USE OF GEOTHERMAL ENERGY FOR TOMATO DRYING

N. Andritsos[1], P. Dalampakis[2] and N. Kolios[3]
[1]Chemical Process Engineering Research Institute, P.O. Box 361, 57001, Thermi, Greece and Dept. of Mechanical & Industrial Engineering, University of Thessaly, Greece
[2]Geologist-Geothermist, Salaminos 5, 54626, Thessaloniki, Greece
[3]Institute of Geology & Mineral Exploration, Branch of Central Macedonia, Frangon 1, 54626, Thessaloniki, Greece

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 (40-150ºC). Fresh or recycled air is forced to pass through an air-water converter and to be heated to temperatures in the range 40-100ºC. 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 used to drive fans and pumps. Agricultural products that are dried using geothermal energy include (Lienau, 1998; Lund, 2000): onions, garlic, various fruits (apple, mango, pear, bananas, pineapple), alfalfa, grain, coconut meat, seaweed, 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. Worldwide, the geothermal energy used for agricultural drying represents about 0.5% of the total geothermal energy use at the beginning of 2000 (Lund and Freeston, 2001). Apart from a small pilot-scale cotton drier in N. Kessani (Perfecture of Xanthi), which operated for a two-month period 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 example of geothermal tomato drying in Greece and discusses the possibilities of using geothermal energy for drying traditional agricultural products in the Aegean islands.

TOMATO DRYING

Tomatoes, 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 (ºbrix) 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 affects 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 treatments, such as inspection, screening and packaging.

Traditional sun-drying has the advantages of simplicity and the small capital investments, but it requires long drying times that may have adverse consequences to 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 color 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 are mild temperatures between 45 and 55ºC, which enable the dried product to retain its nutrients (including vitamins and lycopene, the nutrient responsible for the deep-red color of tomatoes) and flavors.

DESCRIPTION OF THE TOMATO DRYING SYSTEM

The complete tomato dehydration process can be divided into three stages: a 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 (in our case Roma variety, probably one of the most suitable varieties for drying) for the dehydration process. This step involves initially the selection of the tomatoes, regarding their maturity and soundness. About 40-70% of the tomatoes are selected to proceed for drying depending mainly upon the climatic condition during tomato growth and harvesting. 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, 100×50 cm^2). It is noted that blanching of the raw tomatoes is not required because of the richness of tomatoes in antioxidants substances.

The drying step is carried out in a tunnel drier. This drying system consists of the following main components (Figure 2):

Figure 2. Overview of building and drier (the long, light colored box)

1. *Finned-tube coil air-water heat exchanger* (INTERKLIMA) for heating the drying air and having a capacity of 300,000 kcal. The 'cold' air enters the heat exchanger at atmospheric conditions (20-35ºC) and leaves the exchanger at an almost constant temperature of 55ºC. The incoming geothermal water a temperature is 59EC, while the temperature of the water at the outlet is 51-53ºC. The mean water flow rate used during the first two drying periods was about 25 m^3/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 transmitted in non-insulated PVC pipes having diameter 110 mm.
2. *Fan units.* Two fan units were installed in the system, totaling a rated power of 7 kW. During the operation of the drying system in 2001-2002 only a small part (~30%) of this power was used with the

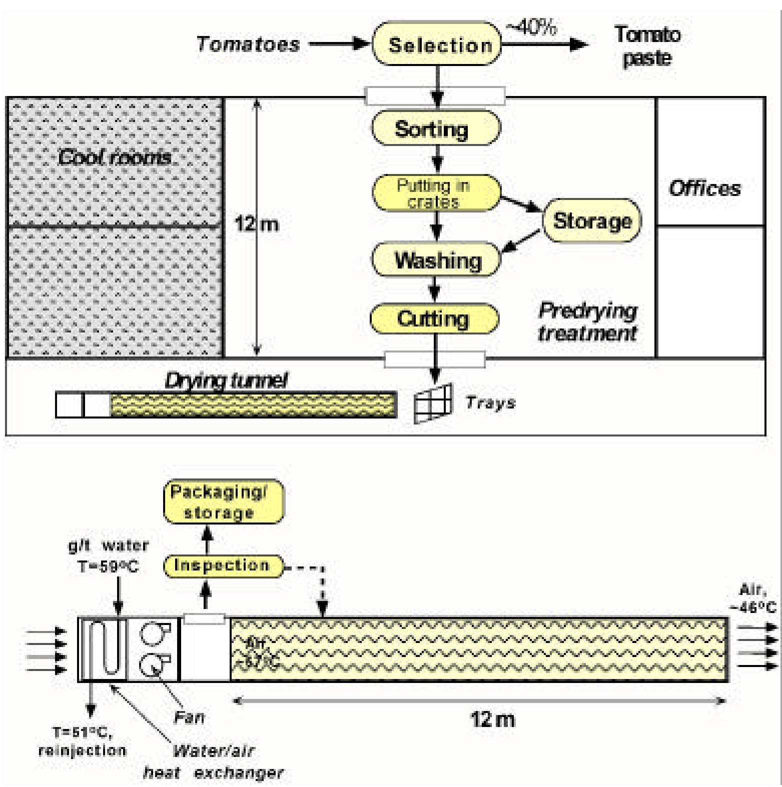

Figure 1. Schematic diagram of the geothermal tomato drier system.

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*. The14-m long rectangular tunnel (width 1 m and height 2 m) is constructed of polyurethane aluminum panels. A picture of the tray entry is illustrated in Figure 3a. The heated air flows counter-currently with regards to the 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 entry 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 in the tunnel.

Figure 4. ***Detail of drying racks with tomatoes.***

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% (Figure 5). 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 achieve 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.

Figure 3. (a) Picture of the tunnel entry and (b) picture of the packaged product.

Figure 5. Final dried tomato product.

Dehydration at 50-57ºC, i.e. at mild temperature conditions and for relatively long times, appears to retain the color and the aroma of the tomatoes, in contrast to the tomatoes dried in industrial driers (employing conventional fuels) using air temperatures higher than temperature 80ºC, shorter drying times and air recycling. Apart of the color 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 color 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 degradation of the nutrient through isomerization and oxidation reactions. Lycopene in fresh tomatoes is found as trans-isomer and isomerization converts all trans-isomers to cisisomers, which are less effective antioxidants.

During the first year of operation of the drying unit about 4 tonnes of dried product were produced, which was packaged in glass jars of various sizes. A picture of a glass jar with dried product is shown in Figure 3b. The dried product was sold in Greece and abroad as 'sun-dried' tomatoes. The geothermal energy use totaled 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. In the summer and early fall of 2002, 5.5 tonnes of dried tomatoes were produced despite the rainy conditions during harvesting, which deteriorated the quality of the raw tomatoes and decreased considerably the selection rate. About 500 kg of the sun-dried tomatoes represented organic tomatoes which had to be transported to the geothermal plant from a distance of 200 km. Such a geothermal drying unit seems to be quite flexible regarding the product to be dried and many agricultural products can be dehydrated without major modifications. As an example, the unit was used successfully in May 2002 to dehydrate about 1 tonne of poorly dried figs. There are also thoughts to extend the drying period and dehydrate peppers and mushrooms. It is noted that the capacity of the unit (geothermal water, heat exchanger, air fans) is more than double of the 2001-2002 production.

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.

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 color, the nutrients and flavors 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). Geothermal drying of fruits and vegetables can be accomplished with water temperatures as low as 55ºC, 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.

REFERENCES

Fytikas, M., 2002. Origin and Characteristics of the Geothermal Energy Resources of the Aegean Island," presented at the Int. Workshop on *Possibilities of Geothermal Energy Development in the Aegean Islands Region*, September 5-7, 2002, Milos Island, Greece.

Fytikas, M.; Ándritsos, N.; Karydakis, G.; Kolios, N.; Mendrinos, D. and M. Papachristou, 2000. "Geothermal Exploration and Development Activities in Greece During 1995-1999," *Proc. of World Geothermal Congress 2000*, (ed. S. Rybach et al.), Kyushu-Tohoku, Japan, May 28 - June 10, 2000, pp. 199-208.

Lienau, P., 1998. "Chapter 16 - Industrial Applications," *Geothermal Direct-Use Engineering and Design Guidebook*, 3rd Edition, Geo-Heat Center, Oregon Institute of Technology, Klamath Falls, OR.

Lund, J. W. and D. H. Freeston, 2001. "Worldwide Direct Uses of Geothermal Energy 2000," *Geothermics*, 30, pp. 29-68.

Lund, J. W., 2000. "Direct Heat Utilization of Geothermal Resources." Geo-Heat Center, Oregon Institute of Technology, Klamath Falls, OR.

Mujundar, A. S., 1987. *Handbook of Industrial Drying*, Marcel Dekker Inc., New York, NY.

Nijhuis, H. H.; Torringa, H. M.; Muresan, S.; Yuksel, D.; Leguijt, C. and W. Kloek, 1998. "Approaches to Improving the Quality of Dried Fruit and Vegetables," *Trends in Food Science & Technology*, 9, pp. 13-20.

Shi, J.; Le Maguer, M.; Kakuda, Y.; Liptay, A. and F. Niekamp, 1999. "Lycopene Degradation and Isomerization in Tomato Dehydration," *Food Research International*, 32, pp. 15-21.

Zanoni, B.; Peri, C.; Nani, R. and V. Lavelli, 1998. "Oxidative Heat Damage of Tomato Halves as Affected by Drying," *Food Research International*, 31, pp. 395-401.