FragariaVesca Dehydration by flat solar collector with natural flow in Bogota

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Summary - Actually optimization concepts in agricultural process are try to involve with major presence over this economical sector worldwide. This, due to use in an efficient way the resources since the cultivation to post-harvest. The last one, provide large amounts of food which are lost due to accelerated maturity and overproduction. In order to minimize the lost and supply the growing demand of natural and health products, process with a low nutritional impact are implemented to preserve the food on the time, solar dehydration is a trend which involve natural resources as primary source in the process related. In this work is presented the results obtained in FragariaVesca dehydration, known as strawberry by a flat solar collector working under natural circulation in Bogota.

Key Words: Solar energy, flat collector, dehydration, lost weight.

I. INTRODUCTION

Dehydration as known as the process by which is possible preserve food like fruits and vegetables, which have a high level of water superior to 90% so are perishable food. Therefore, is essential decrease the enzymatic activity also interrupt the microorganism develop in the fruit related with the food humidity amount, [1].Most dehydration processes use air as fluid, which food humidity is transported to an extern environment, that depends to internal resistance to water movement and to extern resistance between solid and air, dehydration process depends of two principal parameters, time and temperature, [2].

There are different kind of dehydration processes, among the most known is osmotic dehydration, the use of antimicrobials and dehydration by air drying. The first involves the water extraction from inside the food, through immersion in a highly concentrated aqueous solution [3]. When the product to be dehydrated comes into contact with this solution, the water diffuses between the outer tissues of the product towards the more concentrated solution, seeking a chemical equilibrium [4].The method to preserve food trough an antimicrobial agent, prevents the growth of bacteria and fungi in food, but does not prevent the growth of antimicrobial organisms, therefore its success is conditioned by the amount applied to food, but its use in large doses can cause harm to the health of people when consuming these products [5]. Faced with these difficulties, the restricted time for consumption of the product is added, this means that this technique still needs a lot of research and development in order to improve its results and impacts on human health.

Finally one of the most used techniques for food dehydration is dehydration by air flow or air drying. This consists of reducing the humidity of the food through the air-vapor of water ratio, for later storage and commercialization [6]. Hot air drying can affect the product nutritionally when exposed to high temperatures, due to this, temperature is one of the most influential variables in the process, although high temperatures can make the process faster these decrease the product quality, within these parameters it is usually recommended temperatures between 40 to 80 ºC and air speeds of 2.0 ± 0.2 m/s [7]. Among the best known technologies for dehydration with the use of renewable energy such as solar thermal energy, is the solar collector. From this is sought to increase the heat received and captured by the collector to improve the thermal performance of the dehydration process, accelerating it under the optimal conditions of hot air generation, avoiding the use of auxiliary systems that provide heat to the system [8].

Some work has been developed in relation to the fruits dehydration by air drying. In [9], the design, construction and operation of an induced flow solar dehydration system was carried out; The results showed a difference of 20% between the use of solar energy and the energy produced by fossil fuels. On the other hand in [10], the behavior of water and moisture activity and its relationship with strawberry color before and after dehydration was studied by tristimulus colorimetry. Finding that for a temperature of 45 °C and an airflow of 6m / s allows to obtain dehydrated strawberries without great alteration in color, in a shorter drying time.In other works such as in [11] and [12], the quality of dehydrated fruit was analyzed under different methods taking into account variables such as time and temperature. Similarly in [13], [14] and [15], it was found that the drying time decreases with a temperature of 60 °C and an air flow of $1.5 m/s$ in the pre-processes and processes of the Dehydration.

II. METHODS

Design Description

The dehydration system based on the heat concentration by solar energy is composed for three main elements: Flat solar concentrator, thermal storage unit and dehydration cabin. The flat solar collector concentrates the solar rays on a heat absorber plate, which impinges on a coil where the heat is transferred to the fluid (air), led through the coil to the thermal storage unit for later use in the dehydration cabin.

As a whole the concentrator has a total measurement of $50\,cm\,x\,50\,cm$, a total area of 0.25 m^2 and is composed of the base, base plate, thermal insulation, the coil, the absorber plate and a glass cover. As you can see in the design of the Figure 1.

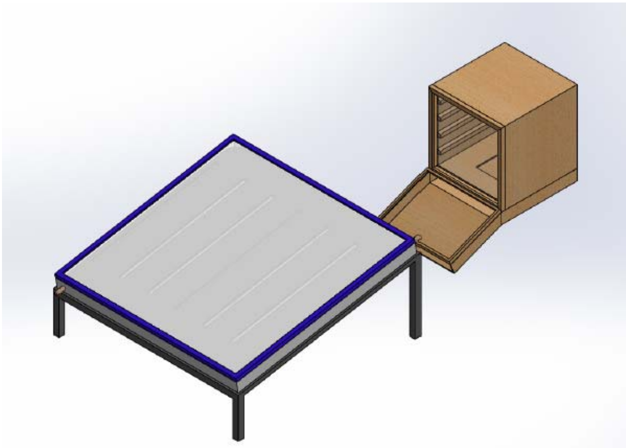

Figure 1. Dehydrator with solar collector.

The thermal storage unity, is the link between the flat solar collector and dehydrator cabin, which is composed by a small flat collector and a base of cabin, where the fluid transferred from collectors is stored and conducted to the fruit to be dehydrated. Finally, the dehydration cabin is the space where the trays are located, so is the main dehydration process is carried out there.

The cabin has an opening system in the front for the entry and exit of fruit trays. At the same time it has an exhaust of the extracted moisture, in the back part and an air inlet in the lower part from the storage unit.

The design of the flat solar collector described above was evaluated from its thermal model, in terms of output temperatures and efficiency from the variation of some design parameters such as angle of inclination, distance between the roof and plate and the incident solar radiation on the system. Through these analyzes we can determine the most efficient conditions of the solar collector.

System Model

Trough Trnsys software, was simulate with analog weather conditions to Bogota city, the solar flat collector behavior, so was possible obtain a system interconnected model. The weather conditions is related with the incident radiation over collector.

Due to simulation properties, was necessary transfer the air flow through a pump as Figure 2.

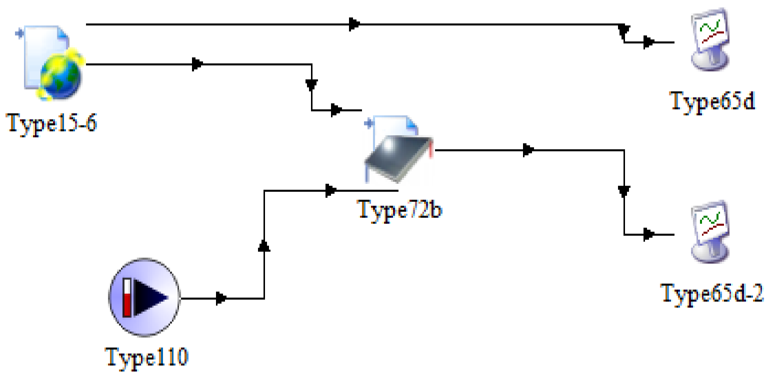

Figure 2. Solar flat collector Model

As a result of this simulation, parameters such as temperature and humidity percentage of the air can be obtained, as Figure 3 under the established climatic conditions.

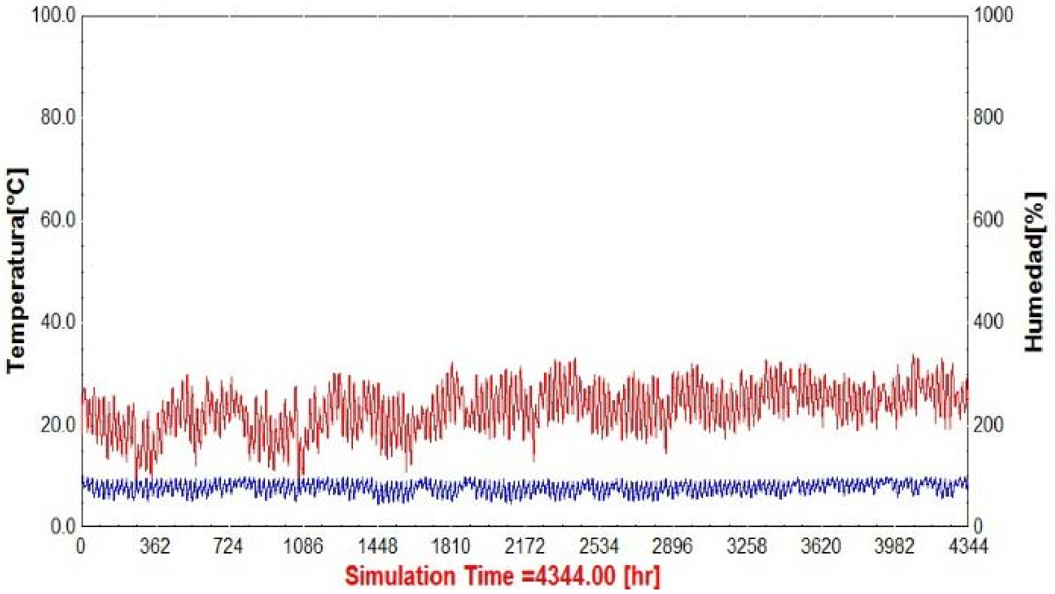

Figure 3. Temperature and humidity of the air Jan-Jun.

Therefore, the outlet temperature of the collector was obtained during 4344 hours. In Figure 4 is related which corresponds to the months from January to June.

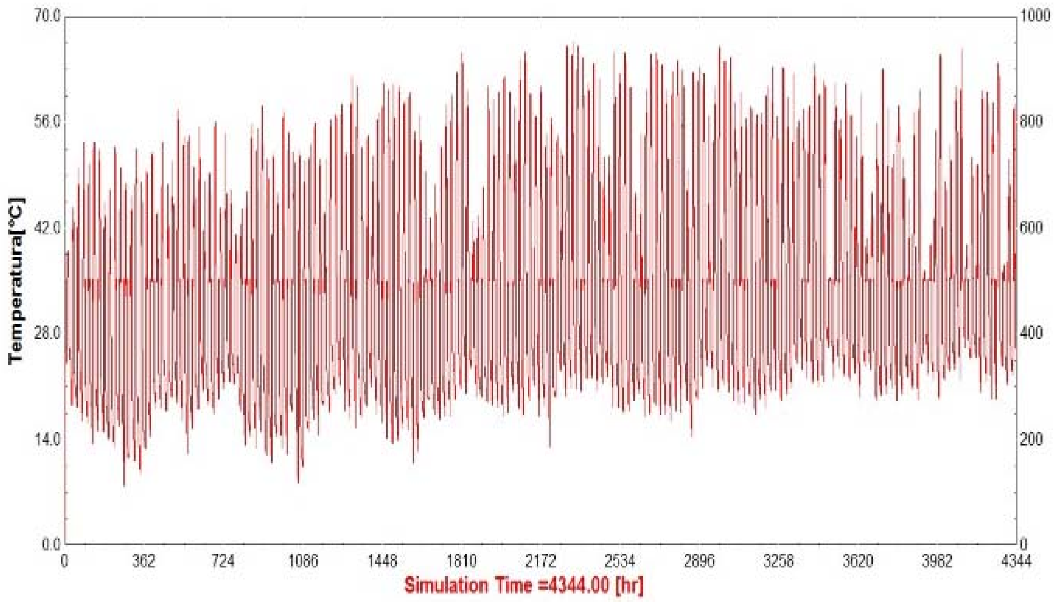

Figure 4. Outlet TemperatureJan-Jun.

The collector temperature for the followings months from July to December is shown in Figure 5.

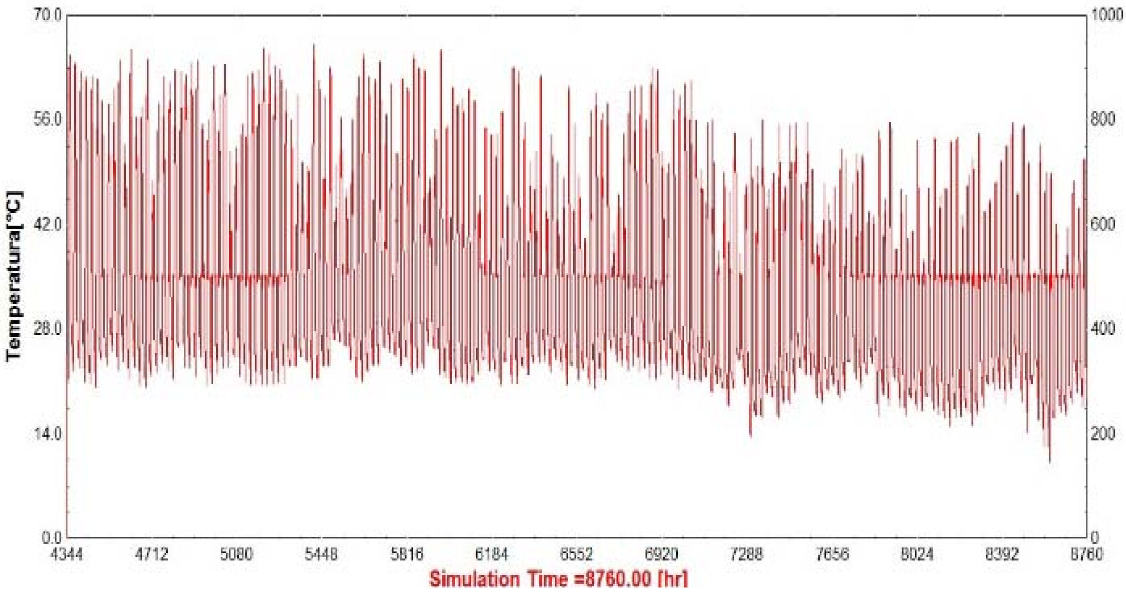

Figure 5. Outlet Temperature Jul-Dec.

After the analyzes and simulations of the designed model, it was built.

Operation

Dehydration is a process of extracting water from the surface of food and transporting it to the environment. In this process two phenomena occur, the first of them known as transmission, in which heat is transmitted from the external environment to the interior of the fruit to dehydrate. On the other hand is the transfer, where the internal humidity of the fruit is transferred to the external environment. According to the design presented initially, the system was constructed, Figure 6.

Figure 6. Dehydrator system built.

The built system was put to the test in the city of Bogotá, in the month of August, where the average temperature was$21°C \pm 5°C$. For this test, the fruit to be dehydrated was *FragariaVesca*, commonly known as strawberry, with an initial weight of 8.3g, Figure 7.

Figure 7. Initial fruit to dehydrate.

The results of dehydration are presented in the results analysis.

III. RESULTS

During the experimental tests carried out on the system in the city of Bogotá, the following graphs and results were obtained. The results obtained for the solar radiation, measured through the radiometer equipment is shown in Figure 8.

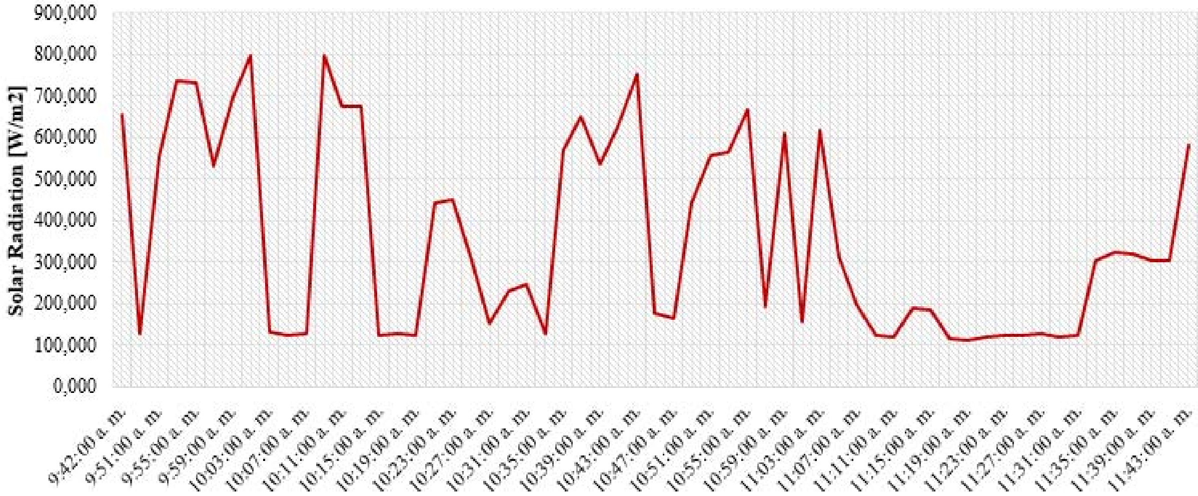

Figure 8. Solar radiation incident on the collector.

On average, the solar radiation incident on the flat solar collector was 359,232 W/m^2, with a minimum radiation of 111,280 W/m^2at 11:19 am and a maximum radiation of 797.700 W/m^2at 10:01 am

The outlet temperatures of the collector, the temperature of the dehydration cabin and the exit temperature of the same were registered during 2 hours between 9:42 am to 11:42 am; this equivalent to 7200 seconds.

The outlet temperature of the registered collector is presented in Figure 9.

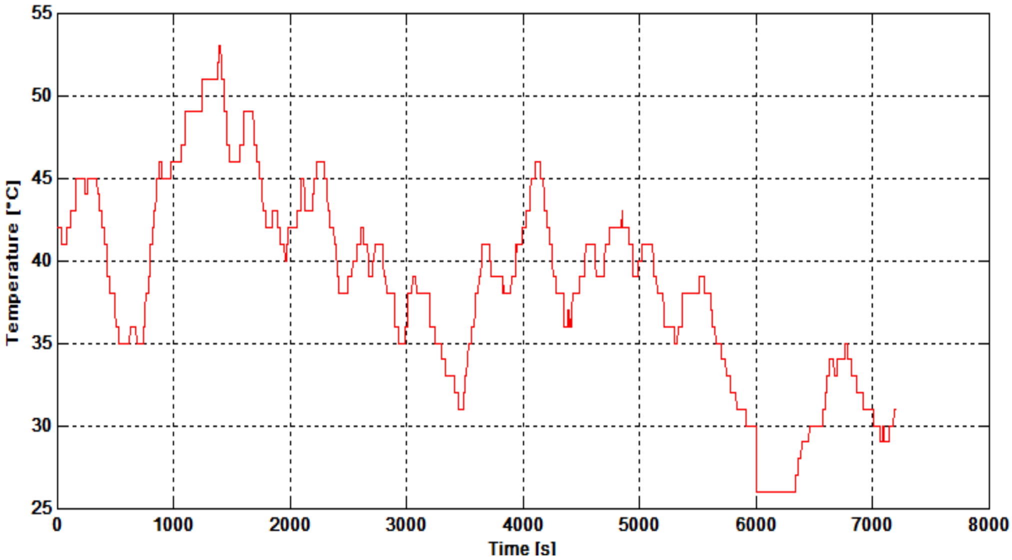

Figure 9. Collector outlet temperature.

It can be observed that the maximum temperature obtained at the outlet of the flat solar collector was 53°C and a minimum temperature of 26 ° C, on average the temperature was 38.58 ° C.

Furthermore, the temperature of the dehydration cabin obtained during the experimentation is shown in Figure 10.

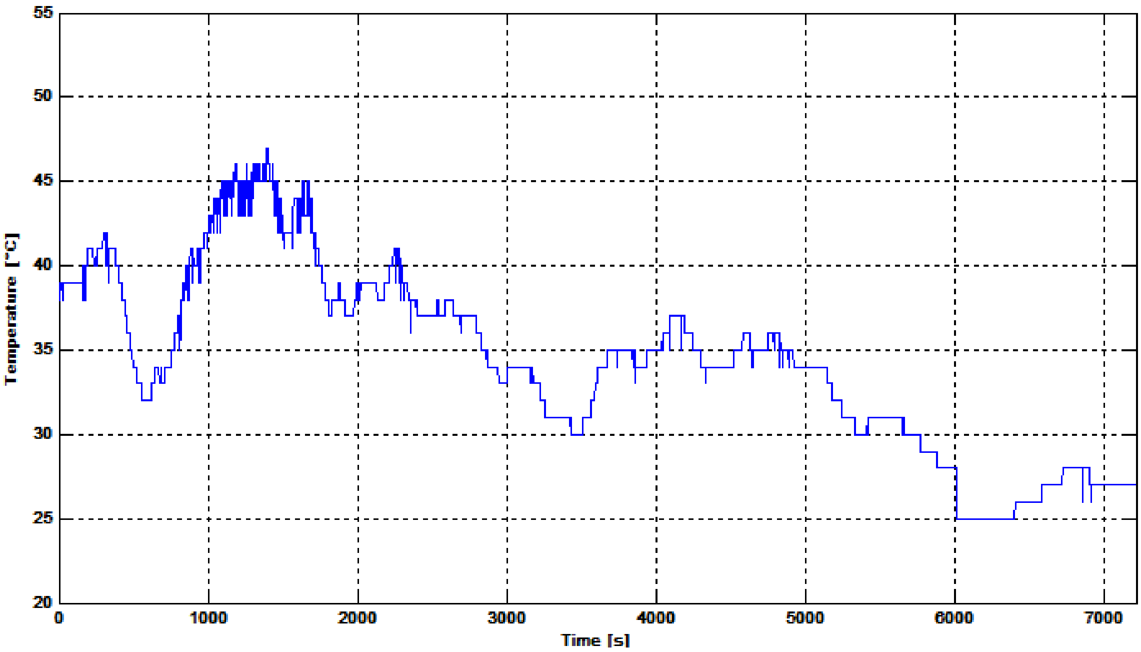

Figure 10. Temperature in the dehydration cabin.

As expected the temperature inside the cabin, has a behavior similar to the outlet temperature of the collector but with a decrease in its value, due to the thermal losses associated with the heat transfer between the collector and the cabin. The maximum temperature inside the cabin was 47°C, having an approximate decrease of 17.47% with respect to the outlet temperature of the collector; On the other hand, the minimum temperature in the cabin was25°C, one degree lower than the minimum collector temperature.

Figure 11 shows the results obtained in the outlet temperature of the dehydration cabin, which refers to the temperature of the fluid extracted from the fruit.

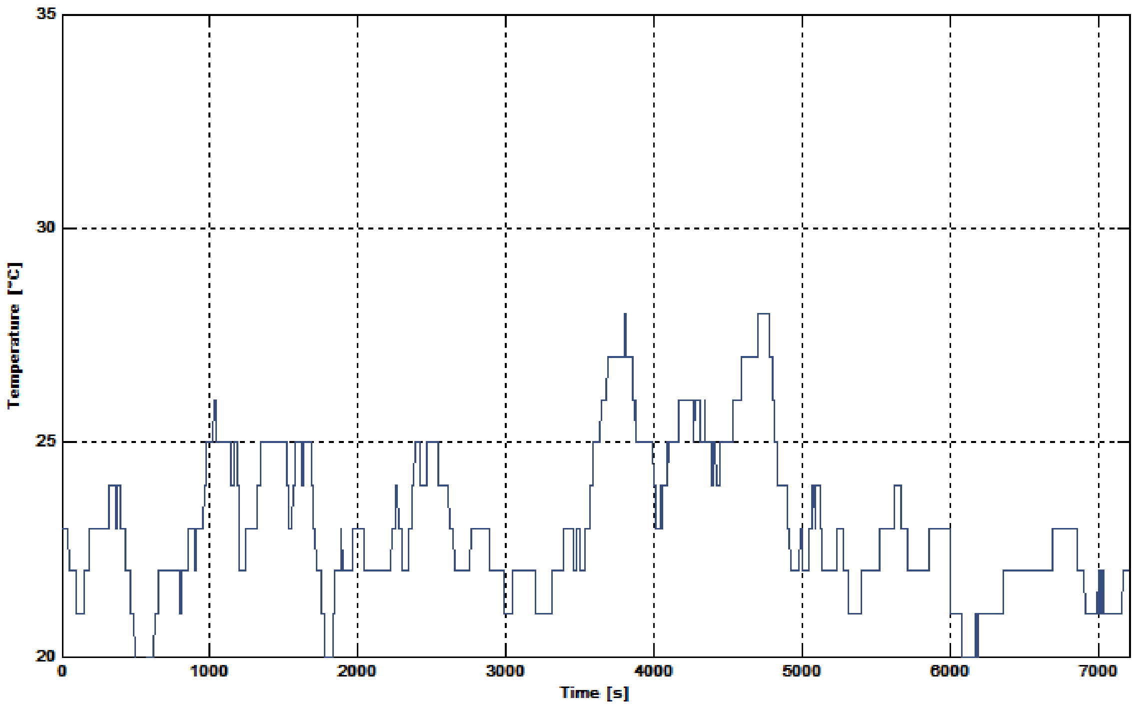

Figure 11. Output temperature.

The temperature at the exit of the cabin obtained its maximum value in 28 ° C and a minimum value of 19°C. This represents a decrease with respect to the maximum entry temperature to the cabin of 58.88% and a decrease of 26.92% with respect to the minimum temperature.

During the experimental test, moisture measurements were also obtained at the different points of the dehydrator. The humidity at the outlet of the flat solar collector is presented in Figure 12.

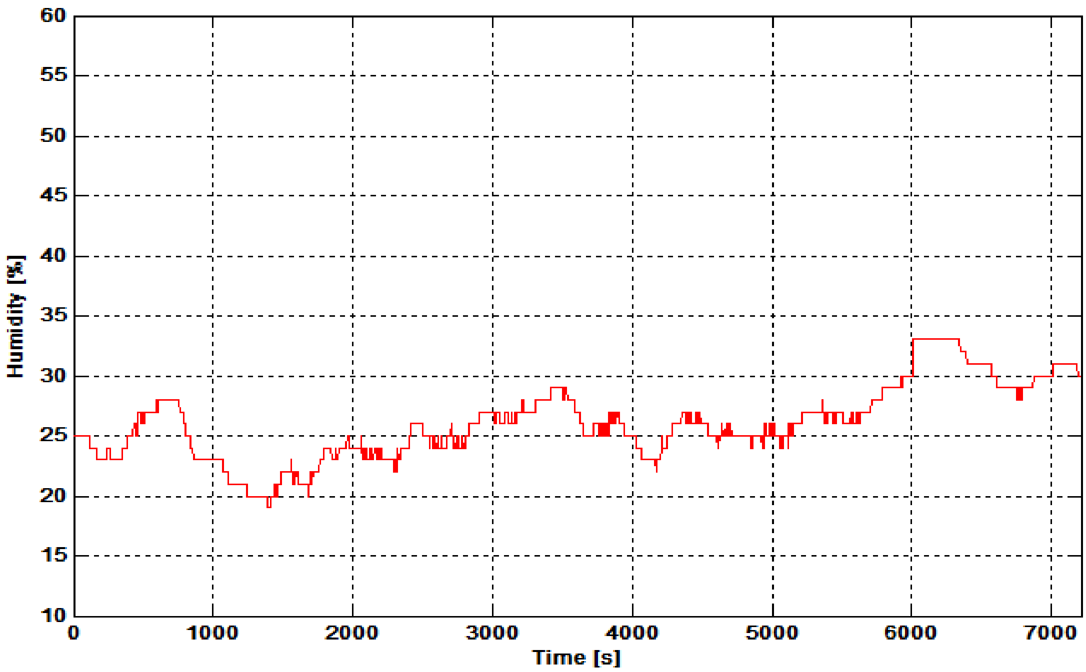

Figure 12. Collector Output humidity.

Figure 13, related below shows the moisture results acquired inside the dehydration cabin.

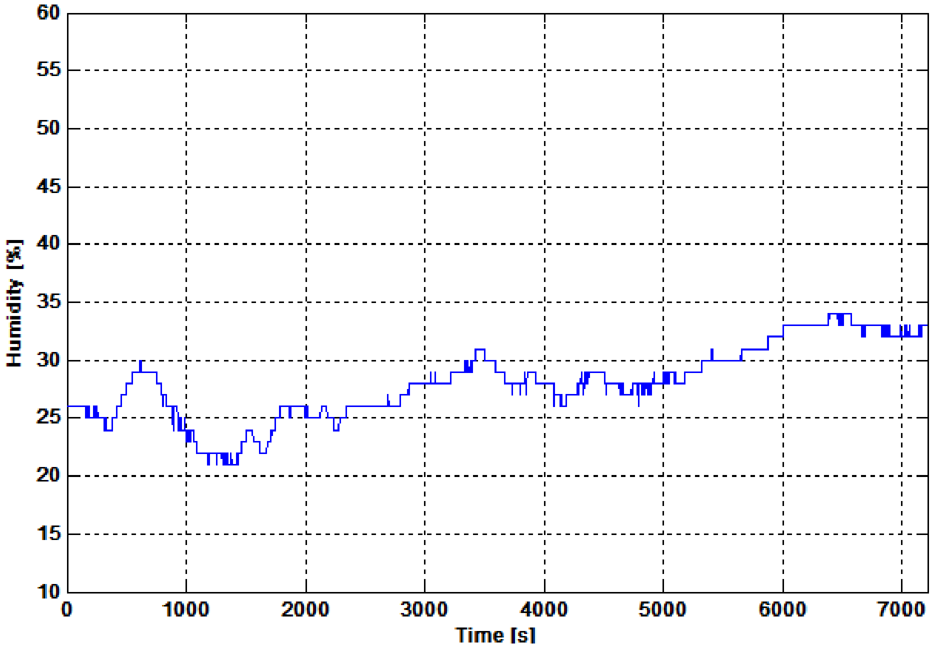

Figure 13. Humidity in the cabin.

Finally, the output humidity of the cabin is illustrated in Figure 14 for each of the recorded instants of time.

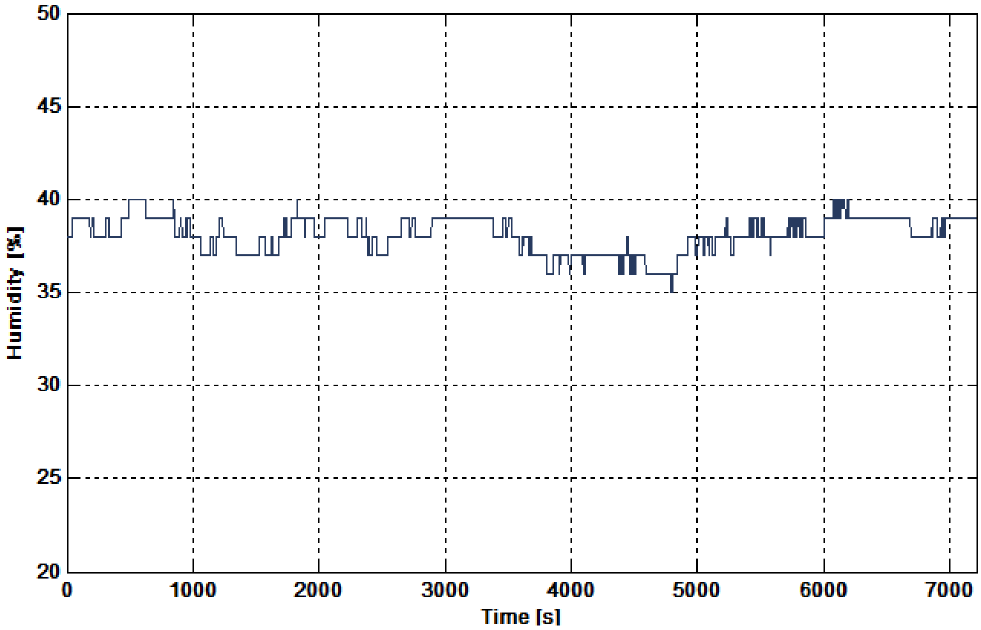

Figure 14. Output Humidity.

The weight loss was calculated for each moment of time, this was possible through a 1Kg load cell with which the weight of the fruit in the cabin was recorded during the experimental test; These results are presented below. The graph in Figure 15 shows the weight of the *FragariaVesca* fruit during dehydration.

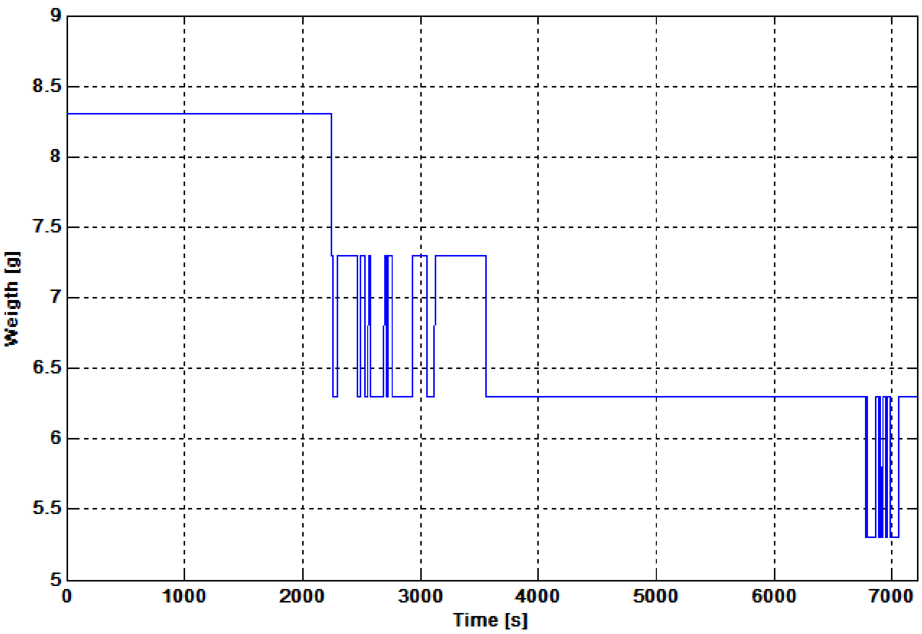

Figure 15. FragariaVesca Weight.

As shown in the graph, the initial fruit weight was 8.3g during the dehydration process a minimum weight of 5.3g was obtained and at the end of the measurements the final weight was 6.3 g.

In Figure 16, the weight loss of the *FragariaVesca* can be observed during the 2 hours of exposure to the dehydration process.

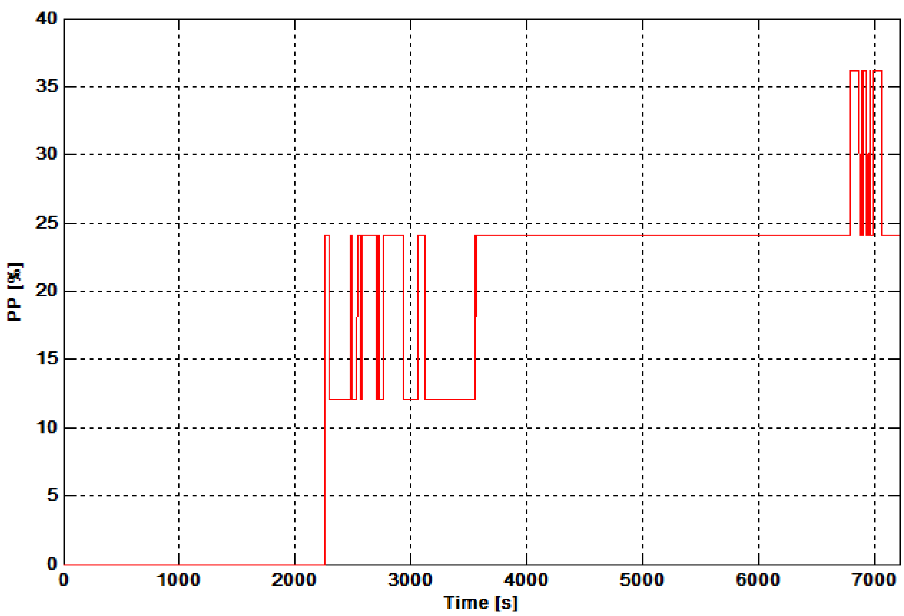

Figure 16. Weight loss during experimentation.

With a final weight of 6.3 g, *FragariaVesca* had a final weight loss of 24.10% and a maximum weight loss of 36.14% in Bogotá, the fruit obtained at the end of the process is shown in Figure 17.

Figure 17. Dehydrated FragariaVesca.

According to the data obtained and the visual results of the product, dehydration of *FragariaVesca* could be evidenced, with a total weight loss of 24.10%.

IV. CONCLUSIONS

The process of dehydration for *FragariaVesca* by natural convection was carried out in Bogotá city, where the day average temperature was 21°C±5°C. The maximum radiation obtained on the flat collector was 797.700 $W/m^2$and minimum radiation of111,280 W/m^2, which represents a variation percentage of 86.05% during the 2 hours of data acquisition.

The maximum temperature reached at the outlet of the flat solar collector was 53°C, therefore the collection and heat concentration product of solar energy, allowed an increase in air temperature of 52.60% to be used as an extractor component of humidity. On the other hand, the cabin temperature reached a maximum temperature of47°C, due to the losses associated with the heat transfer of the process, however its decrease was less than 20%.

In addition to the temperature, the humidity of the different sectors of the solar dehydrator was measured by obtaining 33% humidity at the outlet of the solar collector, 35% humidity in the dehydration cabin and finally a humidity of 40% at the exit. This variable maintains an inverse relationship to the temperature where it can be observed that in the sectors where the temperature was higher, the humidity was lower.

The loss of moisture in the dehydration process is measured through the weight loss of the product, in this work a maximum weight loss of 36.14% and a final weight loss of the fruit of 24.10% was achieved. Although these percentages did not reach a value higher than 50%, if they are considered relevant in relation to the period of time of the experimentation and the climatic conditions of the place of study.

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