INTERNATIONAL SUMMER SCHOOL
on Direct Application of Geothermal Energy

Under the auspice of the
Division of Earth Sciences

USE OF GEOTHERMAL ENERGY FOR TOMATO DRYING – POSSIBILITIES IN THE AEGEAN ISLANDS

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Abstract

This contribution refers initially to the first application of geothermal energy in Greece in the area of industrial drying. A tomato dehydration unit has been established in N. Erasmio, 25 km south of Xanthi, and produced "sun-dried" tomatoes. The unit, operated for the first time during the summer of 2001, uses low cost geothermal water to heat atmospheric air to 55°C in finned tube air heater coils. During its first year of operation 4 tn of high quality dried tomatoes were produced. In the second part of the paper the possibility of geothermal drying is discussed in the Aegean Islands, most of which are rich in low- and moderate-temperature geothermal waters.

1. INTRODUCTION

Dehydration (or drying) of fruit or vegetables is one of the oldest forms of food preservation methods known to man. The process involves the slow removal of the majority of water contained in the fruit or vegetable so that the moisture contents of the dried product is below 20%. In the Mediterranean countries the traditional technique of vegetable and fruit drying (including tomatoes) is by using the sun, a technique that has remained largely unchanged from ancient times. However, on an industrial scale, most fruit is dried using sun (or sometimes solar drying), while most vegetable are dried using continuous forced-air processes.

Dried fruits and vegetables can be produced by a variety of processes. These processes differ primarily by the type of drying method used, which depends on the type of food and the type of characteristics of the final product (Mujundar, 1988, Nijhuis et al, 1998):

1. Sun drying. It is limited to climates with hot sun and dry atmosphere with strong winds. Typical areas with such climates are most of the Mediterranean regions, and most of the Aegean islands. Solar drying can be also used.
2. Atmospheric dehydration by passing heated air over the food to be dried.
3. Sub-atmospheric dehydration
4. Freeze-drying, for added value products, such as coffee.
5. Electromagnetic drying (e.g. microwave drying).
6. Drying using the osmotic phenomenon.

The two last methods have been tried experimentally for the dehydration of fruits and vegetables, but no commercial installation is in place. Although vegetable drying aims primarily at food preservation, food drying also lowers the cost of storing, transportation and packaging. Industrial drying is usually carried out with the second method in batch or continuous processes. Continuous processes include tunnel, fluidized bed, continuous belt and other driers. Tunnel driers are the most flexible and efficient dehydration systems and they are widely used in drying fruits and vegetables. Geothermal energy is a possible energy source for heating the drying air.

Drying of agricultural products is probably the most important industrial application of low or medium-temperature geothermal energy (40-150°C). Fresh or recycled air is forced to pass through an air-water converter and to be heated to temperatures in the range 40-100°C. The hot air passes through or above trays or belts with the raw products resulting in the reduction on their moisture content. In geothermal drying, electric power is also used to drive fans and pumps. Agricultural products that are dried using geothermal energy include (Lienau, 1998): onion, garlic, apple, mango, pear, bananas, pineapple, alfalfa, grain, timber etc. The largest dryings units, which started in the 60s and 70s, deal with drying of diatomaceous earth in Iceland and timber and alfalfa drying in New Zealand (Lund, 2000). Worldwide, the geothermal energy used for agriculrural drying represents about 0.5% of the total geothermal energy use at the beginning of 2000 (Lund and Freeston, 2001). Except from a small pilot-scale cotton drier in Nea Kessani, Xanthi, which operated for a period of two-months in 1991 and demonstrated that geothermal drying is possible, no other application of geothermal drying has been reported in Greece.

This contribution describes the first project of geothermal vegetable drying in Greece and discusses the possibilities of using geothermal energy for drying traditional agricultural products in he Aegean islands.

2. TOMATO DRYING

Tomatoes, as well as other vegetables, can be dried using various methods. In any tomato drying technique the required time for drying the product depends on many parameters such as tomato variety, the soluble solids content (°brix) of the fresh product, the air humidity, the size of the tomato segments, the air temperature and velocity and the efficiency of the drying system. The rate of drying is the key factor controlling the end quality of the dried product.

In general, dried tomatoes undergo the following process steps: predrying treatments, (such as size selection, washing and tray placing), drying or dehydration, and postdehydration treat-ments, such as inspection, screening and packaging.

Traditional sun-drying has the advantages of simplicity and the small capital investment, but it requires long drying times. Long drying periods have adverse consequences on the product quality: the final product may be contaminated from dust and insects or suffer from enzyme and microbial activity. On the other hand, industrial drying under high temperatures (~90ºC) suffers from quality losses regarding colour and aroma and may lead to case hardening (the formation of a hard outer shell) impeding the drying of the interior part of the product. It is obvious that the ideal conditions for drying tomatoes is a mild temperature between 45 and 55ºC, which enables the dried tomatoes to retain its nutrients (including vitamins and lycopene, the nutrient responsible for the deep-red colour of tomatoes) and flavours.

3. DESCRIPTION OF THE TOMATO DRYING SYSTEM

The complete tomato dehydration process can be divided into three stages: the pre-drying preparation step (pretreatment), the drying step, and the postdrying treatment, as illustrated in the schematic diagram of Figure 1. The predrying treatment prepares the raw tomatoes (Roma variety, probably one of the most suitable varieties for drying) for the dehydration process. This step involves initially a selection of the tomatoes, regarding their maturity and soundness. About 50-70% of the tomatoes are selected. The sorting of the tomatoes into two sizes is followed: tomatoes above 90 g and tomatoes of lower weight. The raw tomatoes are then placed in crates, washed to remove dust, dirt, plant parts etc, cut into two halves and placed into stainless steel trays (mesh type, 100x50 cm^2). It is noted that blanching of the raw tomatoes is not required because of the richness of antioxidants substances.

The drying step is carried out in a tunnel drier. This drying system consists of the following main components (Figure 1):

1) *Finned-coil air-water heat exchanger* (INTERKLIMA) for heating the drying air and having a capacity of 300000 kcal. The ‘cold’ air enters the heat exchanger at atmospheric conditions (20-35°C) and leaves the exchanger at an almost

constant temperature of 55°C. The incoming geothermal water a temperature is 59°C, while the temperature of the water at the outlet is 51-53°C. The mean water flow rate used during the first drying period was about 25 m3/h. The geothermal water has a very low TDS and its does not cause any scaling or corrosion problems (Kolios & Sarandeas, 1992). The geothermal wellhead is located about 1400 m west of the drier and the geothermal water is transferred in non-insulated PVC pipes with o.d. 110 mm.

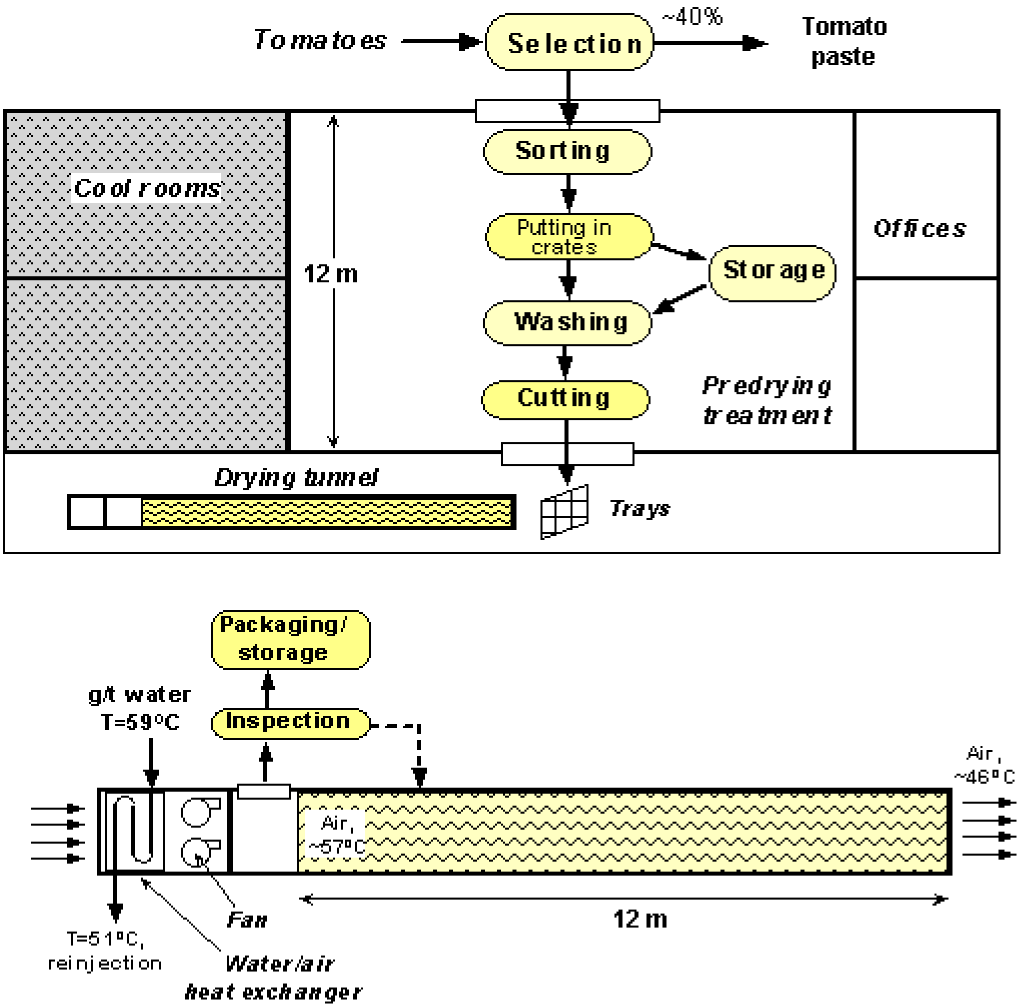

Figure 1. Schematic diagram of the geothermal tomato drier system.

2) *Fan units.* Two centrifugal fan units are installed in the system, having a rated power of 7 kW. During the 2001 operation of the drying system only a small part (~30%) of this power was used with the aid of an inverter. The air flow rate in the tunnel was 10.000-12.000 m^3/h and the superficial air velocity in the tunnel (without the trays loaded with product) was 1.7 m/s. In the presence of the loaded trays that block partially the cross-section of the tunnel the air velocity increases by 20-50%, depending on the location inside the tunnel.

3) *Drying tunnel.* The 14-m long rectangular tunnel (width of 1 m and height 2 m) is constructed of polyurethane aluminium panels. A picture of the tray entry is illustrated in Figure 2a. The heated air flows counter-currently with the move of trays in the tunnel. The tomato-loaded trays are placed at the entry of the tunnel and they are conveyed towards the end (where the hot air enters the tunnel) in a semi-continuous manner: approximately every 45 min a series of 25 trays with dried product are removed and 25 trays loaded with raw tomatoes are inserted at the end and push the upstream trays toward the end. About 7 kg of raw tomatoes

are placed on each tray. The profile of temperature with the height of the tunnel seems to be uniform, as deduced for temperature measurements at various heights and from the uniformity of the product drying regardless of the tray position.

4) *Measuring instruments.* The inlet and outlet temperatures of both air stream and geothermal water are continuously monitored using thermocouples. The moisture content is measured by weighing certain marked trays at various locations of the tunnel.

The *postdehydration step* involves inspection and screening (the removal of dehydrated pieces of unwanted size, of foreign materials etc.) and packaging in glass jars with olive or sunflower oil, wine vinegar, salt, garlic and various herbs.

The solids contents of the Roma tomatoes range between 8 to 10% w/w and the moisture content of the final product is estimated to be about 10%. Accordingly, the weight of the processed product reduced about 10-12 times after drying. The removal of the moisture content appears to be faster at the first half part of the tunnel. The residence time of the product in the drier was 30 hours, adjusted by trial-and-error to achive the best quality product. During that period about 4200 kg of raw tomatoes are introduced in the tunnel and the production of dried tomatoes reaches about 400 kg.

Dehydration at 50-57°C, i.e. at mild temperature conditions and for relatively long times, appears to retain the colour and the aroma of the tomatoes, in contrast to the tomatoes dried in industrial driers (employing conventional fuels) using air temperatures higher than temperature 80°C, shorter drying times and air recycling. Apart of the colour preservation, mild drying conditions are supposed to reduce the isomerization of lycopene (Shi et al, 1999; Zanoni et al, 1998). Lycopene is the tomato nutrient responsible for the deep-red colour of the tomatoes and it has been suggested that lycopene's antioxidant properties - the highest among those of all the dietary carotenoids - may explain its apparent ability to reduce an individual's risk of prostate and certain other cancers. It is reported that high drying temperatures lead to partial degra-dation of the nutrient through isomerization and oxidation reactions. Lycopene in fresh tomatoes is found as trans-isomer and isomerization converts all-trans isomers to cis-isomers, which are less effective anti-oxidants.

During the first year of operation of the drying unit about 4 tn of dried product was produced, which was packaged in glass jars of various sizes. A picture of a glass jar with dried product is shown in Figure 2b. The dried product was sold in Greece and abroad as 'sun-dried' tomatoes. The geothermal energy use totalled ~1 TJ, which represents about 0.5% of the total use of geothermal energy in Greece (Fytikas et al, 2000). This energy use corresponds to ~22 TOE.

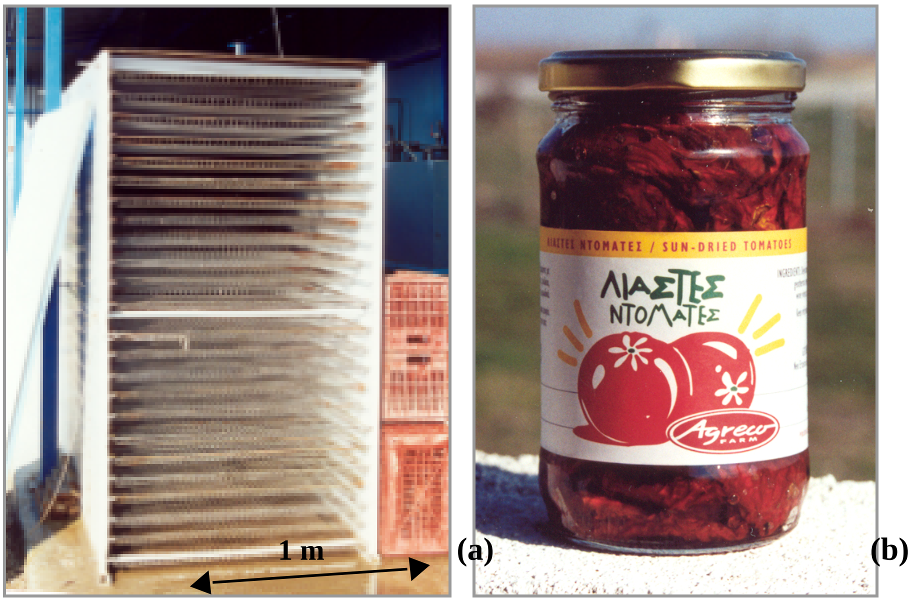

Figure 2. (a) Picture of the tunnel entry; (b) picture of the packaged product.

4. POSSIBILITIES OF GEOTHERMAL DRYING IN THE AEGEAN ISLANDS

Greece, like several other Mediterranean countries, is rich in geothermal energy. In particular, in the Aegean island and coastal areas there are abundant easily accessible geothermal resources reaching almost 100ºC. A review of these resources can be found in Fytikas (2002). Islands with low and moderate temperature geothermal resources include Milos, Santorini, Kimolos, Kos, Nisyros, Evia, Chios, Lesvos and Samothraki. Consequently, there is considerable potential for meeting some of the drying requirements of several agricultural products by geothermal energy.

In Santorini Island (and in other islands in Cyclades) a special variety of small tomatoes (cherry tomatoes) is cultivated for many years. Part of the product is consumed as fresh vegetable, while another part is dried in the sun and is sold as delicatessen. Low-temperature geothermal energy can be used efficiently for dehydrating this variety of tomatoes in these islands. Geothermal drying can be partially substitute the traditional 'sun-drying' process and eliminate some of the quality problems of the dried products associated with this method. Geothermal water, with temperature as low as 60ºC, can be used to heat atmospheric air (to a temperature of 55ºC) in finned tube air heater coils (air-water heat exchanger). In case the geothermal water is corrosive, as is usually the case with the saline geothermal waters encountered in the Aegean region, a second water-water heat exchanger may be required, constructed of corrosion-resistant materials.

It appears that in Cyclades the only traditional agricultural product that can be dried is tomato, because the cultivation of other vegetables and fruits is limited. However, in Evia and the islands of Northern Aegean several fruits (apricots, prunes, figs), and vegetables (e.g. peppers, onions, garlic, asparagus, tomatoes and alfalfa – used for animal feeding) can be dehydrated using geothermal energy.

5. CONCLUDING REMARKS

In the summer of 2001, a new direct use of geothermal energy was demonstrated in N. Erasmio, Xanthi, dealing with the dehydration of tomatoes. It was shown that low-temperature geothermal energy can be used efficiently and reliably in heating the drying air needed in the dehydration process. With geothermal dehydration the product retains the deep-red colour, the nutrients and flavours of the fresh tomatoes and high-quality "sun-dried" tomatoes are produced.

The success of the tomato drying will certainly lead to the extension of the unit regarding its capacity, drying period and drying crops (e.g. peppers, asparagus, figs and apricots). Actually, in a pilot scale the unit was used successfully in May 2002 to dehydrate not well dried figs. It is noted that the capacity of the unit (geothermal water, heat exchanger, air fans) is more than double of the 2001 production. Geothermal drying of fruits and vegetables can be accomplished with water temperatures as low as 55°C, something that is fulfilled by most low enthalpy geothermal resources in Greece. There is a large low-temperature geothermal potential in several Aegean Islands (Santorini, Milos, Kos, Chios, Lesvos etc.) that can be used for "sun-drying" of locally produced fruits and vegetables. In particular, geothermal energy drying of cherry-tomatoes seems to be a viable process in the Cyclades Islands, where this product is cultivated and served as a specialty. Other vegetables and fruits that can be geothermally dehydrated are apricots, prunes, figs and asparagus.

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