the photovoltaic cell, it has enough energy to free electrons. The release near the junction passes through it due to potential difference and creates an electrical current [4].

The principle of the photovoltaic cell is shown in Figure 4.

Advantages of PV technology are:

- do not need fuel;
- lack of wear;
- easy maintenance;
- robustness and high reliability;
- it is useful where network connection is impossible or too expensive.

Energy produced by the photovoltaic panels is used immediately or stored in batteries.

Current disadvantages of such a system are:

- high cost;
- difficult to store large amounts of electricity [5].

4.1. Overview of photovoltaic systems

Photovoltaic cells (PV) or solar cells are semiconductors that convert sunlight into continuously electricity. Groups of photovoltaic cells are electrically configured

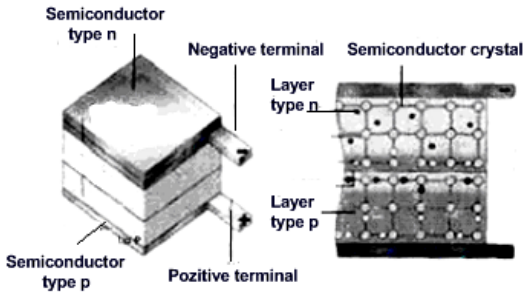

Fig. 4. *The principle of the photovoltaic cell*

into modules or panels and are used to charge the batteries in various applications in telecommunications, rural electrification, power supply etc. for domestic and industrial systems, as can be seen in Figure 5 [7].

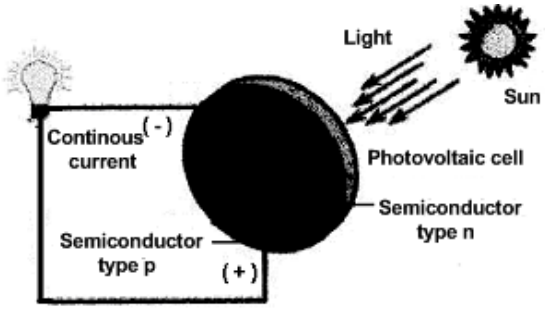

Fig. 5. *Scheme of photovoltaic cell-junction P-N*

5. Conclusions

- In the production of prunes only brownie plums are used (Prunus domestica L. ssp domestica) as well as their derivatives: Stanley, Amers, Węgierka, Dąbrowicka, Empresa, Oneida, Jojo, Top, Valjevka, President and Damacha. Fruits of these varieties have the characteristics necessary for drying including a high sugar content and relatively low water content.
- Removing excess water from the fruit is subjected to dehydration by evaporation under the influence of temperature and air movement. If the rate of air movement exceeds 1 m/s, all wet surfaces that are in the same air flow receive about the same amount of heat, known as wet-heat thermometer.
- The rate of heat transfer by convection and evaporation rate is proportional to the difference between air temperature and considered surface, the difference between dry and wet thermometer temperature. This difference is called the wet thermometer depression (WTD).
- In case of drying with solar energy, exploitation of this type of energy requires conversion of solar energy into electricity. It is possible to simultaneously convert solar energy into chemical energy and electricity by photo electrochemical conversion using chemical reactions of charge transfer.

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