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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).

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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.

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).

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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;

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.

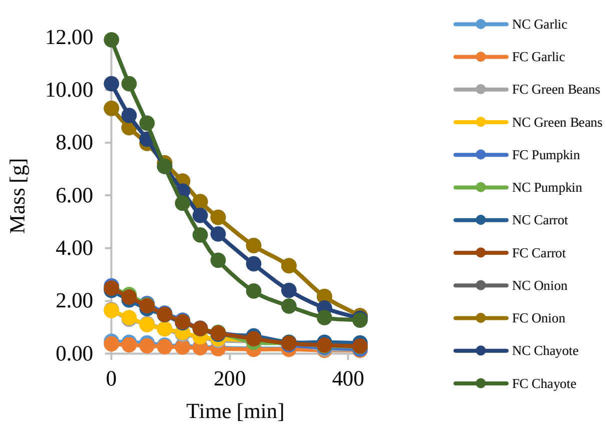

Figure 1 Weight loss of dehydrated products

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.

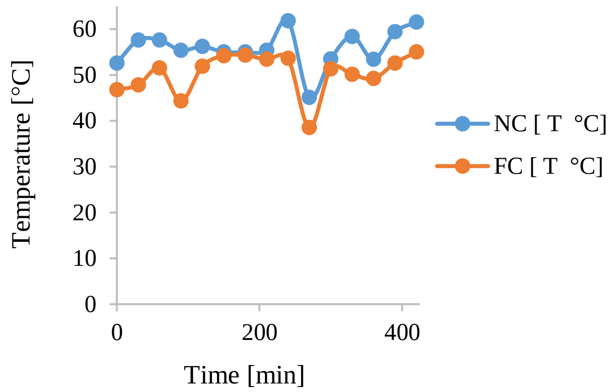

Figure 2 Internal temperature of dehydrators

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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