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Content

Article **Journal of Innovative Engineering**
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Evaluation of coffee drying in a zenith-type solar dryer in cañada region, Oaxaca

Evaluación del secado de café en un secador solar tipo cenital en la región cañada, Oaxaca

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Abstract

A zenith-type solar dryer was evaluated during two drying cycles: one under environmental conditions of rainy and cloudy days; and the other, under one of sunny and clear days. The air temperature and humidity were compared inside and outside the solar dryer by recording these parameters every 20 minutes. The results indicated that solar dryer increases temperature on average by 6.0 °C for wet condition and 4.3 °C for dry condition. The maximum temperature difference between interior and exterior of dryer was 17.7 °C in humid condition and 18.0 °C in dry condition, recording temperatures of up to 48.5 °C in the humid condition and 47.4 °C in dry condition. In relation to humidity of air inside dryer, it decreases on average up to 7.9% compared to outside. According to grain drying curves, in solar dryer, 7 and 10 days were required to reach a grain humidity between 10-12%, under dry and humid conditions, respectively. Therefore, solar dryer generated less aggressive drying and with lower humidity fluctuations in grain compared to traditional drying, which could increase quality of grain produced in Mazatec region, through use of this technology.

Drying, Temperature, Air humidity, Grain moisture, Drying rate

Resumen

Se evaluó un secador solar tipo cenital, durante dos ciclos de secado: uno bajo condición ambiental de días lluviosos y nublados; y el otro, bajo una de días soleados y despejados. Se comparó la temperatura y humedad del aire, dentro y fuera del secador solar mediante el registro de estos parámetros cada 20 minutos. Los resultados indicaron que el secador solar incrementa en promedio la temperatura en 6.0 °C para la condición húmeda y de 4.3°C para la seca. La diferencia máxima de temperatura entre el interior y el exterior del secador fue de 17.7 °C en la condición humedad y de 18.0 °C en la condición seca, registrándose temperaturas de hasta 48.5 °C en la condición húmeda y de 47.4 °C en el ciclo seco. En relación con la humedad del aire al interior del secador, esta disminuye en promedio hasta 7.9 % en comparación con el exterior. De acuerdo a las curvas de secado del grano, en el secador solar se requirió de 7 y 10 días para alcanzar una humedad del grano entre 10-12%, bajo la condición seca y húmeda, respectivamente. Por lo tanto, el secador solar generó un secado menos agresivo y con menores fluctuaciones de humedad en el grano en comparación con el secado tradicional, lo cual podría incrementar la calidad del grano que se produce en la región mazateca, mediante el uso de esta tecnología.

Secado, Temperatura, Humedad del aire, Humedad del grano, Tasa de secado

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Introduction

In Mexico, coffee is one of the most extensive and economically important crops, as it is among the five most important export products. Production areas are concentrated in 12 states, mainly in small production units in mountainous areas, where the state of Oaxaca accounts for 17.3% of national production (SIAP, 2023).

The industrial process for the transformation of cherry coffee into parchment is called processing and comprises the stages of: classification, washing, pulping, removal of mucilage and drying. Of these stages, drying is fundamental, as its purpose is to reduce the moisture content of the washed coffee (48-56% on a wet basis) to a range between 10% and 12% moisture (Ortega, 2010; Ventura-Cruz *et al*., 2019).

One of the alternatives for drying coffee is to use solar energy, through the use of solar dryers (Hii *et al*., 2019). Currently, there is a wide variety of designs and sizes of solar dryers that can be used for drying various agricultural foodstuffs. They are low capital and low maintenance cost installations, easy to construct and any material available in the construction area can be used, with designs tending towards simplicity, as there is no significant difference in the results obtained with more primitive designs compared to more sophisticated ones (Sharma *et al*., 2018).

The operation of solar dryers is based on the greenhouse principle, where solar energy is captured to raise the temperature of the internal fluid (air). They are installations that require little capital and low maintenance costs, are easy to construct and any material available in the construction area can be used, with designs tending towards simplicity, as there is no significant difference in the results obtained with more primitive designs compared to more sophisticated ones. The performance of a solar dryer depends on climatic conditions such as ambient temperature and solar radiation (Jambhulkar et al, 2017; Sandali et al., 2019).

Solar energy collection systems are classified into two main groups: those with a collection device independent of the drying chamber and those that use the drying chamber itself as the solar radiation collection area.

Furthermore, depending on the way the fluid is moved in the solar dryer, they can be classified as greenhouse-type solar dryers with natural convection or passive mode and with forced convection or active mode (Nidhi and Verma, 2016; Kumar et al, 2016).

On the other hand, it should be noted that solar dryers perform the conversion of solar energy to useful thermal energy for the drying process, thus, the thermal performance is a reliable indicator to study the merits of the system and can be quantified by energy analysis (Quintanar and Garcia, 2023). To characterise the performance of a solar dryer, one of the most important parameters is the temperature generated inside, given its importance for the development of the parchment coffee drying process (Parra-Coronado *et al*., 2008). Temperatures inside the dryer should not reach temperatures above 45 °C, while in traditional drying they should not dry at more than 40 °C (Puerta, 2008).

Also, the temperature must be kept at a constant level during certain periods of drying, in addition, the temperature affects the relative humidity, since the higher the temperature, the higher the water vapour saturation pressure increases, therefore, the greater the margin of water uptake to the grain. (Guevara-Sánchez *et al*., 2019). Another important parameter that characterises the behaviour of the dryer is the ratio between the internal and external relative humidity of the dryer. The internal relative humidity has a behaviour that depends on the stage of the drying process. In the first stages of the drying process, the internal relative humidity increases, due to the fact that the product releases the greatest amount of water vapour (Chaverri and Moya, 2008).

Given the difficulties encountered in drying coffee in the Cañada region in the state of Oaxaca by Mazatec producers, who use the traditional drying process, where the wet beans are exposed directly to the sun's rays on concrete slabs (asoliaderos) or mats. However, this method is not recommended due to the many factors that threaten the quality of the product, such as sudden rains, dust, rubbish and animals (Duque et al., 2023); they must also store or cover the coffee at night to prevent it from re-absorbing the ambient humidity, making it impossible to dry a larger volume of coffee.

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In this study, a small-scale, low-cost, zenithal-type solar dryer was built and evaluated for the producer. The use of this structure is a good alternative to provide communities with a drying solution, as it allows them to increase and optimise the production obtained, reducing construction costs by using local materials such as wood and bamboo, among others.

Objective

To evaluate the drying of coffee beans in a zenithal solar dryer and in the open air on sieves, under two different environmental conditions: cloudy and rainy days and sunny and clear days in the region of La Cañada, Oaxaca.

Materials and method

The work was carried out in the Cañada region of the state of Oaxaca, in the municipality of Santa Cruz Acatepec belonging to the district of Huautla de Jiménez, located at the geographical coordinates 18° 9' 44" N and 96° 52' 36" W, at an altitude of 1,617 masl and an average annual rainfall of 2300. 8 mm, concentrated in the months of June to September, however, during the harvest season (January to April) there is an average monthly rainfall of 38.6 mm and an average of 12.1 cloudy days per month during this period (CONAGUA, 2022).

The zenith type solar dryer was built with a wooden base and lined with 720 gauge greenhouse plastic with UV ray treatment, it has an area of 30 m2 (7.5 m x 4 m), with three drying levels (12 screens per level) with a total of 36 screens of 1 m2 each.

A drying cycle was evaluated under an environmental condition of cloudy and rainy days, corresponding to the period from 24 February to 06 March 2023. The data collection of environmental conditions (temperature and relative humidity) inside and outside the dryer was carried out with a Datalogger equipment model RC-4HC of the Elitech brand, programmed to collect data every 20 min. The equipment was installed at a height of 1.80 m, both inside and outside the dryer.

To determine the moisture loss of the coffee beans, a Draminski TwistGrain pro bean and seed moisture meter was used, recording the percentage of moisture in the beans three times a day (morning, afternoon and evening), until a moisture content between 10 and 12% was reached (optimum moisture for storage). Three sieves were randomly monitored inside the solar dryer, with a coffee layer thickness of less than 3 cm, as well as the traditional drying in full sun on palm mats, in order to compare both drying methods and to analyse the drying time.

Results and discussion

Based on the data recorded by the Dataloggers, the average maximum, minimum and average temperatures and humidity of the air were calculated under cloudy and rainy environmental conditions (Table 1), resulting in a difference between the outside and inside of the solar dryer of 6. 0°C with respect to the average temperature, of 13.6°C when the maximum temperatures are reached, mainly at midday, highlighting the maximum temperature of 48.5°C reached inside the dryer when the outside temperature was 35.1°C, and of only 0.8°C when the minimum temperatures are reached, especially at night.

Variable		Wet condition		Dif	Dry condition		Dif
		Dryer	Outside		Dryer	Outside	
T (°C)	Prom	29.1	23.1	6.0	26.5	22.2	4.3
	Máx	41.6	28.0	13.6	46.3	33.6	12.7
	Mín	19.3	18.5	0.8	14.7	15	0.3
HR (%)	Prom	45.2	50.9	5.7	56.3	64.2	7.9
	Máx	64.5	65.7	1.2	80.2	84.6	4.4
	Mín	25.6	38.6	13.0	24.9	34.2	9.3

Table 1 Average air temperature and humidity inside and outside a solar dryer under cloudy and rainy day conditions in the canyon region, Oaxaca

These results are congruent with those reported by Quintanar and García (2023), who mention that the temperature inside the dryer is always higher than the ambient temperature. However, the temperature profile is not constant during the hours of the same day, nor during the days of the drying process (Figure 1). Therefore, the temperatures reached both inside and outside the dryer are lower than 50°C, appropriate values for the drying process of the vast majority of agricultural products that require this process for their preservation. (Costales, 2010).

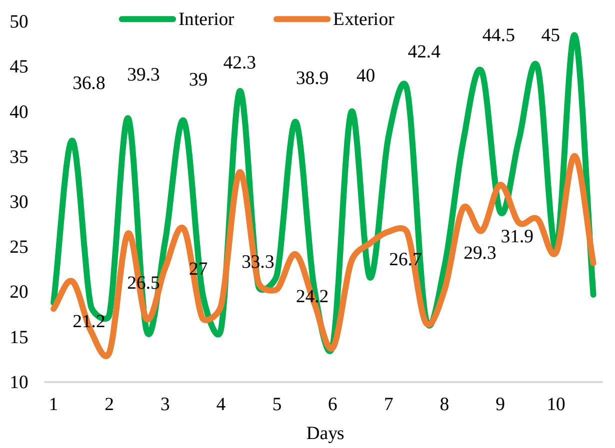

Figure 1 Temperature conditions inside and outside a solar coffee dryer

In relation to the temperature differences inside the dryer with respect to the ambient temperature, the average temperature calculated in the present study is lower than the 10°C difference between the temperatures inside the dryer and the environment reported by Dhurve *et al* (2017) and the 13.6°C difference reported by Menya and Komakech (2013), however, the difference of the maximum temperature reached is identical to that reported by these same authors for a greenhouse type dryer located in Uganda.

It is also similar to the temperature difference of 14.1°C reported by Almuhanna (2012) for a greenhouse solar dryer, and lower than the 29.9°C difference in temperature inside a solar dryer over ambient temperature reported by Sreekumar (2013).

On the other hand, the relative humidity of the air is a critical factor in controlling the drying rate; the lower the relative humidity, the higher the drying air absorption capacity. The relative humidity behaviour during the drying process under study, the relative humidity was always higher outside than inside the solar dryer (Figure 2).

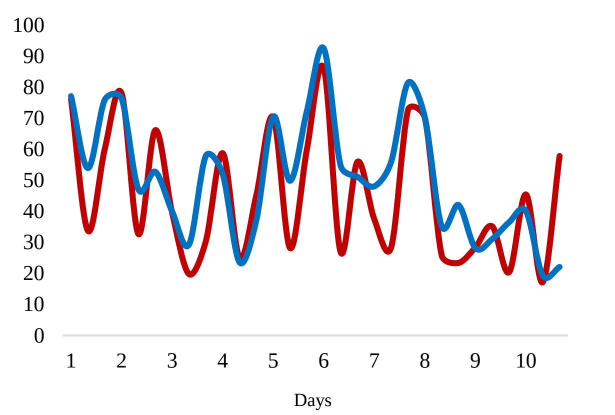

Figure 2 Relative humidity conditions inside and outside a solar coffee dryer

The average initial moisture content of the wet parchment coffee samples was 55%, but the moisture meter only works when the bean has 35% moisture in order to monitor moisture loss. In the first cycle under rainy conditions and high cloud cover, the optimum moisture content of 10-12% was reached in the beans in a period of 10.5 days in the solar dryer, compared to traditional drying, which reached its moisture content in only 8.5 days. The behaviour of moisture losses in the first four days is similar both indoors and outdoors; from the fifth day onwards, there was a difference in the drying rate between the grains exposed outdoors and indoors, being slower inside the solar dryer (Figure 3).

In the second drying cycle under dry conditions (sunny and clear days), even when temperatures higher than the ambient temperature were generated, grain drying was not accelerated, having a similar behaviour to the cycle under humid conditions, with similar moisture loss during the first three days both indoors and outdoors, after this point, the drying rate between the grains exposed outdoors and indoors is different, being slower inside the solar dryer (Figure 4).

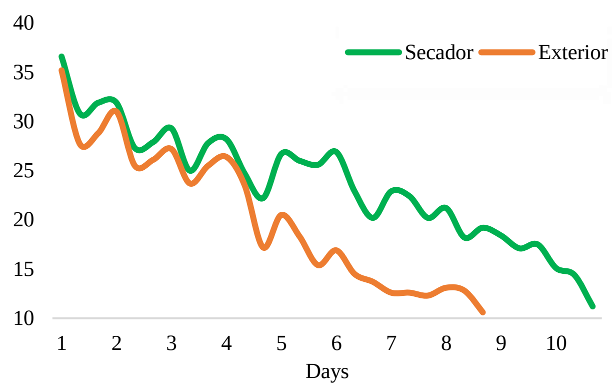

Figure 3 Drying curves of coffee beans inside and outside a solar dryer under an environmental condition of cloudy and rainy days

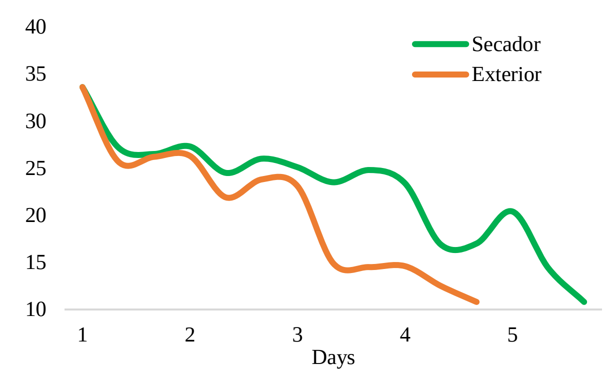

Figure 4 Coffee bean drying curves inside and outside a solar dryer under an environmental condition of sunny and clear days

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At the end of the drying process, the drying rate of the bean inside the dryer is slower, generating a less aggressive curve in the drying of the bean, therefore, the drying of the bean is more uniform, but extending the drying time by one day with respect to traditional drying in both drying cycles. The final moisture content of the grain obtained in both cases was appropriate for storage, according to the SCA protocol.

Conclusions

- The maximum temperature recorded inside the solar dryer was 48.5 °C in the wet condition and 47.4 °C in the dry cycle.
- The solar dryer increased the temperature on average by 6.0 °C for the wet condition and 4.3 °C for the dry condition.
- The maximum temperature difference between the inside and outside of the dryer was 17.7 °C in the wet condition and 18.0 °C in the dry condition.
- The time period required for drying the coffee beans in the solar dryer was 7 and 10 days to reach a moisture content between 10-12% in the dry and wet conditions, respectively.

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Article
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Sustainable housing with block masonry with vertical cells and hollow horizontal ducts

Vivienda sustentable con mampostería a base de blocks con celdas verticales y conductos horizontales huecas

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Abstract

Gradually by anthropogenic actions, the temperature is increasing throughout the planet, and the same human being has been affected, requiring more and more air conditioning mechanisms to maintain their comfort in the spaces they use, Therefore, this article shows a new system of construction of real estate with masonry blocks with vertical hollow cells and hollow horizontal ducts, which mitigate the heat transfer inside the buildings after 8 hours of exposure to sunlight, reducing the temperature by 20 ° C compared to the traditional system. Therefore, this new proposal contributes to the reduction of climate change by requiring less electrical energy for the comfort inside the real estate, besides, it is available to all the inhabitants of the planet because it is a block material that integrates masonry.

Climate change, Masonry with vertical cell block and hollow horizontal duct, Heat transfer

Resumen

Paulatinamente por acciones antropogénicas, se está incrementando la temperatura en todo el planeta, y el mismo ser humano ha estado afectándose, requiriendo cada vez más, mecanismos de aire acondicionado para mantener su confort en los espacios del que hace uso, por lo que el presente artículo muestra un nuevo sistema de construcción de bienes inmuebles con mampostería a base de blocks con celdas huecas verticales y conductos horizontales huecos, mismos que mitigan la transferencia de calor en el interior de los inmuebles después de 8 horas de exposición a los rayos del sol, reduciendo en un 20 °C de la temperatura referente al sistema tradicional. Por tanto, esta nueva propuesta abona en la reducción del cambio climático por requerir menos energía eléctrica para el confort en el interior de los bienes inmuebles, además, está al alcance de todos los habitantes del planeta por ser un material de block que integra a la mampostería.

Cambio climático, Mampostería con block de celda vertical y conducto horizontal huecos, Transferencia de calor

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Introduction

In recent years we have witnessed drastic changes in global temperatures due to anthropogenic activities. According to the Intergovernmental Panel on Climate Change, the increase of greenhouse gases in the atmosphere influenced the global mean or land surface within the range of 0.5 to 1.3 °C during the period 1951-2010 (IPCC, 2013). The increase in global temperature has affected many physical and biological systems, including human systems (IPCC, 2001a; Rosenzweig *et al*., 2007). In Mexico, temperatures of up to 40 °C are recorded, according to data from the National Water Commission of the National Meteorological Service. (CONAGUA, 2020), Figure 1.

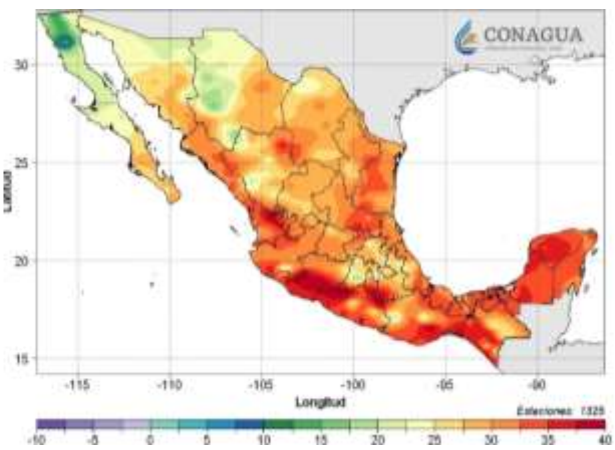

Figure 1 Average temperature in Mexico for the month March 2020, (CONAGUA, 2020)

High temperatures directly affect the condition and well-being of entire populations. Nowadays, industrial and commercial sectors, in order to reduce such temperatures inside buildings, offer the consumption of ventilation and cooling elements that contribute crucially to the greenhouse effect due to the energy used for their production, as well as the energy consumption for the operation of air-conditioning devices, thus causing a negative impact greater than the benefit (Bergeron and Strachan, 2010; de Munck *et al*, 2013; Hamilton *et al*., 2009; Ichinose, Shimodozono, & Hanaki, 1999; Klysik, 1996; Ohashi *et al*., 2007; Ramamurthy, Li, & Bou-Zeid, 2015; Sailor, 2011).

Based on statistics reported by the National Energy Balance, electricity consumption in the residential sector represents 23.3% of the total consumed in Mexico (de Planeación Energética y Tecnológico, 2009), with the highest demand when high temperatures occur, in which the user resorts to air conditioning to maintain comfortable conditions inside their real estate.

Particularly, in the State of Campeche, an average (dashed line) annual maximum temperature of 36.5 °C is observed. (CONAGUA, 2020), Figura 2.

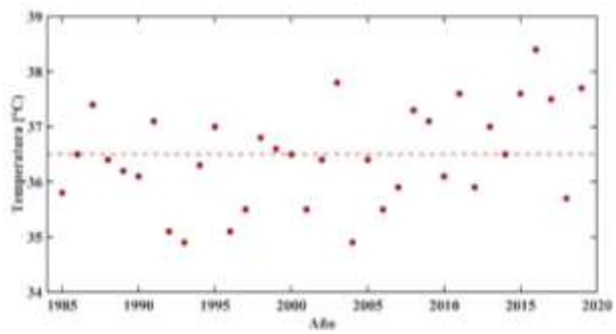

Figure 2 Average maximum temperature in the State of Campeche (dashed red line)

Background

Currently, houses in the State of Campeche are built with artificial masonry using conventional concrete blocks with two and three vertical cells, whose block dimensions including mortar joints in the already built wall (thickness x height x length) are 10x20x40 cm, 15x20x40 cm, and 20x20x40 cm (Rivera *et al*., 2008).

The 15x20x20x40 cm blocks, Figure 3, are the most commonly used in the region for structural purposes; the 10x20x40 cm blocks are mainly used for the construction of dividing walls or perimeter fences of houses; while the 20x20x40 cm blocks are generally used for architectural purposes (Rivera *et al*., 2008). Figure 3a shows the isometric of the piece of block with two and three cells whose size in built wall will be 15x20x40 cm, the dimensions and walls of the lower and upper faces are shown in Figure 3b and the lateral views in Figure 3c.

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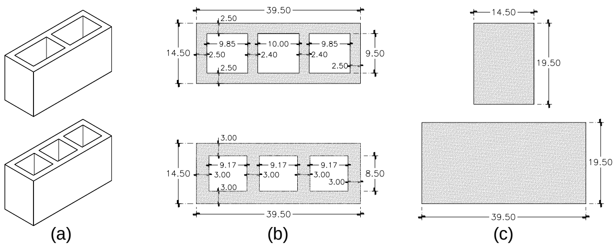

Figure 3 Masonry concrete block used in the State of Campeche, dimensions in cm, (a) isometric of two and three cells, (b) plan dimensions and (c) lateral dimensions

The efficiency of blocks with these characteristics has been observed, one of the advantages being the low weight of the blocks with vertical cells, but with a disadvantage: retaining the hot air resulting from exposure to solar radiation during the day, because there is no access to fresh air or air circulation, i.e. the air trapped inside the cells causes an increase in temperature inside the building that lasts until after the sun goes down.

That is, during the day, any building above the ground level inhabited by humans absorbs and stores a large proportion of heat in the walls and ceiling exposed to the sun's rays, and is released after sunset, which means that the temperature in the masonry remains and is transferred throughout the night to the interior spaces of the building (Grimmond and Oke, 1999b; Kotthaus and Grimmond, 2014a; Offerle, Grimmond and Fortuniak, 2005; Roberts, Oke, Grimmond and Voogt, 2006).

Traditionally, the masonry wall is formed with several pieces of block shown in Figure 3 with the arrangement indicated in Figure 4. The vertical voids are only serving the function of lightening the load-bearing walls without mitigating the heat transfer inside the rooms, moreover, being masonry it is confined with slab and load-bearing chains restricting the mobilisation of the flow of hot air or heat energy inside the wall.

Figure 4a shows the construction of the masonry wall with 3-hole blocks, and Figure 4b shows it with 2-hole blocks, both with the dimensions denoted in Figure 3, the dimensions of the constructed wall are 15x20x40 cm.

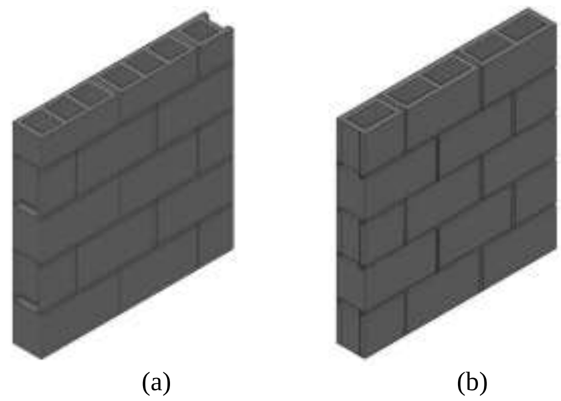

Figure 4 Concrete block masonry with (a) three and (b) two vertical cells

Therefore, to expel the heat energy inside the masonry, the proposal described in the methodology section is presented to mitigate the heat coming from the outside, reducing the consumption of electrical energy through the use of non-conventional block with special characteristics that form a network of internal horizontal and vertical ducts, favouring the mobilisation of the hot air trapped inside the cells, expelling it through the roof of any building with the arrangement shown in the methodology section.

The study area is located in Ciudad del Carmen, Campeche, Mexico. It is located southwest of the Yucatan peninsula, in the western part of the Isla del Carmen, it is situated at 18 ° 38′18 ″ N and 91 ° 50′07 ″ W in the Gulf of Mexico, between the east and the Laguna de Términos, Figure 5.

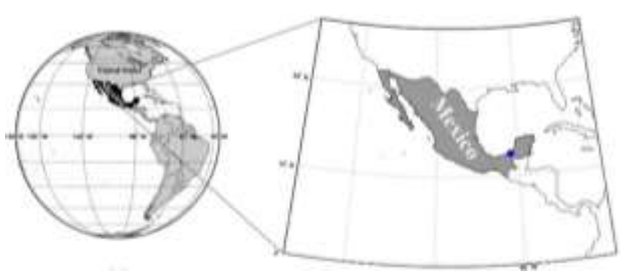

Figure 5 Location of the study area

According to information from the National Water Commission of the National Meteorological Service (CONAGUA, 2020) based on the FV3-GFS model of the National Oceanic and Atmospheric Administration (Kalnay *et al*., 1990; Kanamitsu 1989; Kanamitsu *et al.*, 1991) the temperatures registered in Ciudad del Carmen Campeche oscillate above 40 °C, Figure 6, being this magnitude the average, since in the month of May and June this temperature increases exceeding 43 °C and in winter below 30 °C.

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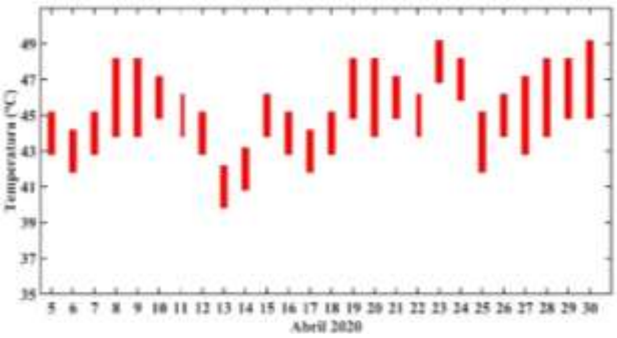


Figure 6 Climogram of Ciudad del Carmen for the month of April 2020

Figure 7 shows the temperatures taken in a house built with 15x20x40 cm hollow block, using a digital indoor and outdoor thermometer. The temperature record was taken on the second level of the building, measuring 5.61 x 4.86 m (27.2646 m2), supplied with light and brightness by two windows to the east of the room and 4 skylights in the roof. This room has a high exposure to the sun from the east, west and south of the room. During the morning, a gradual increase in temperature is observed in the masonry walls; this temperature remains in the walls until the end of the day when it slowly dissipates, causing a greater thermal sensation inside the house. Next, we can observe the graph mentioned above; it shows a dotted line with circles representing the temperatures measured at 10 a.m., a dotted line with small circles representing the temperatures measured at 12:00 p.m., while the dotted line with a + sign represents the temperatures measured at 15 hrs. Finally, the solid line with squares represents the temperatures measured at 19:00 hrs.

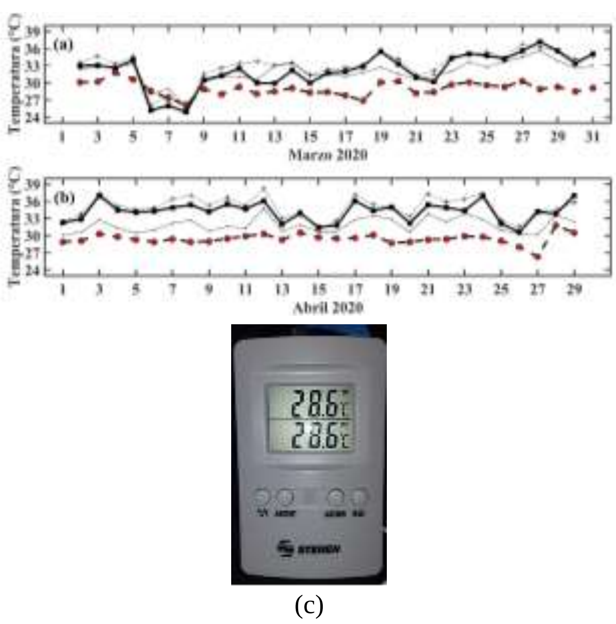


Figure 7 Graph of temperatures recorded in residential houses (a) March and (b) April and (c) equipment used for measurements

Excessive use of air conditioning due to increased heat transfer in buildings generates a high expenditure of electrical energy, therefore, greater ecological damage by increasing greenhouse gas emissions, due to the use of refrigerant gas and electricity consumption that emits more CO2 (carbon dioxide) into the atmosphere. Furthermore, it affects the lifestyle causing stress to the human being, leading to increased health risk (Rosenzweig *et al*., 2007).

Methodology

In order to materialise the proposal, this section will show the materials and arrangements to release the hot air, as well as the type of sensors that will be used to perform the temperature tests.

Figure 8 represents the design of the unconventional block, with two vertical openings and half reeds in the walls to form the ventilation network within the masonry wall. Figure 8a shows the isometric with the half reeds in the walls, Figure 8b the plan view and Figure 8c the profile of the block that will be used to allow the heat to flow through the presence of the half reeds which, when joined with other pieces, will naturally form a horizontal duct at each joint.

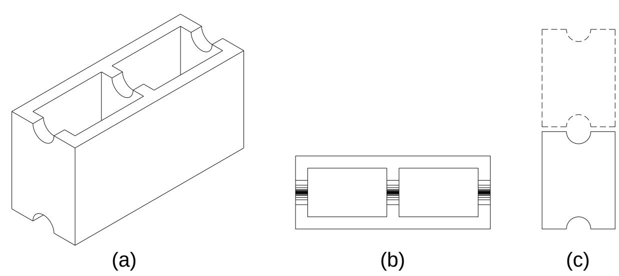


Figure 8. Masonry block, (a) two vertical holes, (b) half reeds for horizontal ducts and (c) forming a masonry wall

Once the masonry wall is built with the block described in Figure 8, we will proceed to record temperatures using a digital thermometer programmed with arduino, the temperature data is printed or displayed on the LCD screen as shown in Figure 9. (Figure 9); This LCD screen is connected to a temperature and humidity sensor (DHT11 sensor), this being one of the most suitable sensors for walls already built and in operation, having the great advantage of obtaining the temperature and humidity digitally filtering white noise. The pins of the PCB version of the DHT11 are: grounding (GND), data transmission (DATA) and power supply (VCC).

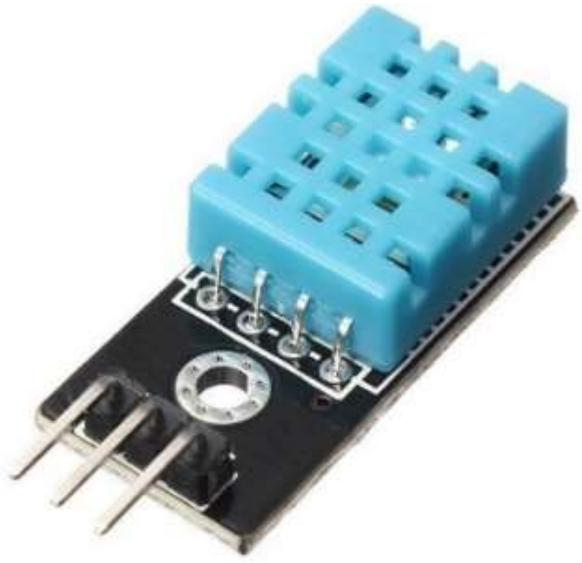
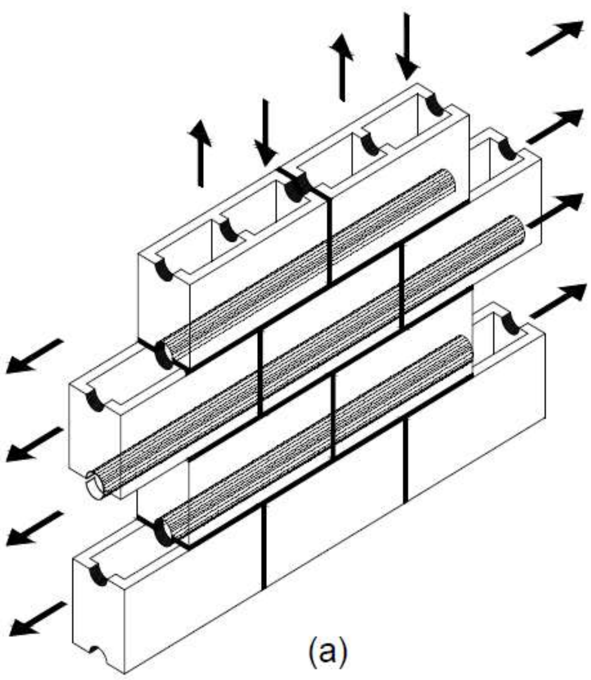


Figure 9 Digital Thermometer programmed with arduino

Results

The hollow block proposed in this work will form horizontal and vertical ducts inside the masonry wall, as shown in Figure 10, which shows a ventilation network by the design of the block inside the wall, thus allowing air flow in the horizontal and vertical direction, simultaneously releasing heat energy at the top of the roof by the constant exposure of the sun's rays.



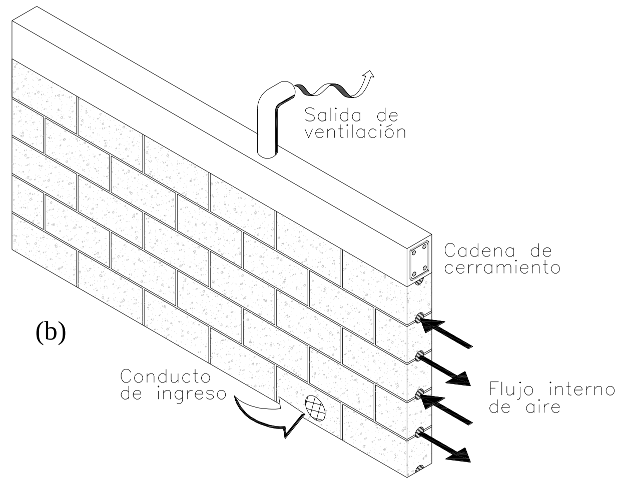


Figure 10 Masonry wall with (a) horizontal and vertical duct layout, (b) access located 1.40 m from finished floor level and ventilation outlet in enclosure chain

Figure 11 shows the full-scale three-dimensional layout of the dwelling house with masonry walls. The blockwork with hollow vertical cells and empty horizontal half-pipe ducts with roof vents to release heat energy are shown.

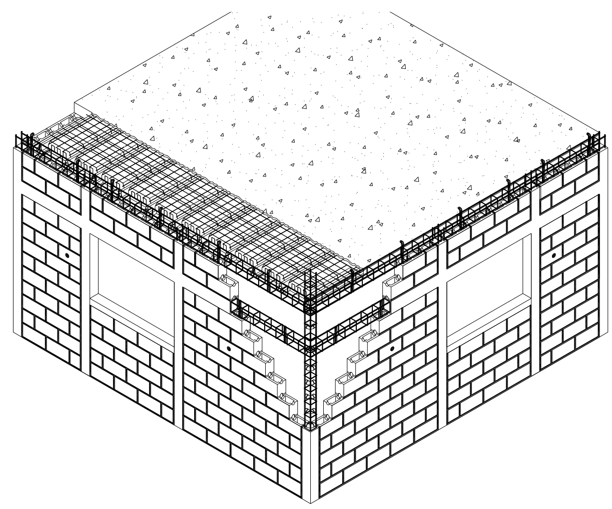


Figure 11. Overall masonry scheme with horizontal ducts and vertical cells

The temperatures were obtained on the walls of the house, recording them at two different times over the course of a day and up to a month, allowing us to know not only the temperature, but also the thermal sensation registered inside the house. These data were used to generate an average of the temperatures recorded, which were then compared with those of the conventional block wall. Figure 12 shows the temperature reduction after the construction of the conventional block walls in one area and in another area of masonry with hollow vertical block cells and hollow horizontal ducts.

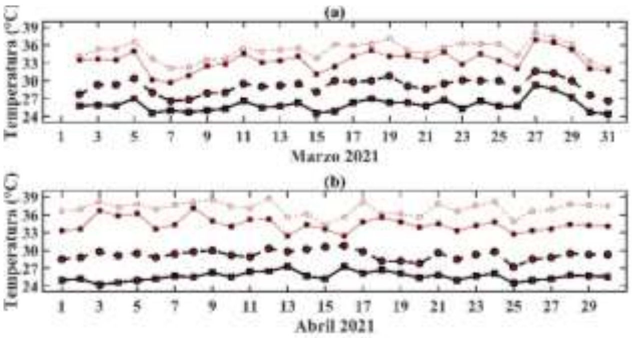


Figure 12 Temperatures inside the house, (a) with conventional block with red lines and (b) with block of the present proposal

The reduction with the proposal shown in Figure 10 is around 20% on average, which means less electricity use.

Acknowledgement

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Conclusions

In high-temperature areas, there are buildings with masonry walls made of solid pieces or blocks with vertical openings which, when they receive the sun's rays for 8 hours, transfer the heat to the interior spaces of the house. In the first hours of sun exposure to the walls, the masonry heats up and being constantly exposed to the heat, the pieces absorb it and transmit the heat to the interior, in such a way that when it gets dark the walls are still hot, spreading the temperature towards the interior of the building. The proposal of vertical and horizontal hollow block masonry reduces heat transfer to the interior of the rooms by 20%.

The network of horizontal and vertical ducts structurally weakens the resistance of the masonry, however, it is reinforced by slightly increasing the number of castles, in this case it is suggested to have a maximum separation of 3m with the type of block proposed, while, if block with only vertical hollows is used, the maximum separation is 4m.

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Prototype of a sustainable photovoltaic energy generation system in the Manzanillos Zitácuaro community

Prototipo de sistema de generación de generación de energía en la comunidad de Manzanillos Zitácuaro

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Abstract

The overarching goal of this project is to develop a prototype of a sustainable photovoltaic energy generation system in the originating community of Manzanillos Zitácuaro. The applied methodology encompasses a detailed diagnosis, assessment of solar potential, efficient system design, integration of storage solutions, and infrastructure development, supported by community awareness and participation. Anticipated outcomes include consistent generation of sustainable energy, reduction of greenhouse gas emissions, improved quality of life, and a positive impact on the local economy through cost reduction and potential reinvestment in community projects.Furthermore, this project aligns with the Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy) and SDG 11 (Sustainable Communities). Beyond addressing energy needs, the initiative aims to empower and bolster community resilience, fostering environmentally responsible practices and contributing to sustainable development in accordance with the UN's Agenda 2030. This holistic approach seeks not only to meet energy demands sustainably but also to empower and enhance the overall resilience of the community, embodying a commitment to environmentally responsible practices and sustainable development in alignment with the UN's Agenda 2030

Photovoltaic, Sustainability, Community Empowermen

Resumen

El objetivo general de este proyecto es desarrollar un prototipo de sistema generador de energía fotovoltaica sustentable en la comunidad origen de Manzanillos Zitácuaro. La metodología aplicada comprende un diagnóstico detallado, evaluación del potencial solar, diseño eficiente del sistema, integración de soluciones de almacenamiento y desarrollo de infraestructura, respaldados por la concientización y participación comunitaria. Se anticipan resultados significativos, como la generación constante de energía sostenible, reducción de emisiones de gases de efecto invernadero, mejora en la calidad de vida y un impacto positivo en la economía local mediante la reducción de costos y la posibilidad de reinversión en proyectos comunitarios.Este proyecto también se alinea con los Objetivos de Desarrollo Sostenible (ODS), especialmente con aquellos relacionados con energía asequible y no contaminante (ODS 7) y comunidades sostenibles (ODS 11). Además de satisfacer las necesidades energéticas, busca empoderar y mejorar la resiliencia de la comunidad, fomentando prácticas ambientalmente responsables y contribuyendo al desarrollo sostenible en consonancia con la Agenda 2030 de la ONU.

Fotovoltaico, Sostenibilidad, Empoderamiento Comunitario

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Introduction

The growing awareness of the significance of adopting sustainable energy sources has spurred a renewed focus on research and development of technologies that can meet our energy needs without compromising environmental balance. In this context, the current project emerges as a proactive response to the energy challenges in the community of Manzanillos Zitácuaro, with the fundamental goal of developing an advanced prototype of a sustainable photovoltaic energy generation system.

Manzanillos Zitácuaro, a community in the central region of Mexico, faces significant energy challenges characterized by dependence on non-sustainable sources and a lack of access to reliable energy. This project addresses these issues with a comprehensive approach that not only aims to provide a cleaner and more sustainable energy source but also seeks to empower the community and enhance its resilience to environmental and economic changes.

The underlying methodology in the development of this prototype spans several critical stages, ranging from a detailed diagnosis of the local context to the implementation and continuous monitoring of the system. It commences with a thorough assessment of solar potential in the region, leveraging the specific geographic and climatic conditions of Manzanillos Zitácuaro. This analysis is crucial to determine the technical and economic viability of implementing a photovoltaic system in the community.

Efficient system design becomes a pivotal component of the methodology, where technological components are carefully selected to ensure optimal energy generation. The integration of storage solutions, such as advanced batteries, is considered to ensure a consistent energy supply even during periods of low solar radiation. The necessary infrastructure for system implementation is planned and developed considering the specific characteristics of the community, promoting effective integration into the existing environment.

A key element in this methodology is community awareness and participation. The community of Manzanillos Zitácuaro is viewed not only as the end recipient of the technology but as an active partner throughout the process. Educational campaigns are conducted to raise awareness about the benefits of photovoltaic energy, and active participation of residents in decision-making and system maintenance is encouraged. This collaborative approach ensures a more effective and sustainable long-term implementation.

The expected outcomes of this project are manifold and encompass technical, environmental, social, and economic aspects. The consistent generation of sustainable energy not only reduces dependence on non-renewable sources but also contributes to a significant reduction in greenhouse gas emissions. The improvement in the quality of life for the community is reflected in more reliable access to essential services backed by a stable energy source.

The positive impact on the local economy is another fundamental component of the expected outcomes. The reduction in costs associated with energy generation can free up resources that can be reinvested in additional community projects, thereby strengthening the local economy and improving social infrastructure. Moreover, the prototype developed in this community has the potential to be replicated in other regions, inspiring similar initiatives and contributing to the global advancement towards a more sustainable future.

This project also closely aligns with the United Nations Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy) and SDG 11 (Sustainable Communities). Beyond addressing energy needs, it seeks to empower the community of Manzanillos Zitácuaro and enhance its resilience to environmental and economic challenges, thereby contributing to sustainable development in line with the United Nations' Agenda 2030.The project represents a comprehensive and visionary endeavor that seeks to transform the energy reality of Manzanillos Zitácuaro, offering a sustainable and participatory model that not only addresses immediate energy needs but also propels progress towards a more equitable and sustainable future

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Methodology to be developed

The project employs an applied descriptive methodology to address the complexities of transitioning towards more sustainable energy sources. It begins with a detailed diagnosis and a comprehensive assessment of the geographical and energy consumption context within the community. A solar feasibility study is conducted using measurements and simulation software to determine the suitability of photovoltaic energy.

The methodology includes meticulous selection and design of the photovoltaic system, integration of storage solutions, and development of infrastructure for efficient energy distribution. Community participation is encouraged through educational campaigns and workshops, and monitoring and maintenance programs are established to ensure optimal performance and project sustainability. This methodology aims not only to implement a technical solution but also to promote awareness and community engagement for achieving sustainable change in energy generation.

Phase 1: Community Diagnosis and Evaluation:

– Conduct a detailed analysis of the community's geographical, climatic, and energy characteristics. Detailed mapping of the community's geographical features, considering terrain, topography, and solar exposure.Examination of potential shading elements, both natural (trees, buildings) and man-made.Analysis of local climate conditions, including temperature variations, seasonal changes, and sunlight hours.Consideration of weather patterns and potential environmental challenges that may impact the performance of the photovoltaic system.

– Evaluate current energy consumption, identifying specific patterns and demands. Evaluation of current energy consumption patterns within the community, including peak demand periods.Identification of key energy-consuming activities, such as residential, commercial, or communal energy usage. Assessment of existing energy infrastructure and the efficiency of the current energy distribution network.

Phase 2: Solar Feasibility Study:

– Conduct an analysis of solar potential using measurements and historical climate data.

– Utilize modeling tools to determine the economic and technical feasibility of the photovoltaic system.

The municipality of Zitácuaro exhibits a variety of climates, primarily characterized by temperate subhumid with summer rainfall, with higher humidity C(W2) covering 49.39% of the municipal area. Additionally, there is a semiarid subhumid climate with summer rainfall, medium humidity Acw1, covering 27.22%; temperate subhumid with summer rainfall, medium humidity C(W1), covering 16.19%; and semicold subhumid with summer rainfall, higher humidity C(E) (w2), covering 7.20% of the municipal territory.

The topography of Zitácuaro is marked by the east-to-west ridges of the Trans-Mexican Volcanic Belt. This geological feature results in a diverse landscape, including mountainous areas, accounting for 33.24% of the municipal surface; mountainous terrain with plateaus, 1.0%; hilly terrain with plateaus, 65.48%; and plains, 0.28%. The municipal territory is highly irregular, lacking valleys and plains. Consequently, 50% of the municipal territory consists of elevations exceeding 2,000 meters, limiting the potential for high-yield agriculture.

Zitácuaro boasts several notable elevations due to its orographic characteristics, including Cerro Cacique at 3,200 meters above sea level (masl), Cerro el Huacal at 3,160 masl, Cerro Ziráhuato at 2,740 masl, Cerro Gordo at 2,660 masl, Cerro Las Flores at 2,540 masl, Cerro La Campana at 2,460 masl, Cerro La Pachuca at 2,460 masl, Volcán El Molcajete at 2,360 masl, Cerro El Epazote at 2,240 masl, and Cerro La Pluma at 2,100 masl.

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Figure 1 Manzanillos, Zitácuaro, Michoacán
Source: Google Maps

Phase 3: Photovoltaic System Selection and Design:

– Select photovoltaic technologies considering efficiency, cost, and adaptability to local conditions.

– Design a system integrating solar panels, inverters, and energy storage systems.

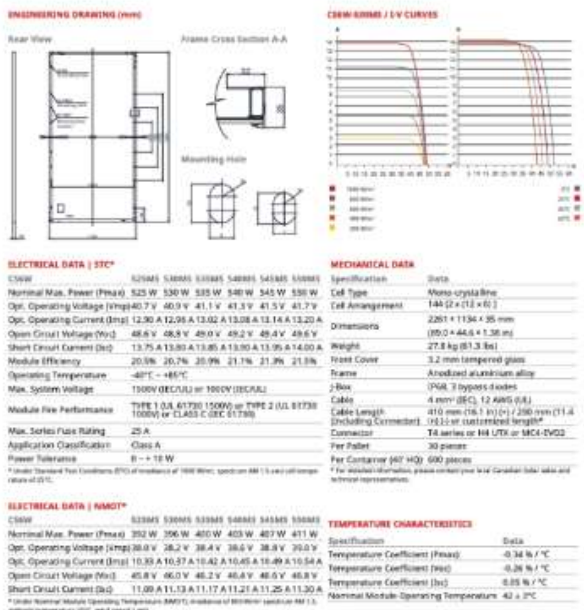
For simulating solar potential and designing photovoltaic systems, one of the widely used and recognized software in the industry is PVsyst. PVsyst is a specialized tool that allows professionals to model, simulate, and optimize photovoltaic systems based on specific site parameters, such as geographical location, solar panel type, tilt, and orientation, among others. With this tool, professionals can forecast solar energy production at a given location, assess system efficiency, and optimize its design to maximize performance.

It's crucial to note that there are other similar tools available, and the choice of software may depend on user preference, project complexity, and resource availability. Some alternatives include SAM (System Advisor Model), HelioScope, and RETScreen, among others.

Phase 4: Integration of Storage Solutions:

– Evaluate and select energy storage technologies, such as batteries, to ensure a stable and continuous supply.

– Design energy management systems optimizing battery charging and discharging.



ELECTRICAL DATA | STC*

CS6W	525MS	530MS	535MS	540MS	545MS	550MS
Nominal Max. Power (Pmax)	525 W	530 W	535 W	540 W	545 W	550 W
Opt. Operating Voltage (Vmp)	40.7 V	40.9 V	41.1 V	41.3 V	41.5 V	41.7 V
Opt. Operating Current (Imp)	12.90 A	12.96 A	13.02 A	13.08 A	13.14 A	13.20 A
Open Circuit Voltage (Voc)	48.6 V	48.8 V	49.0 V	49.2 V	49.4 V	49.6 V
Short Circuit Current (Isc)	13.75 A	13.80 A	13.85 A	13.90 A	13.95 A	14.00 A
Module Efficiency	20.5%	20.7%	20.9%	21.1%	21.3%	21.5%
Operating Temperature	-40°C ~ +85°C					
Max. System Voltage	1500V (IEC/UL) or 1000V (IEC/UL)					
Module Fire Performance	TYPE 1 (UL 61730 1500V) or TYPE 2 (UL 61730 1000V) or CLASS C (IEC 61730)					
Max. Series Fuse Rating	25 A					
Application Classification	Class A					
Power Tolerance	0 ~ + 10 W					

MECHANICAL DATA

Specification	Data
Cell Type	Mono-crystalline
Cell Arrangement	144 [2 x (12 x 6)]
Dimensions	2261 × 1134 × 35 mm (89.0 × 44.6 × 1.38 in)
Weight	27.8 kg (61.3 lbs)
Front Cover	3.2 mm tempered glass
Frame	Anodized aluminium alloy
J-Box	IP68, 3 bypass diodes
Cable	4 mm² (IEC), 12 AWG (UL)
Cable Length (Including Connector)	410 mm (16.1 in) (+) / 290 mm (11.4 in) (-) or customized length*
Connector	T4 series or H4 UTX or MC4-EVO2
Per Pallet	30 pieces
Per Container (40' HQ)	600 pieces

ELECTRICAL DATA | NMOT*

CS6W	525MS	530MS	535MS	540MS	545MS	550MS
Nominal Max. Power (Pmax)	392 W	396 W	400 W	403 W	407 W	411 W
Opt. Operating Voltage (Vmp)	38.0 V	38.2 V	38.4 V	38.6 V	38.8 V	39.0 V
Opt. Operating Current (Imp)	10.33 A	10.37 A	10.42 A	10.45 A	10.49 A	10.54 A
Open Circuit Voltage (Voc)	45.8 V	46.0 V	46.2 V	46.4 V	46.6 V	46.8 V
Short Circuit Current (Isc)	11.09 A	11.13 A	11.17 A	11.21 A	11.25 A	11.30 A

TEMPERATURE CHARACTERISTICS

Specification	Data
Temperature Coefficient (Pmax)	-0.34 % / °C
Temperature Coefficient (Voc)	-0.26 % / °C
Temperature Coefficient (Isc)	0.05 % / °C
Nominal Module Operating Temperature	42 ± 3°C

Figure 2 Solar Panel
Source: HiKu6 Mono PERC

Figure 3 Battery
Source: Signature Line

Phase 5: Infrastructure Development and Distribution:

– Implement the necessary infrastructure for solar panel installation and storage systems.

– Design distribution systems allowing efficient energy delivery to consumption points.

Figure 4 Solar Panel Installation
Source: Own Elaboration

Phase 6: Awareness Campaigns and Community Participation:

- Develop educational campaigns to inform the community about the benefits of solar energy and encourage active participation.

- Facilitate community meetings to gather feedback and expectations from residents.

Phase 7: Maintenance and Monitoring Programs:

- Establish preventive and corrective maintenance programs to ensure optimal system functioning.

- Implement real-time monitoring systems to assess the performance and efficiency of the prototype.

Phase 8: Environmental and Social Impact Assessment:

- Conduct periodic assessments of environmental impact, including the reduction of greenhouse gas emissions.

- Evaluate the social impact of the project in terms of improved quality of life and community participation.

Phase 9: Economic Analysis and Financial Sustainability:

- Conduct an economic analysis to assess the long-term financial viability of the photovoltaic system.
-
- Identify opportunities for financial sustainability and project scalability

Results

Activities	%
Stable Photovoltaic Energy Generation Achieving consistent and reliable electricity production through the implementation of photovoltaic technology.	40%It is in testing
Reduced Environmental Impact Contributing to a decrease in environmental impact by harnessing clean and renewable solar energy, thereby lowering carbon emissions.	50% It makes a big difference
Improved Energy Access Ensuring a continuous and reliable energy supply to meet the community's needs, enhancing overall energy accessibility and reducing dependency on conventional sources.	40% As it is in testing, definitive data is not obtained
Community Engagement Encouraging active participation and engagement from the community members in the use and maintenance of the photovoltaic system, fostering a sense of ownership and sustainability.	70% Since he changed to the community committee

Table 1 Quantitative results
Source: Own Elaboration

It can be seen in table 1 that the percentage may seem low, but no, it is very significant since as it is in the testing phase, the data is not yet definitive, but the trends are growing.

Conclusion

The prototype has demonstrated a consistent production of photovoltaic energy, providing a reliable electrical supply for the community, a significant decrease in greenhouse gas emissions has been achieved, contributing to the environmental sustainability of the community. The community has shown active involvement in the project, evidenced by collaboration in system maintenance and management. Explore technologies and practices to enhance the efficiency of the photovoltaic system to increase energy production.

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Provide ongoing training to the community to strengthen their ability to operate and maintain the system efficiently. Investigate the possibility of integrating energy storage systems to ensure a continuous supply during periods without sunlight. Addressing these areas of improvement can enhance the effectiveness and long-term sustainability of the photovoltaic energy generation system in the community of Manzanillos Zitácuaro.

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Dehydrated vegetables using solar energy to make a vegan soup

Deshidratado de verduras mediante energía solar para la elaboración de una sopa vegana

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Abstract

Nowadays the topic of food is increasingly complex. It is no longer just about the degree of access, but also the way of producing, processing, transporting, trading and consuming them, without forgetting the effects that these activities generate. As food is cooked, processed and sterilized, its nutritional value decreases, losing enzymes and vitamins, as well as other nutritional and healing qualities (Vitola, 2022). The objective of this work is the dehydration of vegetables using solar energy, to formulate a vegan soup. The methodology used was the preparation of the samples to be deposited in solar dehydrators, which operate in natural and forced convection. The % initial and final humidity, temperature of the dryers and drying time were evaluated, setting a final time of 7 hours. The irradiance at the experimental site was 527.7 W/m². The results obtained on average of the humidity removed were 83.3%. It is concluded that for dehydration, the forced operation is ideal to achieve the stated objective.

Dehydrated, Onion, Vegan soup

Resumen

En la actualidad el tema de los alimentos es cada vez más complejo. Ya no sólo se trata del grado de acceso, sino además la forma de producirlos, procesarlos, transportarlos, comerciarlos y consumirlos, sin olvidar los efectos que estas actividades generan. A medida que la comida se cocina, procesa y esteriliza disminuye su valor nutricional perdiendo enzimas y vitaminas, a la vez que otras cualidades nutricionales y sanadoras (Vitola, 2022). El objetivo de este trabajo es la deshidratación de hortalizas mediante energía solar, para formular una sopa vegana. La metodología empleada fue la preparación de las muestras para ser depositadas en deshidratadores solares, que operan en convección natural y forzada. Se evaluaron el % de humedad inicial y final, temperatura de los secadores y el tiempo de secado, fijando al final un tiempo de 7 horas. La irradiancia en el lugar de la experimentación fue de 527.7 W/m². Los resultados obtenidos en promedio de la humedad retirada fue de 83.3 %. Se concluye que para el deshidratado, la operación forzada es la ideal para alcanzar el objetivo planteado.

Deshidratado, Cebolla, Sopa vegana

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Introduction

Nowadays the topic of food is increasingly complex. It is no longer just about the degree of access, but also the way of producing, processing, transporting, trading and consuming them, without forgetting the effects that these activities generate. In addition to, the malnutrition deficits that have been accumulating over several decades. Around 700 million people are suffering from hunger in the world; while, it is found that overweight and obesity, along with its link to non-communicable diseases (diabetes, cardiovascular problems, and even cancer) continues to advance in a worrying manner. It is estimated that, worldwide, the prevalence of overweight and obesity has increased in the last three decades, affecting two out of every three adults. Childhood obesity is projected to increase by 60 percent in the next decade. The 2020 National Health and Nutrition Survey in Mexico offers a clear and precise x-ray of the circumstances of overweight and obesity that the Mexican population has been suffering in various age groups. Given these undesirable consequences, it is necessary to transform agri-food systems. The construction of an equation that integrates sustainability, inclusion, but, above all, that raises nutrition levels and reduces deficits such as malnutrition, overweight and obesity, is the central challenge that will have to be faced as a country and at a global level. (Gobierno de México, 2022).

Although it is true, the WHO recommends the consumption of natural products, the national market is limited when it comes to dehydrated vegetables and fruits. In the case of fruits, in recent years there has been an increase in the appearance of various brands with dehydrated fruit products, but with respect to vegetables, it is observed that the market offers only one tuber, the potato, which is industrialized and diversified in presentation, flavor, among others.

Raw veganism, live feeding, conscious eating, raw food or living food are the terms used to refer to a form of alternative production and consumption of food based on plant products in preparations that avoid temperatures higher than 48 °C, as the Food is cooked, processed and sterilized, its nutritional value decreases, losing enzymes and vitamins, as well as other nutritional and healing qualities (Vitola, 2022).

Dehydrated soups are called certain healthy foods that are close to the flavor presented by traditional gastronomy, which have some benefits such as cutting the preparation times of some dishes close to the normal diet of any person, due to their protein content. , vegetables and greens (Caballero, 2016).

Paz-Yépez *et al.* (2023), evaluated the nutritional content and determined the organoleptic acceptance of a hummus-type product using lupine and dehydrated tomato as the main raw materials. A formulation was developed by applying lupin 56% and dehydrated tomato 30%, the nutritional content was evaluated obtaining the following results: protein 30.51%, 7.12% fiber, 10.43% carbohydrates; 3.2 mg/100g iron; 7.2 mg / 100 g of calcium and finally 5.90% of total fat, presenting a higher protein content and sensory acceptance compared to a commercial hummus, thus showing that the application of lupine affects the nutritional value of the product and the dehydrated tomato in sensory acceptance (Paz-Yépez, 2023).

Álvarez & Laverde (2023) carried out a bibliographic review of the nutritional and functional properties of dehydrated soups offered in the food industry market. They presented the composition, raw materials, manufacturing process, nutritional and functional benefits of this type of food, and its contribution as a dietary alternative (Álvarez, 2023).

Silva (2023), determined and highlighted the phenolic compounds present in the Chinese potato and white carrot, in addition to their antioxidant capacity, through UV Visible HPLC analysis and the antioxidant capacity of these food matrices was determined by the DPPH test, where identified Malonic acid, Protocatechuic acid, Ferulic acid hexoxide, Gallic acid, 3-O-caffeoylquinic acid, Rutin, 5-O-caffeoylquinic acid, Quinol, Quinic acid, p-coumaric acid, Chlorogenic acid and Caffeic acid, which are considered nutraceuticals of great importance as they present great health benefits, especially for the prevention of chronic diseases such as diabetes II, heart disease, obesity and metabolic syndrome, thanks to their antioxidant properties, obtaining a percentage of inhibition of DPPH radicals of 24.29 percent for white carrot flour and 18.61 percent for Chinese potato flour (Silva, 2023).

Acosta *et al.* (2023), designed and built a solar dryer to use surpluses from agricultural production. Its operation is based on the heliotropic movement of the sunflower, moving autonomously and/or through the mobile application. It has an approximate capacity of 3 kilos of sliced product, which dehydrates between 5 and 10 hours depending on its humidity level, temperature and environmental radiation. (Acosta, 2023).

Paucarchuco *et al.* (2023), summarized the recent advances, opportunities and challenges in solar fruit drying. In addition, they analyzed the mathematical models commonly used for the evaluation, design and optimization of solar dryers. They highlighted the importance of simulation conditions, characteristics of mathematical modeling and construction materials in the design of more efficient and sustainable solar dehydrators. In addition, they present the thermal efficiency of an indirect solar dehydrator and optimal values of temperature and humidity in a predictive model. (Paucarchuco, 2023).

Moreno *et al.* (2023), present the design and construction of the electrical, electronic and control systems for the operation of a forced convection tray-type food dryer with hot air. The dryer is a hybrid system that combines solar and electrical energy to heat air (Moreno, 2023).

The objective of this research is to dehydrate green beans, chayote, pumpkin, onion, carrot and garlic, to formulate a vegan soup.

Green beans

Also known as green beans or broad beans, it is a variety of bean native to Mexico and Central America that is consumed, pod and all, when it is still green. This legume is rich in water, contains vitamins A and C, folic acid, soluble fiber, minerals such as sodium, potassium, calcium, magnesium and iron, which makes its consumption ideal for strengthening the immune system. The annual production of green beans in Mexico is more than 102 thousand tons, and Morelos is the national leader with a contribution of more than 31 thousand tons.

In its fresh presentation, every hundred grams of green beans have a content of 88 g of moisture, 0.8 g of ash, 0.2 g of fat, 1 g of protein, 5.2 g of dietary fiber, 200 mg of potassium, 72 mg of calcium, 44 mg of phosphorus, 30 mg of sodium, 2 mg of iron and 0.4 mg of zinc (Pérez R. V., 2022).

Because it is rich in dietary fiber and minerals, but low in fat, green beans are considered a recommended food for consumption by people with obesity, a physical condition that has been identified as a health problem worldwide, since people have modified their diet and eating habits due to a variety of factors: economic growth, urbanization, incorporation of women into working life and mass production of processed foods, among many others that make up the so-called “obesogenic environment.”

Green beans are a highly perishable vegetable and the recommended storage conditions to maintain quality are temperatures between 5 °C to 7.5 °C and a relative humidity of 95%. Green beans can be kept for approximately 2 days at 1°C (34°F), 4 days at 2.5°C (36°F), and 8-10 days at 5°C (41°F) before browning symptoms appear. Browning does not occur in green beans stored at 10°C (50°F). When green beans have suffered cold damage, rot caused by various pathogens occurs. During storage above 7.5 °C (45 °F), rot may also occur on the surface of the stems and fruits if free moisture is present (Mixtún, 2018).

Carrot

It is a source of various vitamins, minerals and carbohydrates, which is why it provides energy. Provides vitamin E, folates, ascorbic acid (vitamin C) and B complex vitamins, such as niacin. A 64-gram (g) serving contains 28 calories, 2 g of fiber, 1,800 milligrams (mg) of vitamin A, 207 mg of potassium, and moderate amounts of folates, vitamin E, vitamin K, phosphorus, magnesium, iodine, and calcium. Some advantages of its consumption are that during growth it promotes the development of bones. By having carotenoid pigments, the body's needs for vitamin A are met, which is essential for the proper functioning of the immune system.

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Due to its excellent fiber content, it prevents constipation, helps control blood sugar levels, is a natural diuretic and can help reduce gastric discomfort and excess acidity. In combination with other fresh and natural foods, carrot contributes to the intake of antioxidant compounds that allow the mitigation of free radicals and when accompanied with lemon it helps to strengthen the skin, hair and nails. Because it is rich in antioxidants, its consumption prevents cancer and combats visual problems such as cataracts, dry eyes, conjunctivitis and night blindness (El poder del consumidor, 2021).

Verano (2023), dehydrated carrot (*Daucus carota*) by osmotic dehydration in a honey bee solution, where the effect was evaluated in different concentrations, to optimize the process and determine the optimal dehydration conditions. The optimal conditions of osmotic dehydration were the concentration of 55.71 °Brix, honey/carrot solution ratio of 2.94/1 and temperature of 46.17 °C, the maximum water loss was 55.19%, the maximum weight loss was 69.14%. and the maximum solute gain of 15.75% (Verano, 2023).

Jiménez (2010), carried out a carrot drying process in sheets, evaluating the behavior of the hot air inside the solar dehydrator. The product variables, as well as the distribution in the dehydrator and organoleptic characteristics of the product, were evaluated for the process. The data obtained allowed us to establish an optimal drying model for carrots (Jiménez, 2010).

Pérez *et al.* (2017), They dehydrated carrots using solar shed dryers that operate in free convection or forced convection. The variables determined in this study were; drying time and temperature, air flow speed in forced convection, percentage of moisture removed. The moisture content of the product obtained after subjecting it to drying was 10.96%. The drying time in the natural convection operation was 3.75 h and using forced convection 4.5 h on average. The irradiance measured during the process was 569.9 W/m^2, the average temperature in the environment was 18.51 °C, the percentage of air humidity used for drying was 27.84%, the barometric pressure was 774.96 mbar, the wind speed where the booths were placed was 3.78 m/s and its direction was 198.23° (Pérez L. L., 2019).

Chayote

Chayote, also called cidrayota, chayota, tayota, güisquil, guatilla, chuchu (Brazil and the Philippines), papapobre or guatila, has a color that goes from dark green to light green or light yellow, almost white. The name chayote in Nahuatl (chayotli) means thorny gourd. Its nutritional composition per 100 g. Energy 26 Kcal, 3.9 g of carbohydrates, 0.82 g proteins, 1.7 g of fiber, 0.13 g of fats, Sodium 2 mg, Calcium 17 mg, Iron 0.34 mg, Phosphorus 18 mg, Potassium 125 mg. Vitamin B1 0.03 mg, Vitamin B 20.03 mg, Vitamin B3 0.47 mg, Vitamin C 7.7 mg, 90% of its weight is made up of water which makes it a highly perishable fruit.

Chávez (2017) evaluated the effect of the freeze-drying process on the physicochemical characteristics of chayote, as a complement, the rehydration behavior was studied. The results clearly showed that the water activity (aw) and humidity (X) decreased between the first 9 and 12 h from 90,380 to 8%. In terms of quality, the color results obtained were acceptable within the color range of dehydrated fruits. Finally, during rehydration the dried samples regained their shape due to swelling and it was observed that there was no significant difference in the rehydration kinetics (Chávez, 2017).

Onion

Onion (*Allium cepa*) has a large proportion of water (90%), the caloric intake is very low, about 40 kcal per 100 g of edible part when consumed raw. It has small amounts of simple carbohydrates (3-9%) and some protein (1%). It does not contain fat or cholesterol. The quantity and quality of dietary fiber stands out (approximately 2%). It is soluble fiber, mainly fructooligosaccharides, small carbohydrate molecules that help maintain and improve gastrointestinal health. It also provides potassium, phosphorus, magnesium, some calcium, iron or selenium and very little sodium. Among the vitamins, those of group B stand out (B1, B2, B6, niacin, folic acid) and vitamin C. In addition to sulfur and flavoid compounds (Carbajal, 2016).

Valdivia *et al.* (2022), designed, built and evaluated a prototype for dehydrating fruits and legumes using solar thermal energy. The results demonstrated the significant effect of solar radiation to reduce the drying time of onion (Valdivia, 2022).

Pumpkin

The zucchini, also known as zucchini, tender squash or summer squash, is called in some Latin American countries as zapallito. Its scientific name is *Cucúrbita pepo L.* It contains lutein and zeaxanthin, two antioxidants that are believed to help prevent cataracts and may even slow the development of macular degeneration. It is rich in B complex vitamins (B6, B1, B2 and B3), folate, choline and minerals such as iron, manganese and phosphorus. Approximately 90% of its weight is water, so it provides few calories. Its pulp has a high content of mucilage, which has a softening and protective action on the stomach mucosa. Rich in vitamins C and A, especially carotenes that function as antioxidants. It is advisable to eat it with everything and skin, since that is where most of its antioxidants and fiber are found.

Castilla (2022), presented a techno-economic analysis using different indicators (return on investment, operation cost and net present value), of the dehydration of zucchini by tray and fluidized bed using the SuperPro Designer software, in order to compare the economic viability of dehydration between both. equipment; In addition, the effect of dehydration on the sensory, bromatological and nutraceutical characteristics of the dehydrated product was compared. The dehydration time decreased according to the increase in the applied temperature, being lower in the fluidized bed system than in the tray. The sensory evaluation with 30 semi-trained panelists indicated that the tray-dried zucchini was preferred as it was perceived as harder and with less moisture compared to the bedding (Castilla, 2022).

Garlic

Garlic has a high nutritional value and contains very few calories, 28 grams contain 42 calories, and a lot of vitamin C, vitamin B6 and manganese. Garlic is rich in vitamin B, an essential compound that reduces homocysteine levels.

Good for the liver, good for colds and lung conditions, reduces cholesterol levels, takes care of our digestive system.

Del Rio *et al.* (2019), dehydrated garlic (*Allium sativum*) through the use of solar shed dryers that operate in natural convection or forced convection. The variables determined in this study were; the drying temperature, the air flow speed in forced convection, the drying time, the percentage of moisture removed, the color of the product and the irradiance. The moisture content of the product obtained after subjecting it to drying was 10.3% with respect to the initial one. The drying time in the natural convection operation was 5.75 h and using forced convection 7 h on average. The irradiance measured during the process was 569.9 W/m².

Methodology

In this work, green beans, zucchini, onion, carrot, chayote and garlic with a similar degree of maturation were used. They are washed, peeled and sliced. They are placed in plastic meshes, with dimensions of 27 cm x 34 cm. Samples are identified, numbered and weighed. To dehydrate, a 4 mm thick transparent solar dryer was used, with a 70 cm x 80 cm base, with perforations to allow humid air to escape. In the central rear part of the house there is a fixed fan that acts as an extractor of humid air (The diameter is 9 cm). The tests are carried out using natural convection and subsequently are carried out with forced convection with air outlet velocities of 3.2 m/s and 8.0 m/s respectively.

The house is placed facing south and thermocouples and thermohygrometers are placed. The plastic meshes are introduced with the slices. The percentage of humidity is measured by the difference in weight of the trays throughout the drying process by taking weight readings as a function of time, starting with 30 min intervals and ending with 60 min intervals with an analytical balance.

At the time of taking each mesh, the temperature in the booth and the color of the slices are recorded. Additionally, the initial and final humidity is verified using an OHAUS thermobalance. Samples are taken until there is no change in weight between them. Only sun hours were considered in the time records;

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Therefore, if the drying process has not finished and there is no longer sun available due to the schedule, the shed with the product is stored in a place that does not have high humidity and some of the samples are weighed. The next day the system is exposed to radiation again, after weighing the sample to estimate the variation in humidity during the time in which the product was not exposed to the sun.

Resultados

In Table 1, the initial values of the different vegetable samples are presented, as well as their corresponding dimensions, as a starting point for solar dehydration.

	Sample diameter [cm]	Length [cm]	Broad [cm]	Thickness [cm]	% Moisture	Sample Mass [g]
Garlic		1.53	0.70		57.74	0.53
Green Beans		3.60	0.77		82.35	0.89
Pumpkin	3.00			0.30	92.23	2.13
Carrot	2.83			0.40	73.97	2.59
Onion	5.80			0.3	85.42	9.84
Chayote	5.80			0.4	93.75	9.13

Table 1 Initial values of the vegetable samples

Figure 1 shows the weight loss during dehydration in direct solar dryers operating in natural and forced convection.

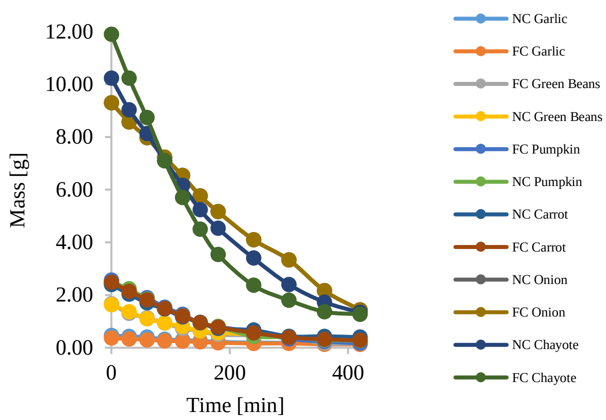

Figure 1 Weight loss of dehydrated products

In Figure 1, it is observed that the use of solar energy for dehydration in the sheds is efficient and can be improved.

Figure 2 shows the internal temperature reached during the experiment in both dehydrators.

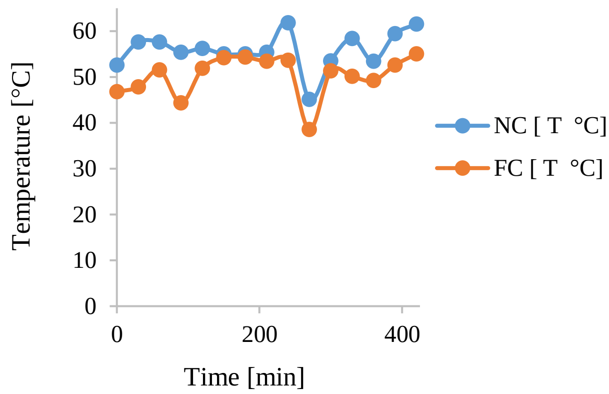

Figure 2 Internal temperature of dehydrators

It can be seen in Figure 2, that during the process there was no constant temperature, affected mainly by solar radiation at the dehydration site. It is also observed that the temperature in the forced convection operation was lower. This will help to evaluate the modification of nutrients in the dehydrated samples, which will complete this study.

Table 2 shows the results obtained in the dehydration process, which was carried out for 7 hours, taking advantage of the presence of the sun. The global average irradiance on the days of the experimentation was 527.7 W/m², taken at the Zacatecas_04 Solarimetric Station of the Mexican Solarimetric Service, located in Building 6 of the UAZ Siglo XXI Campus.

	Sample diameter [cm]	Length [cm]	Broad [cm]	Thickness [cm]	Sample Mass [g]
Garlic		1.13	0.57		0.22
Green Beans		2.80	0.63		0.16
Pumpkin	2.40			0.10	0.16
Carrot	1.80			0.10	0.47
Onion	5.00			0.10	1.43
Chayote	3.20			0.20	0.57

Table 2 Final values of the vegetable samples

Finally, the comparison of the operation in natural and forced convection is presented in Table 3.

	% Moisture Final NC	% Moisture Final NC	% Moisture removed NC	% Moisture removed FC
Garlic	15.98	14.16	72.33	75.47
Green Beans	15.42	21.59	81.27	73.78
Pumpkin	7.05	11.28	92.35	87.77
Carrot	11.42	7.93	84.56	89.27
Onion	13.11	13.11	85.43	85.43
Chayote	13.69	13.01	85.39	86.12

Table 3 Comparison of % Humidity in solar dryers operating in natural convection (NC) and forced convection (FC)

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In general, it can be observed that forced convection operation is better, in addition to being carried out at a lower temperature, which can favor the conservation of the nutritional components of the dehydrated vegetables. It is considered that if the dehydration time is prolonged in forced convection, the presence of humidity can be further reduced.

Conclusions

It can be concluded that solar dehydration is an excellent tool to remove the water present in the studied vegetables.

Forced convection operation is the best form of operation in this case.

The nutritional analysis of the product is pending, as well as the decision on the presentation of the product, whether how it comes out of dehydrated or in the form of flour.

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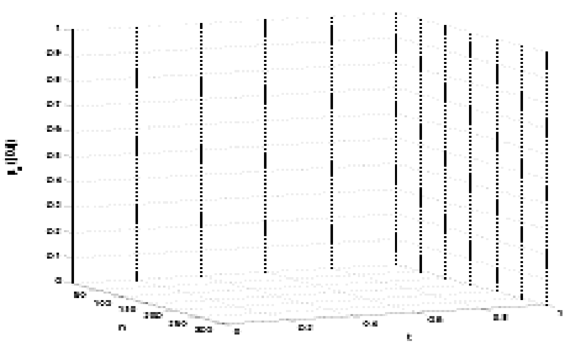

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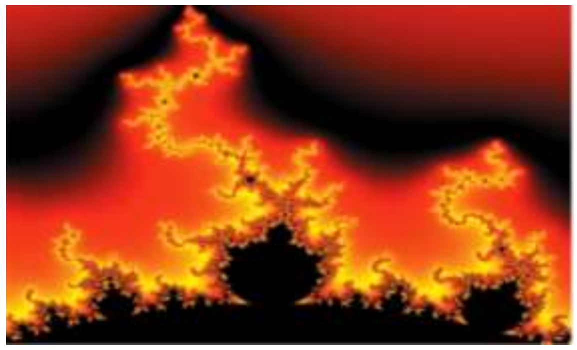

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