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Dehydration: An efficient process for ensuring food conservation in vulnerable regions

Deshidratación: Un proceso eficiente para asegurar la conservación de alimentos en zonas vulnerables

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Abstract

Approximately 860 million people throughout the world currently live in extreme hunger and poverty due to income reductions, unemployment, and layoffs from the COVID-19 pandemic, all of which disproportionately affect disadvantaged homes (Unated Nations, 2022). One of the objectives of the World Bank (2022) for 2030 is to end extreme poverty and promote shared prosperity. In Mexico, there are 55.7 million people in poverty, extreme poverty, high or very high marginalization, and vulnerable situations on account of lack of food, healthcare, housing, and employment (CONEVAL, 2020). However, there is no immediate solution to rid the world of poverty and food shortage. In this project, we propose to combat the issue of poverty and food inequality with a system for conserving food that takes advantage of the solar energy available in the most disadvantaged and marginalized regions. The solar dehydration used to naturally dry fruits, vegetables, and animal proteins after the harvest will contribute to the food supply, do no harm to the environment, and create an alternative job source.

Dehydration, Food conservation, Marginalized regions, Environment, Alternative jobs

Resumen

Actualmente en el mundo existen aproximadamente 860 millones de personas en situación de pobreza extrema y hambre debido a la disminución de los ingresos, la pérdida de puestos de trabajo y los ceses laborales durante la pandemia del COVID19, que han afectado principalmente a los hogares más desfavorecidos (Naciones Unidas, 2022). Uno de los objetivos del Banco Mundial (2022) para 2030 es poner fin a la pobreza extrema y promover la prosperidad compartida. En México hay 55.7 millones de personas en pobreza, pobreza extrema, alta y muy alta marginación y en situación de vulnerabilidad por carencias en alimentación, salud, vivienda y empleo (CONEVAL, 2020). Sin embargo no existe una solución inmediata para acabar con la pobreza y el rezago alimentario. En el presente proyecto se propone utilizar como estrategia para combatir la pobreza y la desigualdad alimentaria, un sistema para la conservación de alimentos que aprovechen la energía solar disponible de las zonas marginadas del país menos favorecida a través de la deshidratación solar para el secado natural de vegetales, frutos y proteínas de animales, después de la cosecha que contribuyan a mejorar la alimentación de las personas, el cuidado del medio ambiente y una fuente de trabajo alternativo.

Deshidratación, Conservación alimentos, Zonas marginadas

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Introduction

The sun is the source of various forms of energy that human beings have used since the beginning of their history to satisfy their needs, solar energy being one of them. Every day the sun radiates, or emits, an enormous amount of energy in one second (VIU, 2021). It continuously emits a power of 62 thousand 600 kilowatts per square meter of its surface (Arancibia Bulnes and Best and Brown, 2010) (Romero Crespo, Flores Peralta, 2019). This is equivalent to about 60 times the annual consumption of human society, noting the potential of the Sun's energy to meet the world's energy demands.

Solar radiation reaching the Earth can be harnessed through the heat it produces, as well as through the absorption of radiation. In the upper part of the earth's atmosphere, on a surface perpendicular to the radiation, there is an average power of 1367 W/m2, an amount called Solar Constant (IDEAM, 2022), more than enough for its use. The sunlight that reaches the earth is composed of millions of high-energy particles called photons, where each unit of solar radiation, or photon, carries a fixed amount of energy, showing the potential of the sun's energy to meet the world's energy demands. The use of solar energy has been little disseminated in the history of mankind despite the fact that it is unlimited and without cost, making it competitive with respect to the use of fossil fuels (Bravo, 2012).

The growing energy demand is mainly due to population growth and is causing fossil fuel reserves to be depleted faster than expected, which is why energy does not reach all human beings in the same way or in the required amount, a situation that is accentuated when the marginalization and poverty level of the population is more evident (González *et al*., 2021). In the great oil crisis of the seventies of the last century is when the massive diffusion of solar thermal systems began, in particular, with the use and dissemination of water heating for domestic use (Bravo, 2012), so that the real development of solar thermal energy occurs from this time, when all those nations involved in the embargo motivated many Western countries dependent on oil to decide to promote other energy sources such as renewables, and within these to the use of solar thermal panels (Carbonell, 2022).

Renewable energies

Solar energy has always been used by human beings in daily life and domestic tasks. The first records indicating that the sun's energy was used as a source of heat and light for constructions are in ancient Greece around 400 B.C. (Romero Crespo, Flores Peralta, 2019).

The first drying method developed by man consisted of direct exposure of the product to the sun (Hernández, 2017). This technique is still used today in rural areas of developing countries, however a large amount of product is lost due to contamination or deterioration by natural phenomena and insect attack.

Drying or desiccation is one of the oldest food preservation processes dating back to the Paleolithic era, approximately 400,000 years ago, where antecedents indicate that foods such as fruits, grains, vegetables, meats and fish were dried in the sun, learning through trial and error, to achieve a possibility of subsistence in times of scarcity of nutritious food (Bravo, 2012).

According to (Cortés, 2017) there are two alternatives for food dehydration: naturally in the sun, or mechanically, however it can also be done in a combined way, some stages in the sun and others mechanically.

Dehydration is one of the oldest forms of food processing. It consists of extracting a good part of the moisture from them, so that they do not decompose (CEUPE Magazine. (n/d). Dehydration or drying is one of the most used techniques for food preservation throughout history (De Michelis Antonio, Ohaco Elizabeth, n/d) through a simultaneous process of heat and mass transfer, accompanied by a phase change (Espinoza, 2016).

It is a food preservation procedure that, by removing all the free water from the food, prevents microbial activity and reduces enzymatic activity (CEUPE Magazine, n/d). All foods are susceptible to being altered in a greater or lesser space of time, due to the action of microorganisms that contaminate them or to enzymatic reactions of the food itself (Pinzón, 2016). Water is the main component of food, helping to maintain its freshness, flavor, texture and color (Marín *et al*., 2006).

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Its importance lies in the fact that it serves as a transport for substances, in addition to being key in the development of microorganisms, the main agents of food spoilage. The reduction of water present in a food has been a strategy used since ancient times to preserve quality during storage periods (AgriNova, 2009). The reduction of weight and volume results in a reduction of transportation and storage costs, generally of high cost, due to the energy required during the process (Espinoza, 2016).

In addition to the water or moisture of a food, it is necessary to know its availability for certain biochemical, enzymatic and microbial reactions, the solutes present in the food, such as proteins, carbohydrates, lipids and vitamins (Marín *et al*., 2006). The moisture in the food is absorbed by the air that is in contact with the food. For this to occur, the air must be warm, dry and moving (Cutnei, 2007). This procedure allows extending the life of the food, preserving its properties as well as facilitating storage, transport and handling. Another way is the method of food processing through the application of heat, hot air (Espinoza, 2016). As can be seen, it constitutes an energy saving alternative, since the use of solar energy in food dehydration reduces the consumption of fossil fuels, is efficient, low cost and eliminates the emission of greenhouse gases (Cortés, 2017).

Likewise, the solar dehydrator is a device that allows using solar energy to dehydrate food, in less time than drying in the sun and with greater hygiene. Transforming useful heat through the greenhouse effect (Kajekui, 2017).

Another alternative is solar food drying. It is carried out by exposing the products to the open air to receive direct energy from the sun and air, drying naturally. The ideal conditions to achieve dehydration are a mass of air surrounding the product with a high temperature and low relative humidity (Cutnei *et al*., 2007). The drying process can be applied to all types of foods, from vegetables and greens to meat and fish, fruits, spices, aromatic herbs, among others (Pinzón, 2016). A current of air that accelerates and renews the environment around the product to be dehydrated, replacing the already humidified one with a dry and warm one that continues the drying process (Cortés, 2017).

Artisanal production is based on dehydration in direct sunlight resulting in poor product quality due to high solar radiation (Espinoza, 2016), sanitary errors, which involve the presence of dust, stones and organic remains, among others. Currently, a great variety of agricultural products require drying for their adequate preservation or commercialization until they reach consumers. Drying offers an alternative to the farmer when there are transportation problems or when the market demands a dry and not fresh product. Solar drying technologies offer a viable alternative to process agricultural products in a clean and hygienic way, complying with existing regulations for food handling, contributing to reduce the consumption of traditional fuels, improve product quality, reduce post-harvest losses and care for the environment (Hernández *et al*., 2017).

Food preservation is considered of utmost importance to extend the shelf life of fruits and to have access to more distant markets. Food can take from 1/2 to 3 days to reach its proper point. This will depend on the original humidity of the product and the climatic conditions of the environment (temperature, ambient humidity and level of sun radiation) (Cutnei *et al*., 2007).

The various solar energy systems are rapidly becoming a common method for fluid heating, dehydration processes of fruits, grains, flowers or electricity generation. Foods that are dehydrated with the sun's energy maintain a large proportion of their original nutritional value if the process is carried out properly. As in all preservation processes, some percentage of vitamins is lost during preparation, drying or storage (Cutnei *et al*., 2011). Healthy eating is a trend that is growing strongly, markedly so in industrialized economies but also in emerging ones (Buitrago, 2014).

Impact of dehydration

It allows preserving all foods for months or years as less water they retain; it maintains the nutritional properties of foods with the best preservation the lower the dehydration temperature (Villén, 2012), (Kajekui, 2017); flavors are intensified by concentrating their properties; in addition, storage, handling and transportation space is reduced, especially the preservation of surplus crops.

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When these properties become a problem, they imply a restriction of access to green international markets (Espinoza, 2016). In the dehydrated market, priority is given to large producers, who obtain better prices and availability for their production (Espinoza, 2016), which is why it is necessary to work on the dehydration of products that provide socioeconomic support for low-income people.

There are drying techniques where firewood can be used as fuel, however the use of these types of techniques cause damage to the environment via deforestation and air pollution (Hernández *et al*., 2017), the use of industrial dryers offers drying quality but their high initial and operating costs limit their use.

Mexico's situation

Mexico is located between latitude 23.634501 N and longitude -102.552784 W, considered a region favored in solar resources, where it receives daily, on average, 5.5 kWh/m2, being one of the best in the world (Global Solar Atlas, 2021). Its privileged location allows it to use solar radiation to obtain environmentally friendly alternative energy.

Mexico has more than 55.7 million people living in poverty, of which 10.8 million are in extreme poverty (CONEVAL, 2020) (El Economista, 2021) (El Economista, 2021), high and very high marginalization and in a situation of vulnerability due to lack of food, health, housing and employment, the project is aimed at contributing to environmental care and socioeconomic support for the most vulnerable people in the country. According to the International Renewable Energy Agency (IRENA) (Lavagne *et al*., 2015).

This also has an impact at the energy level, since the lack of communication routes to reach these rural communities, or the distance to which they are located, is an important factor that makes it more difficult to access natural gas and electricity (González *et al*., 2021). Forecasts show that the world is not on track to achieve the goal of zero hunger by 2030.

Food safety

The food security and nutritional status of the most vulnerable population groups for the case of Latin America (with a population of 644 million inhabitants, according to the World Bank (WB), 2020) and, particularly for Mexico, deteriorate further due to the socioeconomic and health repercussions of the coronavirus disease pandemic (COVID-19) (UN, 2021). Anticipating the increase of the undernourished population (FAO-UN-PAHO-UNICEF. (2021).

The consequences of the pandemic are diverse and have been directly manifested in the reduction of family income, loss of employment as a result of home confinement during the first year and a half of the health emergency and its temporary extension (WHO, 2020). The impact on the health of the population has been devastating (ECLAC-PAHO, 2020), directly affecting the physiology of those who have contracted the virus. The situation that has prevailed since the beginning of the pandemic has also been reflected in the decrease in food supply and as a result has further affected the quality of nutrition (FAO, 2020).

Given the uncertainty about the duration of the pandemic, it is expected that the population living in poverty and vulnerability will increase to 220 million people (UN, 2020). At the same time, in economic terms, the impact on the global loss of GDP amounts to 14.1% (Bank of Mexico 2020 and 2020.1), directly affecting -among others- those who depend on their own trade and/or services activities, which have been halted since the end of March 2020 (ECLAC, 2020) and with 13.5% of the population that will lose their jobs, particularly in the agricultural sector, which -by 2019- amounted to 120 million people (ECLAC, 2019, UN, 2020.1).

Both poverty and vulnerability have to be addressed jointly, since the former detonates the latter if it deepens. For this reason, they must be addressed through an integrated policy (ECLAC, 2020.1; FAO, 2020; SB, 2021).

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Specifically, the National Institute of Public Health (INSP), the Intersecretarial Group of Health, Food, Environment and Competitiveness (GISAMAC), the Food and Agriculture Organization of the United Nations (FAO), the Pan American Health Organization (PAHO-WHO) and UNICEF, the United Nations Children's Fund (2020), expressed their concern about the great inequalities that have prevailed in Mexico for decades and the current crisis has revealed that 55.5% of households present some degree of food insecurity; it is not possible for them to satisfy their minimum food needs for a prolonged period of time.

On the other hand, the decline in economic activities will make it difficult to stimulate the generation of wealth in a rapid manner, and to buy food, as in the past. Particularly in rural areas and areas of great natural wealth, according to the United Nations report (2020.1), the drop in economic activity was 5.3%, comparable to the Great Depression of 1930 (ECLAC, 2020.2).

Mexico's natural resources are of great importance - nationally and internationally - as they represent more than 40 percent of the biodiversity on planet Earth (CONABIO, 2022, SEMARNAT, 2012; 2016 and 2018, UNDP, UNEP, ECLAC & UNCTAD 2010, UNEP, 2019 and United Nations, 2020) and at the same time they are the country's natural heritage and only source of life.

However, as a result of COVID19, production in the countryside has decreased or ceased and, at the same time, the price of the basic food basket has risen, as well as fruits, vegetables and grains, according to CONEVAL (2021) and the Ministry of Economic Development (SEDECO, 2021). As a result, their supply has decreased.

All of the above has a direct impact on food security, making it a national priority that demands to know its requirements; in order to add to the availability of food products, orienting their care and management towards sustainability and, as a whole, contribute to maintaining a healthy environment and access to food (Political Constitution of the United Mexican States, 2021).

In particular to add to the actions that reduce the effects of climate change (SEMARNAT, 2022), such as climate variability and extreme conditions, droughts, extreme rains, increasing weather events that, at the same time, affect the economy and are the main factors affecting food security and nutrition (FAO, IFAD, WHO, WFP and UNICEF, 2021). Hunger is most significant in countries where agri-food systems are affected by extreme rainfall and temperature conditions, and the livelihoods of a large part of the population depend on agriculture (FAO, IFAD, WHO, WFP and UNICEF, 2021), noting that poverty and inequality are more evident in socially excluded and marginalized groups.

Renewable energies

The solar radiation received by the earth is of the order of 1.5 kilowatts (kW) per hour, which is the amount of energy capable of supporting world consumption (Pareja, 2010), however, when using this energy source, disadvantages arise such as: the way it is captured and stored; in addition to presenting variations due to meteorological, environmental and geographical conditions. However, the solar radiation emitted by the sun reaches the Earth's atmosphere considerably weakened with approximately 1360 Watts per square meter (W/m^2), due to the distance between the Sun and the Earth; subsequently it suffers an attenuation due to the atmospheric layer, so that the radiation on the Earth's surface is approximately 1000 W/m^2. The estimated share of renewables in global electricity production in 2018 was 73.8% non-renewable electricity; 26.2% renewable electricity; 15.8% hydropower; 5.5% wind power; 2.4% solar PV; 2.2% bioenergy; and 0.4% geothermal, CSP, and ocean energy (REN21, 2019) (González *et al.*, 2021).

Conditions for food drying

The typical drying rate for a solar food dehydrator is 0.25 kg/h at the start of the process, which depends on the design of the dehydrator and the climate of the location. If the drying rate is much lower than this number, it is possible that the air temperature or air velocity is too low or the moisture content of the product is too high (Blanco Cano and Valldecabres Sanmartín, 2016).

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Generally, the temperature of the dryer should be 10-15°C above ambient temperature, while in artificial (fuel-fired) dryers it can be up to 60-70°C or higher.

On the other hand, the relative humidity of the air entering the dryer should be less than 60% to absorb water from the food. Each food or product requires an airflow with specific conditions.

Target

To develop an efficient solar dehydration system for vegetables, fruits and meats through a process with quality materials and control devices.

Materials and methods

The research was carried out by identifying the needs of the population living in poverty, and from there determining which project is viable for the entities in Mexico, whose population is in this situation of energy marginalization. With the information gathered and analyzed, the engineering design of the prototype was carried out and later the development of the system, including the ad hoc mechatronic mechanisms for its proper operation.

The work that led to the project was developed in an interdisciplinary manner, covering the areas of knowledge related to the project's objective (Environment and Development, Renewable Energies and Mechatronics).

Development Results and Analysis

Operation of the solar dehydrator

A solar collector is an equipment designed to capture solar radiation and convert it into heat, to transfer it by convection processes to fluids such as air that circulates through this system in a natural or forced way.

The present device for food preservation through dehydration based on the use of energy from the sun for the natural drying process of fruits, vegetables and animal proteins after harvesting, with technological basis and integrating emerging technologies for the preservation of micronutrients necessary for the feeding of the personnel.

With high social responsibility for the care of the environment and the socioeconomic potentialization of the inhabitants of vulnerable areas of a given region, based on scientific and technological knowledge in agribusiness and renewable energy for the development of projects through heat transfer and fluid mechanics is a low cost system for the agro-industrial, livestock and forestry sector.

It contributes to reduce the generation of CO_2 eq, compared to a conventional dehydrator that uses electricity or gas for its operation, and it is also a source of income for the family economy and the region where it is used.

For the design of the dehydration system, a decision matrix was established to analyze the parameters that govern the quality of the solar food dehydrator. This information was obtained from the needs, climatic conditions of the study area and the predominant natural, livestock and agroindustrial resources in Hidalgo, in addition to the engineering issues that are relevant to solar dehydrators such as heat transfer and fluid mechanics, considering the updraft solar dehydrator as the best option.

The design parameters that were considered high priority to effectively meet the needs in the municipalities considered high and very high marginalization in the state of Hidalgo -in a first stage- and then replicate them throughout the entity. Six key design parameters of approach were considered to obtain the required temperature and humidity for food dehydration, considering that with these parameters, the quality function would cover the needs of the end users.

Product cost

Materials should be accessible, low cost and widely used in the region.

Function

It must be functional at all levels required by the end users with the capacity to dry fruits, vegetables predominant in each region - bananas, tomatoes, apples, oranges, mangos, papaya, beef, pork, chicken - among others. With zero contamination of the food product inside the apparatus by insects and the same waste, and having the capacity to move the dehydrator to the sunniest areas by adults.

Safety

Its construction should be considered for the yard of a house or site where it can be operated mainly by adults without risk, so its weight should be light, without sharp or pointed edges; to avoid injury to users. Toxic or hazardous materials shall be excluded to ensure maintenance of edible micronutrients.

Reliability

The dehydrator is a great investment for a family in a low-income community; when the dehydrator performs its function, success is achieved and a product in conditions to feed the users and the sale of surplus dehydrated products is assured; therefore, the quality and cleanliness of the products and the apparatus is basic to avoid mold growth in a dehydration period of two days or less, through easy routine maintenance procedures that a mother of a family can perform on a daily basis.

Quality

Having a low budget solar dehydrator does not mean that it affects the quality of the design, the materials must be non-toxic, aesthetically pleasing, with a useful life of at least five years and that it fulfills the objectives and functions of dehydration in a short time.

Operating instructions

It will be delivered with a manufacturing manual and instructions for operation, functioning and basic maintenance, which are key factors for successful dehydration. The specifications of the device allow its construction in the place of use by the operators and specifically by rural women, this means that the training and instructions must be clear, concise and with a language that ensures its functionality and daily operation.

Manufacturing process

For the construction of the solar dehydrator, the following Mexican Official Standards related to the development of the project were considered - NOM-OO1-SEDE-2012, NOM-086-SSA1-1994, Goods and services.

Food and non-alcoholic beverages with modifications in their composition; nutritional specifications and NOM-044-FITO-1995, Establishing phytosanitary requirements and specifications for the importation of nuts, processed and dehydrated vegetable products and by-products.

For the construction of the dehydrator we used low-cost raw materials of the best quality whose components are for the casing, mechanics, control and power electronics, design and computer modeling software, electronic design, electronic control card -based on microcontrollers and graphic interface, which allows monitoring variables of interest to ensure optimal and correct dehydration.

The materials used are: Arduino Mega 250, 3.5" TFT display, DHT11 temperature, humidity and solar UV sensor Ml8511, relay relay module, solid state Ss, Channels 2nd, push botton 2 pins, power supply switching power supply voltage 12V 10A 120W, male DC connector, fan extractor turbine blower 12v - 24 Volts Pc Game, power adapter Jack 5.5mm X 2. 1mm, ceramic capacitor capacitor 22pf arduino pic, phenolic copper plate Pcb 10x10 cm, ferric chloride for electrical circuits 220ml, cable to connect or UTP cable, 12 gauge AWG cables 30m, connector strip Header, gray plastic mosquito netting 1.05 Mt Fiero 44960, diffuse green LED 5 mm, terminal block 2 pins, pitch 200, 5.08 mm, epoxy paint colares black, white and gray, potentiometer 1k 3 pins 15 mm, Pic 18F4550 microcontroller, cold silicone.

Results

Dehydration system

The high performance hybrid system that uses energy coming from the sun converting it into natural heat energy to perform the dehydration or natural drying process with temperature and humidity control, free of contaminating agents of different foods at low cost.

Figure 1 shows the side view of the dehydrator.

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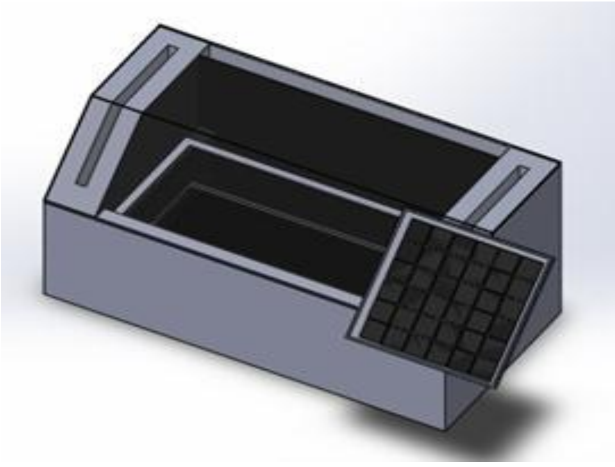

Figure 1 Side view of the dehydrator
Source: Own Elaboration

Figure 2 shows the inside view of the apparatus and Figure 3 shows the front of the hybrid system.

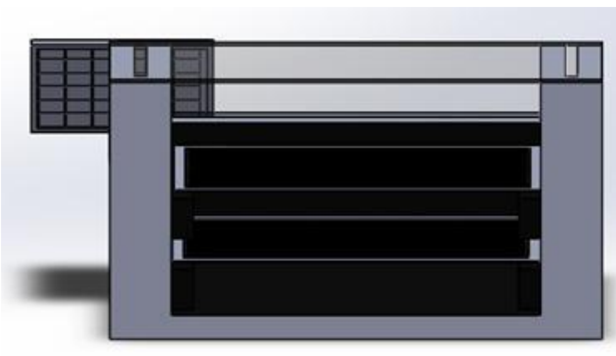

Figure 2 View of the inside of the dehydrator where the feed grids are located
Source: Own Elaboration

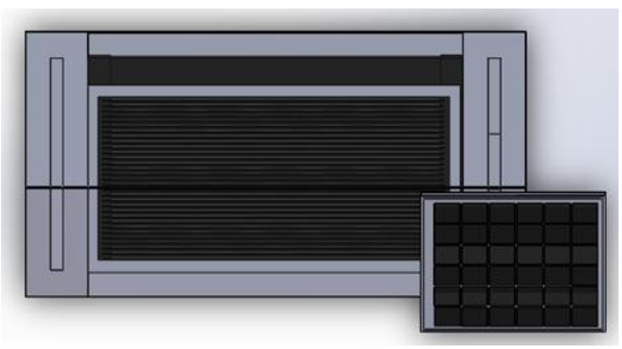

Figure 3 Front view of the dehydrator
Source: Own Elaboration

Monitoring system

The humidity and temperature monitoring system helps to make the drying process in the dehydrator more efficient, by recording and controlling inside the drying chamber and depending on the values of each of the variables, the fan is activated to maintain the temperature and humidity required for each food.

The connection circuit was elaborated using an arduino with free access software. Figure 4 shows the control variables monitoring circuit diagram.

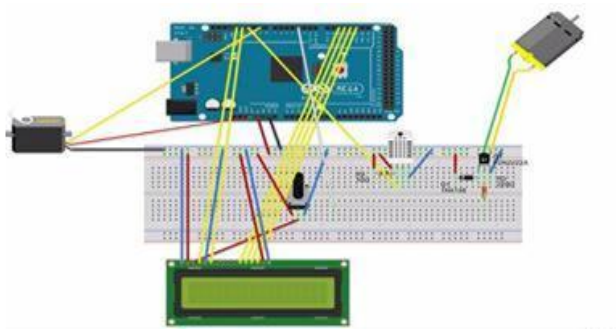

Figure 4 Diagram of the circuit developed for humidity and temperature monitoring
Source: Own Elaboration

Figure 5 shows an example of the dehydration process of duces.

Figure 5 Dehydration of jams and jellies
Source: Own Elaboration

The following foods have been dehydrated: apple, mango, cucumber, banana, broccoli, tomato, potato, and jelly candy and oatmeal. Table 1 shows the characterization of the products to be dehydrated.

Product	mini (g)	ms (g)	H initial (%)	H recommended (%)	T maximum permissible (°C)
Handle	15	5	67	15	65
Broccoli	5	2	60	6	65
Cucumber	3.5	1.5	57	8	75
Banana	5	1.8	64	15	70
Tomato	10	2	80	8	65
Papa	5	1.7	66	13	75
Note: Slices of approximately 0.5 cm thick.					

Table 1 Characterization of the products to be dehydrated
Source: Own Elaboration

Taking these data into account, the dehydrator characterization was carried out and the following data were obtained.

Characterization of the solar dehydrator					
Day 1: 03/05/2022					
Time	T. environment (ºC)	H. environment (%)	T. input to the chamber (ºC)	H. camera input (%)	Caudal del colector (m3/s)
11:00	24	27	38	13	4.19
12:00	25	25	39	58	5.12
13:00	27	31	43	65	5.6
14:00	25	45	42	77	5.89
15:00	21	60	36	95	5.89
16:00	20	69	35	94	4.65
Prom	23.67	42.83	38.83	67	5.22

Table 2 Process characterization of the prototype dehydrator day 1
Source: Own Elaboration

Duration of the test was 5 hours from 12:00 to 16:00 hours.

Solar radiation 5.15 kWh/m² in Tulancingo de Bravo, Hidalgo, Mexico.

With an initial sample weight of 43.5 g and a final sample weight of 14g.

With a Yield of 32.18%, a Drying Ratio of 30.7 g/hour, and a Drying Rate of 30.7 g/hour. Several tests were carried out on different days and at different times, Table 3 shows the results of the characterization of the dehydration process of different products.

Food dehydration process					
Product	mini (g)	ms (g)	H. initial (%)	H. recommend (%)	T. maximum permissible (ºC)
Handle	35	20	43	12 - 15	65
Broccoli	2	1.5	25	6	65
Cucumber	5	2	60	8	75
Banana	5	2	60	15	70
Tomato	10	2	80	8	65
Potato	10	5	50	13	75
Approximately 0.5 cm thick slices					

Table 3 Result of the food dehydration process
Source: Own Elaboration

Characterization of the solar dehydrator					
Day 2: 04/05/2022					
Time	T environment (ºC)	H environment (%)	T entrance to the chamber (ºC)	H in drying chamber (%)	Collector flow rate (m³/s)
10:00	25	26	38	47	3.87
11:00	25	25	40	40	4.18
12:00	25	31	42	46	5.12
13:00	25	45	39	77	5.59
14:00	21	60	50	55	5.89
15:00	20	69	36	53	5.89
16:00	20	70	45	52	5.89
Prom	23	46.57	41.43	52.86	5.20

Table 4 Process characterization of the day 2 solar dehydrator prototype
Source: Own Elaboration

The duration of the test was 6 hours from 10:00 am to 4:00 pm.

Solar radiation 5.2 kW/m². Tulancingo de Bravo, Hidalgo, Mexico.

Initial sample weight 67g, final weight 32.5g.

Yield 48.51%.

Drying rate 61,583 g/hour.

Figure 5, below, shows a sample of the result of dehydration of fruits and vegetables.

Figure 5 Example of dehydrated vegetables and fruits day 2 in a time of 6 hours
Source: Own Elaboration

Direct sunlight should be avoided as it bleaches the color and reduces the level of vitamins A and C. Drying temperature should be controlled to avoid overheating and deterioration (Espinoza, 2016).

Air circulation around the product to be dehydrated is very important, since it evacuates the moisture already extracted, maintaining a dry environment, which accelerates dehydration. For the case study, forced circulation was used because a fan was used as an electrical means to force air movement; this system is suitable for large and complex systems; a photovoltaic panel was used as external energy supply in addition to the energy coming from the sun.

The drying performance of the dehydrator with a sample of 110.5 g was 40% and an average drying rate of 51.14 g/h, easily accessible, making it an innovative system that contributes to the social and economic development of highly marginalized municipalities in the state of Hidalgo, the country and abroad in vulnerable situations.

Conclusions

The indirect solar dehydration system with insulating materials, concentrators and low-cost heat transporters controlling the temperature and humidity for fruits and vegetables that are found in most of the municipalities and localities in isolated areas of precarious economic conditions, the values obtained throughout the study have shown that solar radiation is more than enough to perform an adequate dehydration process for drying the foods described above without affecting their nutrients, even when the average temperature is at 20°C, drying of fruits and vegetables is obtained.

The solar dehydrator achieves a 35.74% temperature increase over a conventional dehydrator, confirming that this dehydrator gives the dehydration results.

Based on the results of the tests carried out, it is possible to contribute both to access to food for the vulnerable population and, if accompanied by greenhouse production strategies, to increase the intake of seasonal fruits and vegetables and to strengthen the nutritional status of families.

These alternatives add to the care of the environment with products from the region, considering the seasonal climates, the productive vocation of the place, making it possible to program and then dehydrate them.

Finally, promote the recovery of sowing-cropping-harvesting practices that have been carried out in the localities over time, and incorporate them as training for family members and reactivate these cultural traditions in rural production, achieving comprehensive attention to the problem of food security and that the population itself has new ways to address it for their benefit.

References

AgriNova Science. (2009). Proceso de deshidratación de frutas. Recuperado el 2 de diciembre de 2022 de https://infoagro.com/frutas/deshidratacion_frutas.htm#:~:text=La%20deshidrataci%C3%B3n%20es%20una%20de,para%20que%20no%20se%20arruinen.

Arancibia Bulnes Camilo, Best y Brown Roberto. (2010). Energía del Sol, Revista Ciencia abril-junio 2010, Energías Alternativas, México. Recuperado el 9 de diciembre de 2022, de https://www.revistaciencia.amc.edu.mx/images/revista/61_2/PDF/EnergiaSol.pdf.

Banco de México. (2020). Informe Trimestral Enero-Marzo 2020, México. Recuperado el 27 de mayo 2022 de https://www.banxico.org.mx/publicaciones-y-prensa/informes-trimestrales/%7B23C2DCA8-4AD3-FBE0- B0BF4D30C8066B84%7D.pdf.

Banco de México. (2020.1). Informe Trimestral Abril-Junio 2020, México. Recuperado el 11 de diciembre de 2022 de https://www.banxico.org.mx/publicaciones-y-prensa/informes-trimestrales/%7BC881F572-772F-B4E2- 5CC4-2715D6C43CC5%7D.pdf.

Banco Mundial. (2020). Datos de la Población Total en América Latina 2020. Recuperado el 10 de diciembre de 2022 de https://datos.bancomundial.org/region/america-latina-y-el-caribe

Banco Mundial. (2022). Pobreza. Entendiendo la Pobreza, Panorama general. Recuperado el 1 de diciembre de 2022 de https://www.bancomundial.org/es/topic/poverty/overview.

Blanco Cano Lucía, Valldecabres Sanmartín Laura. (2016). Guía para el desarrollo de proyectos de secado solar en comunidades rurales. Energía Sin Fronteras y la Universidad de Navarra Tecnun. Recuperado el 7 de diciembre de 2022 de https://energiasinfronteras.org/wp-content/uploads/2020/03/GuiaSecadoV3.pdf.

Bravo Cadena Román. (2012). Sistema de colector plano para deshidratación solar en el valle de la muerte. Tesis del Centro de Investigación en Materiales Avanzados, S.C. (CIMAV). Recuperado el 5 de diciembre de 2022, de https://cimav.repositorioinstitucional.mx/jspui/bitstream/1004/784/1/Rom%C3%A1n%20Bravo%20Cadena%20MER.pdf.

Buitrago Huertas Carlos Armando (2014). Estudio preliminar para deshidratación solar de mango (Mangifera Indica L. var. Común) en Colombia. Universidad Nacional Abierta y a Distancia – UNAD. Bogotá Colombia. Recuperado el 2 de diciembre de 2022 de https://repository.unad.edu.co/bitstream/handle/10596/3488/1075625400.pdf?sequence=1&isAllowed=y.

Carbonell Marcos. (2022). La historia de la energía solar fotovoltaica está marcada por el desarrollo tecnológico de una forma lenta pero segura. HogarSense. Recuperado el 9 de diciembre de 2022 de https://www.hogarsense.es/energia-solar/historia-energia-solar

CEPAL. (2020). Contracción de la actividad económica de la región se profundiza a causa de la pandemia: caerá -9,1% en 2020. Recuperado el 9 de diciembre de 2022 de https://www.cepal.org/es/comunicados/contraccion-la-actividad-economica-la-region-se-profundiza-causa- la-pandemia-caera-91.

CEPAL. (2020.1). América Latina y El Caribe ante la pandemia COVID-19. Efectos económicos y sociales**.** Recuperado el 11 de diciembre de 2022 de https://repositorio.cepal.org/bitstream/handle/11362/45337/4/S2000264_es.pdf Consulta 26082020.

CEPAL. (2020.2). Pandemia del COVID-19 llevará a la mayor contracción de la actividad económica en la historia de la región: caerá -5,3% en 2020. Recuperado el 11 de diciembre de 2022 de https://www.cepal.org/es/comunicados/pandemia-covid-19-llevara-la-mayor-contraccion-la-actividad- economica-la-historia-la.

CEPAL-OPS. (2020). Informe CEPAL-OPS Salud y economía. Una convergencia necesaria para enfrentar el COVID-19 y retomar la senda hacia el desarrollo sostenible en América Latina y El Caribe. Recuperado el 11 de diciembre de 2022 de http://docs.bvsalud.org/biblioref/2020/07/1116086/opshsscovid-19200027_spa.pdf.

CEPAL. (2019). América Latina y El Caribe: Estimaciones y proyecciones de población. Recuperado el 11 de diciembre de 2022 de https://www.cepal.org/es/temas/proyecciones-demograficas/estimaciones-proyecciones-poblacion-total- urbana-rural-economicamente-activa.

CEUPE Magazine. (s/f). La deshidratación de los alimentos. Recuperado el 1 de diciembre de 2022 de https://www.ceupe.com/blog/la-deshidratacion-de-los-alimentos.html.

CONABIO. (2022). Índice de capital natural. Recuperado el 15 de diciembre de 2022 de https://www.biodiversidad.gob.mx/pais/indice_capnat

CONEVAL. (2021). Evolución de las líneas de pobreza por ingresos (canasta alimentaria). Recuperado el 14 de diciembre de 2022 de https://www.coneval.org.mx/Medicion/MP/Paginas/Lineas-de-bienestar-y-canasta-basica.aspx.

CONEVAL. (2020). Medición de la pobreza. Recuperado el 14 de diciembre de 2022 de https://www.coneval.org.mx/Medicion/MP/Paginas/Pobreza_2020.aspx.

Cortés Ramos José Carlos (2017). Tecnologías apropiadas para la transformación Agropecuarias. Deshidratadores solares. Tecnologías para el Desarrollo Humano. Recuperado el 3 de diciembre de 2022 de https://esf-cat.org/wp-content/uploads/2017/06/Manual-Tecnologia-para-la-Transformacion-Agropecuaria-Deshidratador-Solar-ESF-1.pdf./ https://docplayer.es/63766351-Serie-tecnologia-para-el-desarrollo-humano-tecnologias-apropiadas-para-la-transformacion-agropecuria-deshidratadores-solares.html.

Cutnei Guillaux Diego; Mamani Javier; Rocha Luis Alberto; Rojas Lizbeth; Saavedra Pedro. (2011). Deshidratador solar de alimentos**.** Ucebol. Universidad Cristiana de Bolivia. Recuperado el 4 de diciembre de 2022 de http://www.revistasbolivianas.ciencia.bo/pdf/ucs/n5/n5_a07.pdf./ http://www.revistasbolivianas.ciencia.bo/scielo.php?pid=S8888-88882011000300007&script=sci_arttext#:~:text=Los%20alimentos%20que%20son%20deshidratados,el%20secado%20o%20el%20almacenaje.

De Michelis Antonio, Ohaco Elizabeth (s/f). Deshidratación y desecado de frutas, hortalizas y hongos. Procedimientos hogareños y comerciales de pequeña escala, INTA Ediciones, Comunicación Téncia Nº 84 Área Desarrollo Rural ISSN 1667-4014, Argentina. Recuperado el 1 de diciembre de 2022 de https://inta.gob.ar/sites/default/files/script-tmp-inta_cartilla_secado.pdf.

El Economista. (2021). ¿Cuántos pobres hay en México? Datos del Coneval de 2020.México. Recuperado el 1 de diciembre de 2022 de https://www.eleconomista.com.mx/empresas/Cuantos-pobres-hay-en-Mexico-Datos-del-Coneval-de-2020-20210813-0069.html.

Espinoza S. Jaime. (2016). Innovación en el deshidratado solar. Ingeniare. Revista Chilena de Ingeniería, Vol. 24. Número Especial, 2016, pp. 72-80. Recuperado el 9 diciembre de 2022 de https://www.scielo.cl/pdf/ingeniare/v24nEspecial/art10.pdf.

FAO. (2020). Documento interino de cuestiones sobre el Impacto del COVID-19 en la seguridad alimentaria y la nutrición (SAN) preparado por el Grupo del Alto Nivel de Expertos en Seguridad Alimentaria y Nutrición (GANESAN). Versión 1. Recuperado el 13 de diciembre 2022 de http://www.fao.org/fileadmin/templates/cfs/Docs1920/HLPE_2020/New_HLPE_paper_COVID_ES.pdf Consulta 26082020.

FAO. (2020.1). Sistemas alimentarios y Covid-19 en América Latina y El Caribe: Cómo disminuir las pérdidas y desperdicios de alimentos. Recuperado el 13 de diciembre de 2022 de http://www.fao.org/3/ca9728es/CA9728ES.pdf.

FAO. (2020.2). La nueva enfermedad coronavirus (COVID-19) y los Sistemas Alimentarios en América Latina y el Caribe. Recuperado el 13 der diciembre de 2022 de http://www.fao.org/americas/publicaciones-audio-video/covid19-y- sistemas-alimentarios/es/

FAO-UN-OPS-UNICEF. (2021). Panorama regional de la seguridad alimentaria y nutricional. Recuperado el 17 de diciembre de 2022 de https://mexico.un.org/es/165342-panorama-regional-de-la-seguridad-alimentaria-y-nutricional-2021

Fondo Monetario Internacional. (2020). Perspectivas de la economía mundial: El Gran Confinamiento. Recuperado el 26 de noviembre de 2022 de https://www.imf.org/es/Publications/WEO/Issues/2020/04/14/weo-april-2020.

Global Solar Atlas. (2021). Mapa de la radiación solar fotovoltaica en la República Mexicana en línea. Recuperado el 5 de diciembre de 2022 de https://globalsolaratlas.info/map?c=20.146206,-98.780823,8.

González-Rosas Angelina, Ortega-Marín Blanca Andrea, González-Islas Juan Carlos. (2021). Estudio de la factibilidad del desarrollo de sistemas de biodigestión para su aprovechamiento en zonas rurales. Innovación y multidisciplinariedad en la práctica docente: Contribución significativa al aprendizaje. ISBN: 978- 607- 8705 -52- 8, pp. 305-316, Ediciones ILCSA S.A. DE C.V. Tijuana B.C. México. Recuperado el 6 de diciembre de 2022 de https://investigadores.unison.mx/ws/portalfiles/portal/42751502/banda_diagnostico_2021.pdf.

Hernández Rodríguez José, Quinto Diez Pedro, Barbosa Pool Glicerio R, Aguilar Aguilar Jorge O. (2017). Secado solar de frutas y verduras en Quintana Roo, México. Revista Iberoamericana de Tecnología Postcosecha, Vol.18, Núm. 1, 2017, pp. 1-8. ISSN: 1665-0204. Hermosillo, México. Recuperado el 5 de diciembre de 2022 de https://www.redalyc.org/pdf/813/81351597001.pdf.

INSP, FAO, OPS-OMS y UNICEF. (2020). Prevención de mala nutrición en niñas, niños y adolescentes ante la pandemia del COVID 19. Recomendaciones dirigidas a tomadores de decisiones. Recuperado el 15 de diciembre de 2022 de https://www.unicef.org/mexico/comunicados-prensa/urgen-medidas-para-evitar-mala-nutrición-en-méxico-por-covid-19.

Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM). (2022). Generalidades del sol. Ministerio de Ambiente y Desarrollo Sostenible, Bogotá, Colombia. Recuperado el 3 de diciembre de 2022 de http://www.ideam.gov.co/web/tiempo-y-clima/generalidades-del-sol.

Kajekui Kuja Lucas. (2017). Secador solar, deshidratador solar, baño ecológico seco. Asistencia Técnica para la instalación de tecnologías apropiadas. Ingeniería Sin Fronteras. Recuperado el 3 de diciembre de 2022 de https://esf-cat.org/wp-content/uploads/2017/06/Informe-asistencia-instalacion-tecnologias-apropiadas-2017.pdf.

Lavagne d'Ortigue Olivier, Whiteman Adrian, Elsayed Samah (2015). Renewable Energy Capacity Statistics 2015, International Renewable Energy Agency IRENA. Recuperado el 6 de diciembre de 2022 de: https://www.irena.org/?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=604 / http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=604.

Marín B. Eduardo, Lemus M Roberto, Flores M. Verónica, Vega G. Antonio. (2006). La rehidratación de alimentos deshidratados. Departamento de Química, Departamento de Ingeniería en Alimentos, Universidad de La Serena, La Serena, Chile. Rev Chil Nutr Vol. 33, Nº3, Diciembre 2006. Revista chilena de nutrición, On-line versión ISSN 0717-7518, http://dx.doi.org/10.4067/S0717-75182006000500009. Recuperado el 28 de noviembre 2022 de https://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0717-75182006000500009&lng=en&nrm=iso&tlng=en.

NU. (2022). ¿Qué pasará cuando la población mundial de pronto alcance los 8000 millones?. Recuperado el 15 de diciembre del 2022 de https://www.un.org/es/crónica-onu/global-population-will-soon-reach-8-billion—then-what

NU. (2020). El número de pobres en la América Latina puede crecer en 35 millones por el coronavirus COVID-19. Recuperado el 11 de diciembre del 2022 de https://news.un.org/es/story/2020/03/1471522.

NU. (2020.1). América Latina y El Caribe precisan salvaguardar con urgencia la biodiversidad de sus bosques. Recuperado el 11de diciembre del 2022 de https://news.un.org/es/story/2020/05/1474922 Consulta 26082020.

NU. (s/f). Objetivo 2 Poner fin al hambre. Hambre cero. Recuperado el 15 de diciembre del 2022 de https://www.un.org/sustainabledevelopment/es/hunger/

OMS. (2020). Actualización de la estrategia frente a la COVID-19. Recuperado el 26 de noviembre del 2022 de https://www.who.int/docs/default-source/coronaviruse/covid-strategy-update-14april2020_es.pdf?sfvrsn=86c0929d_10.

Pinzón Lourdes. (2016). El secado como método de preservación de alimentos. Ingeniería y Ambiente. Recuperado el 30 de noviembre de 2022 de https://lvpinzon.wordpress.com/2016/11/05/el-secado-como-metodo-de-preservacion-de-alimentos/.

PNUD-PNUMA-CEPAL & UNCTAD. (2010). América Latina y el Caribe: una superpotencia en biodiversidad. Programa de las Naciones Unidas para el Desarrollo. Recuperado el 13 de diciembre de 2022 de:https://www.undp.org/content/dam/undp/library/Environment%20and %20Energy/biodiversity/Latin-America-and-the-Caribbean---A- Biodiversity-Superpower--Policy_Brief_SPANISH.pdf.

Romero Crespo Janeth Fernanda, Flores Peralta Jonnathan Ismael. (2019). Estudio e implementación de un sistema de micro generación solar fotovoltaico para autoconsumo (caso de estudio considerando la regulación Nro. ARCONEL003/18). Universidad de Cuenca. Facultad de Ingeniería. Carrera de Ingeniería Eléctrica. Recuperado el 15 de diciembre del 2022 de: http://dspace.ucuenca.edu.ec/bitstream/123456789/33564/1/Trabajo%20de%20Titulaci%C3%B3n.pdf.

SEDECO. (2021). Precios de la canasta básica en México 2021. Recuperado el 11 de diciembre del 2022 de https://www.sedeco.cdmx.gob.mx/storage/app/media/Canasta%20Basica/2021/precios-de-la-canasta-basica-2021.pdf.

Secretaria del Bienestar (SB). (2021).Hidalgo informes anuales sobre la situación de pobreza y rezago social. Recuperado el 28 de octubre del 2022 de https://www.gob.mx/busqueda?utf8=%E2%9C%93#gsc.tab=0&gsc.q=Hidalgo%20informes%20anuales%20sobre%20la%20situaci%C3%B3n%20de%20pobreza%20y%20rezago%20social&gsc.sort=.

Secretaría de Gobernación. (2021). Constitución Política de los Estados Unidos Mexicanos. Diario Oficial de la Federación 28 de mayo 2021. Recuperado el 14 de diciembre de 2022 de https://www.diputados.gob.mx/LeyesBiblio/ref/cpeum.htm.

SEMARNAT. (2022). Algunos datos que debemos saber sobre la desertificación y la sequía. Recuperado el 8 de diciembre del 2022 de: https://www.gob.mx/siap/articulos/algunos-datos-que-debemos-conocer-sobre-la-desertificacion-y-sequia?idiom=es.

SEMARNAT. (2018). Informe de la Situación del Medio Ambiente en México. Compendio de Estadísticas Ambientales, Indicadores Clave de Desempeño Ambiental y Crecimiento Verde. Recuperado el 13 de diciembre del 2022 de https://apps1.semarnat.gob.mx:8443/dgeia/informe18/index.html.

SEMARNAT. (2016). Situación del Medio Ambiente en México 2015. Recuperado el 13 de diciembre del 2022 de https://apps1.semarnat.gob.mx:8443/dgeia/informe15/tema/pdf/Informe15_completo.pdf.

SEMARNAT. (2012). Informe de la Situación del Medio Ambiente en México. Compendio de Estadísticas Ambientales, Indicadores Clave y de Desempeño Ambiental. Edición 2012. Recuperado el 13 de diciembre del 2022 de https://apps1.semarnat.gob.mx:8443/dgeia/informe_12/pdf/Informe_2012.pdf.

Universidad Internacional de Valencia (VIU). (2021). Analizamos el Sol como fuente de energía. Recuperado el 4 de diciembre del 2022 de https://www.universidadviu.com/es/actualidad/nuestros-expertos/analizamos-el-sol-como-fuente-de-energia.

Villén Martha. (2012). Deshidratación, la forma más antigua y sana de conservar los alimentos. Conosi Vive la cocina natural. Recuperado el 7 de diciembre del 2022 de https://www.conasi.eu/blog/consejos-de-salud/deshidratacion-la-forma-mas-antigua-y-sana-de-conservar-los-alimentos/#:~:text=Conservaci%C3%B3n%20durante%20meses%20o%20a%C3%B1os,sea%20la%20temperatura%20de%20deshidratado.