Installation and Testing of the Iidea Geothermal Food Dehydrator in the Domo de San Pedro Nayarit Mexico Geothermal Field

***Héctor Miguel Aviña Jiménez, Eduardo Pérez González, Alfonso García-Gutiérrez**

Instituto de Ingeniería, UNAM, Ciudad Universitaria, México, D.F.

***havinaj@iingen.unam.mx, eperezg@iingen.unam.mx, ag_gutie06@outlook.com**

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ABSTRACT

In Mexico about 20 million tons of food are lost and wasted annually. Among the most affected foods are fruits and vegetables, which represent 40% of the total [1]. On the other hand, medium- and low- enthalpy geothermal energy resources in Mexico are enormous [2] and are not being used or exploited due to the lack of technological developments and investment [3]. This energy can be used in various processes such as food dehydration, refrigeration, heating, greenhouses, heat pumps, milk pasteurization, wood drying, etc. [4]. In this context, the iiDEA group of the Institute of Engineering of the National Autonomous University of Mexico (UNAM for its name in Spanish) currently develops one of the Direct Use projects of the Mexican Center for Innovation in Geothermal Energy (CeMIE-Geo for its name in Spanish). In such project, technology is being developed for several direct use applications one of which is the development of a Geothermal Food Dehydrator (GFD), which currently is under a patenting process, with ID number MX/a/2015/007318. Thus, in this paper results are presented on the installation and testing of the DGA carried out in the Domo de San Pedro, Nayarit state, Mexico, geothermal field. So far, several fruits have been dehydrated such as pineapple, guava, mango, pear, papaya, as well as sea food such as shrimp. It is one of the first food dehydrators in Mexico that employ geothermal fluid as the main energy source, and it is expected that with the results obtained, escalation to an industrial-sized GFD can be constructed in the short future, which will contribute to the development and application of Direct Uses of geothermal energy in the country and worlwide.

Introduction

Mexico owes its great diversity of fruits, vegetables and seeds to its privileged geographical position in the world, a situation that positions it among the main fruit and vegetable producing countries in the world and the main fruit and vegetable supplier of the United States of America [5].

The main importing countries of dehydrated fruit are Russia with 12%, Germany and England, both with 11%, and United Sates with 10%, while the rest of countries account for 56% of world imports. Mexico only imports 1.9% (Figure 1). On the other hand, the main exporting countries of dehydrated fruit (Figure 2) are Turkey with 24%, the United States of America with 21% and Chile with 12%. Argentina ranks tenth country with 2% of world exports whereas Mexico does not figure in the top 10 of the countries that lead this list. However compared with Argentina, Mexico has a greater diversity of fruit and vegetable production, with 4.4 ton of orange, 3.3 ton of tomato, 2.3 ton of chili, 2.1 ton of lemons and bananas, and 1.9 ton of mangoes and guavas. So the place in the exportation that Mexico has could be better.

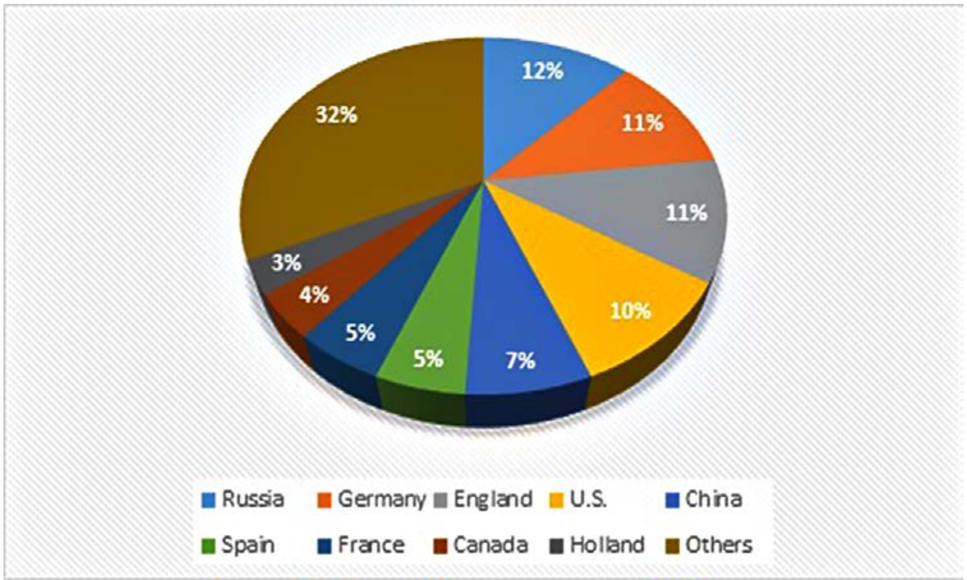

Figure 1 Main importing countries of dehydrated fruit [6]

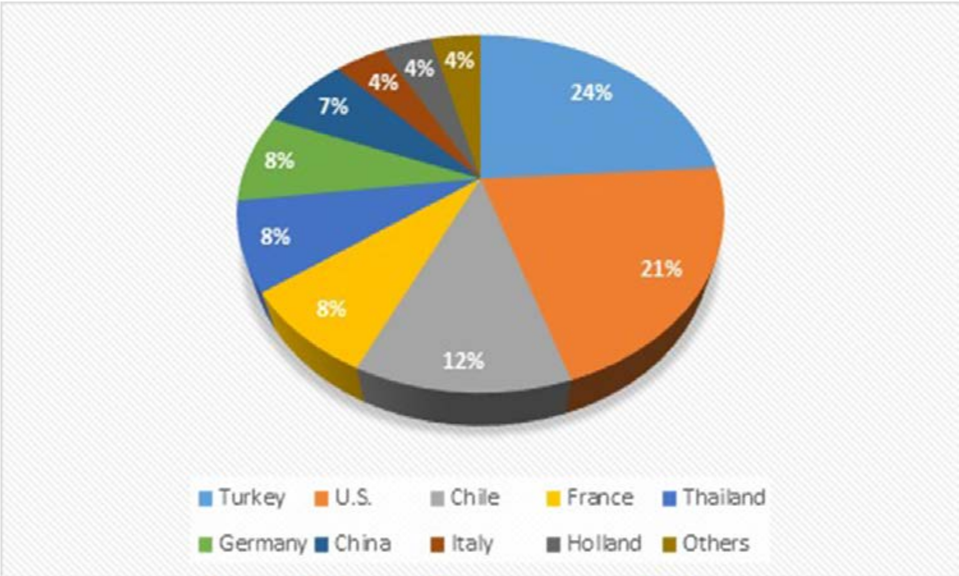

Figure 2 Main exporters of dehydrated fruit [6].

Geothermal Resources In Mexico

Power generation

Currently there are five geothermal power plants in operation with a total installed capacity of 982.3 MWe (Figure 3) with a running capacity of 916.4 MWe [7]. This places Mexico in 5th position in installed capacity among the countries generating electricity with geothermal energy.

Figure 3 Map of Mexico showing the location of its geothermal power plants

Four of the five geothermal electricity generating power plants in Mexico are owned by the Federal Electricity Commission (CFE for its name in Spanish), while the fifth is a private initiative. The plants administered by CFE s are: Cerro Prieto in Baja California (570 MWe), Los Azufres in Michoacán (247.9 MWe), Los Humeros in Puebla (118.9 MWe) and Las Tres Vírgenes in Baja California Sur (10 MWe). The fifth geothermal plants is owned by a the Mexican Company called Geothermal for Development (GEODESA), and is located the municipality of San Pedro Lagunillas, in the state of Nayarit, Mexico. It has an installed capacity of 35.5 MWe and 4 production wells and 3 injection wells. The electricity generated by these 5 power plants was 5,937.4 GWh in 2017 [7] which accounts for about 3% of the total national electricity generation.

Direct Uses

The direct use of geothermal energy has been an alternative to be used in the industry in general, as published in the Mexican Official Diary for the Law for the Use of Renewable Energy and the Financing of the Energy Transition (LAERFTE) and contemplated in the recent Energy Reform in order to reduce dependence on hydrocarbons and to diversify the energy matrix through the use of renewable energies.

Direct use of geothermal energy accounts for a very small fraction of the country´s low- to medium temperature energy resources and amount to 155.8 MWt with an energy use of

4,171 TJ/yr [8]. A more recent report [7] shows that the installed capacity dropped to 148.6 MWt with an energy use of 1,158.6 GWh/yr. Table 1 shows the various direct use applications reported in 2015.

Table 1 Direct uses of geothermal energy in Mexico [8];

*. It is include the estimated total flow rate of all the bathing sites in the state, and the average inlet & outlet temperature.
1) Type: A: Agricultural drying, B: Bathing and swimming, G: Greenhouses, H: Individual space heating (other than heat pumps).
2) Enthalpy Information is given only if there is steam or two-phase flow.
3) Capacity (MWt) = Maximum flow rate (kg/s) x [inlet temperature (°C) – outlet temperature (°C)] x 0.0044184
4) Energy use (TJ/yr) = Average flow rate (kg/s) x [inlet temperature (°C) – outlet temperature (°C)] x 0.1319
5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171.

Locality	Type1)	Maximum Utilization					Capacity3) (MWt)	Annual Utilization		
		Flow rate (kg/s)	Temperature (°C)		Enthalpy2) (kJ/kg)			Ave. Flow (kg/s)	Energy4) (TJ/yr)	Capacity Factor5)
			Inlet	Outlet	Inlet	Outlet				
Los Azufres, Mich.	A	0.100	77.0	60.0			0.007	0.030	0.067	0.300
Los Azufres, Mich.	B	38.000	72.0	55.0			2.703	34.960	78.391	0.920
Los Azufres, Mich.	G	0.050	60.0	40.0			0.004	0.011	0.028	0.210
Los Azufres, Mich.	H	4.583	110.0	86.0			0.460	1.389	4.397	0.303
La Primavera, Jal.	B	63.000	48.0	31.0			4.481	58.650	131.511	0.931
Aguascalientes*	B	265.000	43.0	30.0			14.414	194.139	332.890	0.732
Chiapas*	B	1,000.000	36.0	29.0			29.288	847.656	782.640	0.847
Chihuahua*	B	38.000	39.3	25.0			2.274	29.680	55.982	0.781
Coahuila*	B	56.000	32.0	25.0			1.640	33.390	30.829	0.596
Durango*	B	34.000	52.5	38.0			2.063	15.975	30.553	0.470
Guanajuato*	B	293.000	40.8	29.0			14.466	254.232	395.692	0.867
Hidalgo*	B	271.000	41.5	32.0			10.772	250.800	314.265	0.925
Jalisco*	B	368.000	37.8	30.0			12.010	316.350	325.467	0.859
México*	B	103.000	35.1	25.0			4.353	95.424	127.123	0.926
Michoacán*	B	161.000	44.5	33.0			7.747	152.785	231.752	0.949
Morelos*	B	95.000	45.0	30.0			5.962	74.580	147.557	0.785
Nuevo León*	B	295.000	38.0	30.0			9.874	250.700	264.539	0.850
Querétaro*	B	770.000	31.8	26.5			17.075	697.174	487.373	0.905
San Luis Potosí*	B	292.000	36.8	31.0			7.086	233.888	178.929	0.801
Sinaloa*	B	7.000	72.5	61.0			0.337	4.601	6.979	0.657
Tlaxcala*	B	10.000	35.0	28.0			0.293	8.308	7.671	0.831
Veracruz*	B	42.000	65.0	48.0			2.987	39.328	88.185	0.936
Zacatecas*	B	163.000	36.6	28.5			5.524	138.700	148.186	0.851
TOTAL		4,368.733	49.1	37.0			155.820	3,732.750	4,171.006	0.749

It can be observed that balneology is a recreational activity that dominates direct use applications and is found in most of the country, except for the space heating system installed in the Los Azufres geothermal field in the state of Michoacán, for the heating of enclosures such as offices and cabins. The greenhouse and food dehydrator that were installed in the same geothermal field there were projects that did not continue since the end of the 1990's.

Stored Geothermal Resources

Mexico has an enormous potential for geothermal exploitation. It has been estimated that the stored energy in 927 systems (1,637 geothermal manifestations) amounts to a mean value of 1,383 EJ. These resources span the range of temperatures between 36 and 208°C of which 5% of the systems have temperatures between 149 and 208°C, 40% of the systems have temperatures between 100 and 149°C, 50% of the systems have temperatures between 62 and 100°C, and 5% of the systems have temperatures between 36 and 62°C [2].
However, these resources are practically unexploited at present. Figure 3 (above) shows in orange dots the location of these geothermal resources which are found through most of the country

In summary, Mexico is a leading country in electricity generation using geothermal energy and has vast amounts of low- to medium temperatures geothermal energy resource suitable for direct use and electricity generation using ORC technology, however direct uses are marginal and offer a unique opportunity to use these geothermal resources (T<180°C) since the potential is enormous for the development of industrial, agriculture and service activities, grouped under the generic name of geothermal direct uses.

Geothermal Food Dehydrator, GFD-IIUNAM

The iiDEA group has developed a modular dehydrator prototype, which can produce 2 kg of dehydrated product per day. It is currently being tested in the called San Pedro Dome geothermal field, which is administered of GEODESA, in the state of Nayarit, Mexico. For its commissioning, it was necessary to enable the use of a pair of maritime containers, 20 x 8 x 8.6 ft (Figure 4). They were conditioned inside to enable three main areas; 1) food reception and washing, 2) food peeling and chopping, and 3) dehydration.

The geothermal resource that is being used is the residual energy produced in the power plant. On the separation platform, 50 ton/h of hot water at 90°C are available at atmospheric pressure. The hot water after separation is streamed into an open-air pond, where part of the resource is taken for the dehydration process.

The heat necessary to remove the moisture contained in various fruits and vegetables has been determined experimentally. It is calculated from the initial humidity and the characteristics of each food, and the final humidity suitable to the nature of each food. In the case of mango, one of the products with greater demand in the national and international market, the amount of energy required is 7.73 kW/kg dry product [9].

Figure 4 Dehydration Food Processing Unit (DFPU).

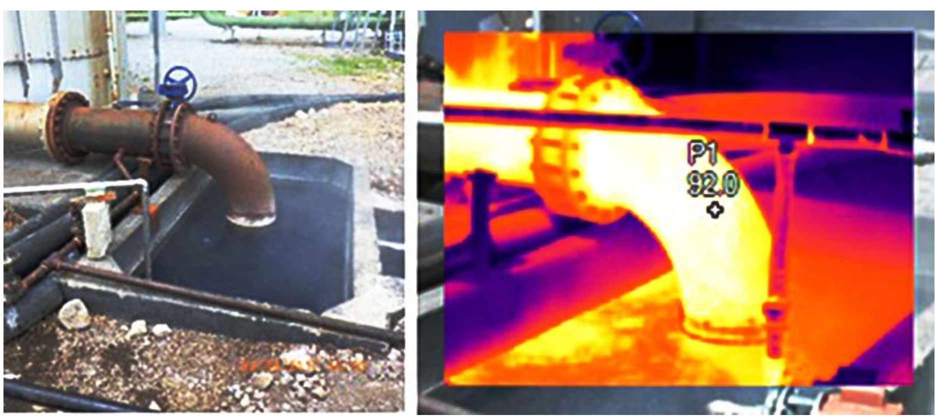

Figure 5 Geothermal fluid dump and temperature measurement with a thermographic camera.

Figure 6 Process Description of Geothermal Food Dehydrator

The products that have been dehydrated since include: pineapple, mango, papaya, guava, pear, melon, apple and shrimp. For all of them, drying curves were obtained, and the microbiological and sensorial analyses of the dehydrated samples were carried out by the Faculty of Chemistry of UNAM. Through the implementation of a Standardized Operational Procedure, a homogeneous quality in the production of dried fruits has been achieved. Figure 7 shows the various fruits that have been dehydrated in the DPFU.

Figure 7 View of different dehydrated fruits using the DPFU.

System Scaling Depending On The Energy Available In The Geothermal Power Plant

The technology is currently being scaled up to a model of industrial capacity. As a first step, three scenarios were analyzed for the use of the remaining geothermal energy at the San Pedro Dome geothermoelectric power plant.

Scenario One

It is proposed to collect all the geothermal fluid after its separation phase at 90 °C and atmospheric pressure of 0.086 MPa. The total flow of geothermal fluid available at these conditions is 150 ton/h. At these conditions, the available energy is 16 MWt. The total amount of energy available depends on the drop of temperature of the geothermal fluid, that is, the drop of fluid temperature was analyzed at various levels from 70°C down to 40°C. Figure 8 shows in the energy available for the dehydration process.

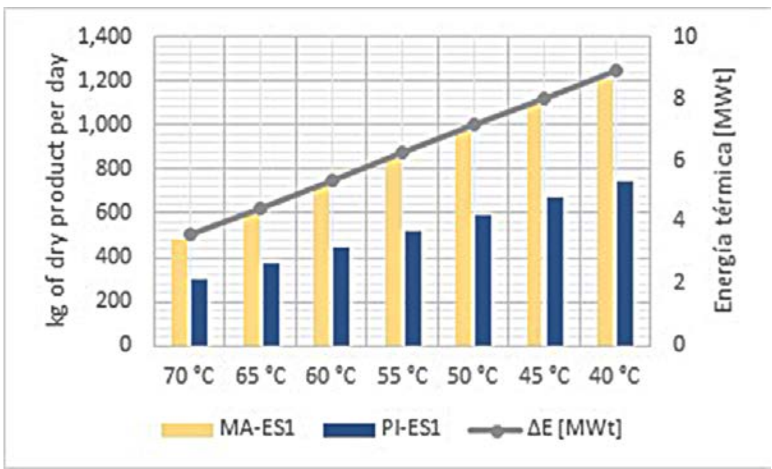

Figure 8 Production of mango and pineapple for scenario one based on the usable temperature drop of the geothermal fluid. Secondary axis shows usable net thermal energy.

Scenario Two

For scenario two, it is proposed to collect all the flow of geothermal fluid from the field, but in its highest energetic state available for its use, which is after the separation process and prior to its entry to the silencers. For this scenario, the following thermodynamic states characteristic of the energy level are considered: 186 ton/h of geothermal fluid, fluid temperature and pressure of 17°C and 0.8 MPa, respectively.

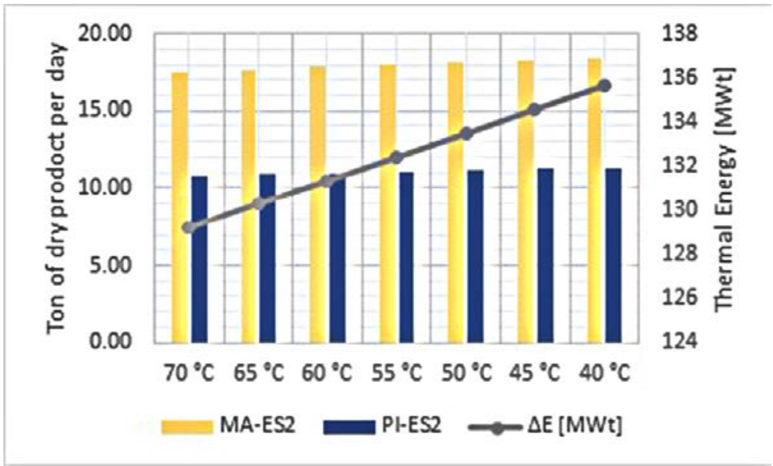

Figure 9 Production of mango and pineapple for scenario two based on the usable temperature drop of the geothermal fluid. Secondary axis shows usable net thermal energy.

Scenario Three

For scenario three, it is proposed, as in the previous scenario, to use all the remaining energy of the geothermal power plant but in this case, prior to the dehydration process the geothermal fluid is used in a binary cycle power plant for electricity generation. The energy quality available for dehydration can then be obtained from the following values: geothermal fluid flow rate of 186 ton/h, fluid temperature of 100°C and fluid pressure of 0.2MPa.

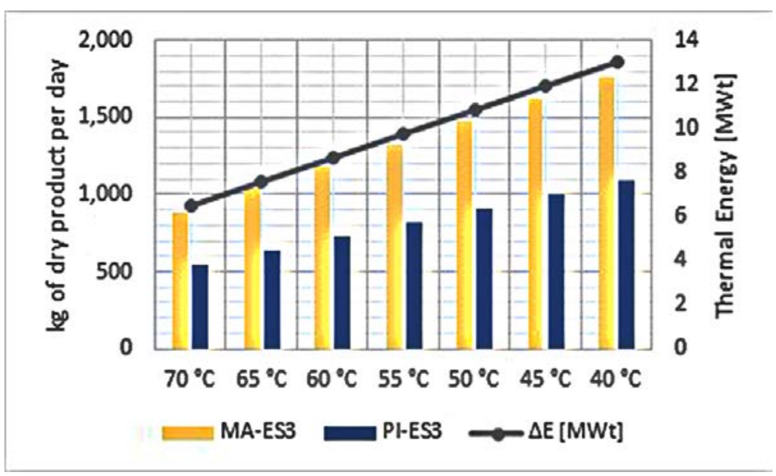

Figure 10 Production of mango and pineapple for scenario three based on the usable thermal gradient of the geothermal fluid.

From the previous analyzes on energy technical feasibility to implement a dehydration system with industrial capacity in Nayarit geothermal power plant, it allows us to know the amount of raw material that can be processed per day as well as determine the technical economic analysis of the project and its social impact in the region.

So far it has been determined that in the worst case, the production of 600 to 1,000 kg of dehydrated product per day, with scenario number 1, allows the creation of 60 direct jobs and 150 indirect jobs. On the other hand it avoids burning 20 thousand liter of gas, which is burned monthly in a commercial dehydrator to produce the 1,000 kg of dehydrated fruit, which translates into stop emitting more than 40 tons of CO2 and a monthly saving in fuel of more than $ 200,000.00 pesos or approximately US $ 10,000.00. Extrapolating to stage two, it would create 900 direct jobs, avoid emitting 600 tons of CO2 monthly, as well as a savings of US $ 150,000.00.

Any of the three scenarios is feasible and has a wide implementation potential, in this case everything will depend on the policies that the directive of the company that manages the power plant decides to take. However, scenario number one represents greater energy consumption in the pumping system, since the geothermal resource is being taken at atmospheric pressure, while in the other two scenarios the energy due to the pressurization of the working fluid is used. Analyzing this economically is more profitable scenarios where it is not necessary to invest in sophisticated pumping equipment and saving in electricity consumption represents not only economic but also energy savings.

Among several successful cases, the Resource Park is a geothermal complex in Iceland, made up of a group of companies, which have scope in the residential, agricultural, industrial and commercial sectors or services. In total all these corporations generate about 650 jobs. In 2013, the economic wealth generated by the field was $ 3.8 million pesos MN, of which HS Orka, geothermal, had a 35% share and the rest of the activities that represent the direct uses of geothermal energy, in the field of Iceland, generated the remaining 65% of the wealth, equivalent to $ 2.45 million pesos, for that year [10]

Conclusion

With the dehydration tests that have been run with the DGA-IIUNAM, comparative studies of the samples processed with geothermal energy, solar energy and gas. These results are available for the next year.

Similar results in the laboratory, simulating operational parameters in the field, indicate that the microbiological and sensorial quality is acceptable for three products analyzed: tomato, mango and guava [5].

In order to determine the appropriate parameters for the dehydration of horticultural products, a study was carried out in which the affections to the physicochemical and microbiological phenomena associated with the hot air dehydration process are considered. From this research it was determined that the operational qualities that can be achieved with a geothermal dehydration system are the conditions that allow to have a superior quality to commercially dehydrated products, which are processed with sun energy and gas.

With regard to geothermal energy, Mexico has a great wealth of low enthalpy geothermal energy sources. This resource can have a wide variety of applications as direct use, but in our country only 1,158.70 [GWh / year] [11] of geothermal energy is used for balneology; said use is limited by the lack of knowledge about the characteristics and uses of these resources. However, the opportunity to use the geothermal resource of intermediate-low temperatures (<180 [° C]) in Mexico has enormous potential for the development of industrial, agricultural and service activities, grouped under the generic name of direct uses.

The main objective of the project is to encourage the development of large-scale productive projects, which promote the necessary conditions that drive the economic development of the localities surrounding these projects.

The experience gained from the experimental work, shows that it is better to start a geothermal power plant project with the exploration and development of the field through low-enthalpy geothermal projects such as a food dehydrator, greenhouses or aquaculture, because they allow to develop the geothermal field, capitalize and prepare for strong investments in the drilling of geothermal wells for power generation and, last but not least, involving the population in the development of the geothermal project, since in the end if the project is not socially well accepted, however feasible it may not be carried out.

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