Design of a Temperature Control for a Solar Dehydrator

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Abstract: ***This work arises by the need to control the temperature in a fruit dehydrator, taking into account that the temperature must be at a suitable and constant level. To achieve the optimal fruit dehydration ratio, while allowing the system to become autonomous. In order to make this possible, the temperature control will be implemented by an Arduino microcontroller, which will measure the temperature using three thermocouples type J. These sensors will be in three different areas inside the dehydrator identifying variations of the temperature, in order to keep a constant temperature level inside the dehydrator during the process, two fans will be implemented which will allow to maintain a suitable temperature allowing the dehydration of different sorts of fruit. Therefore, the control will be developed by programming a microcontroller that will allow to modify as necessary the temperature suitable to dehydrate different types of fruit by modifying the "temperature variable", accordingly to the fruit which is required to be dehydrated, as well as verifying the temperature constantly during a dehydration process, these will be programmable and performed with the help of a keyboard, where both temperature and percentage of dehydration will be displayed on a LCD screen (Liquid crystal display).***

Keywords: control, constant, dehydrator, system, thermocouples

1. Introduction

Fruit dehydration began since the Iron Age in Northern Europe when the first furnaces were used to dry recently harvested wheat. Methods to dehydrate and preserve fruit and other organic elements have been used ever since in bucolic areas as an easy and common way to preserve fruit all throughout the year. This practice is not only used as means of self-supply as it was used back then, it is currently a rather profitable alternative for the national and international market.

Fruit dehydration is suitable for remote areas where people require to stretching the normal lifespan of organic goods, where there is a high agricultural production during the summer but where perishables are destined to decompose without a simple and economic alternative to preserve the harvest. Dehydrated fruit not only keeps flavor concentrated, but also brings up the sweetness of the fruit. Drying or dehydration of fruit brings down the water percentage of fruit between 10-20% giving it a distinct and nuanced flavor to it while achieving to preserve food during the rest of the year.
This research's focus is to allow and regulate temperature of a solar dehydrator, which is based the application of simple and appropriate technology, its use will allow the fruit or other perishables to maintain most of its original nutritional value. The Huamantla perish has moderately cold weather, with rainfall durng the months of May, June, August and September, the hottest months are March, April and May, the minimum annual average temperature recorded is 5.4 ° C and the maximum is 23.2 ° C. this data will be the cornerstone for a solar fruit dehydrator project(for Apples).

2. Theoretical Framework

There are several dehydration methods, among which is osmotic dehydration which involves immersing a organic products in a solution with a high osmotic pressure, creating a gradient of chemical potential between the water contained in the food and the water in the solution, allowing the flow of water from the inside to the surface of the product in order to match the chemical potentials of the water on both sides of the vegetable's cellular membranes. [1]

Fruits are widely consumed in the world and their conservation is necessary to avoid waste, which would generate unnecessary expenses. Therefore, several techniques are used for its conservation. Dehydration being the most widely used since it is the most economically viable and reduces water content to a level at which microorganisms cannot develop. However, this technique has disadvantages such as the loss of nutrients in the food, as well as physical and flavor changes. For these reasons, it is important to review the literature in order to analyze the changes that occur with the physical and chemical properties during the dehydration process with hot air, as well as a brief description of complementary dehydration techniques that can help improve the stability of these products so that finally, one can obtain high quality products with low risk of microbial degradation. [2]

The quality of apples dried by conventional air and lyophilized methods and after treatment of impregnation (IV) with vitamin E. The conventional air drying process (PSAC) was carried out in a tray dryer at 40ºC, with relative humidity of 59 ± 7% and air velocity of 0.7 m / s; while, the lyophilization process (PL) was carried out at a vacuum pressure of 1.2 x 10-3 kPa, condenser temperature of -45 ° C and tray temperature of 25 ° C. The quantification of vitamin E was carried out by gas chromatography with a flame ionization detector on hexane sample extracts. The PSAC and PL apples presented 0.72 ± 0.12 and 1.34 ± 0.14mg dl-α-tocopherol acetate / g; 12.6 ± 1.7 and 7.9 ± 2.0% humidity, respectively. The PSAC products showed browning, while the PL products were lighter (> L *), greenish (<a *), less yellow (<b *) and less saturated (<Cab *). The products

obtained by PL presented a crunchy texture; while the PSAC products were rubbery. [3]

The mango drying process (Tommy Atkins). With the use of osmotic dehydration (65 ° Brix from 37 to 40 ° C for 60 min), microwave (560 W for 7 min) and combined drying (70 ° C in a tray-type stove and in the sun) Mangos with 11 to 14 ° Brix and a humidity level of 80% were sized at 1 x 1 x 0.4 cm, Weight loss and drying time in the pre-treated mangoes showed significant differences ($p \leq 0.05$) .The greatest weight loss being 66.0% in the combined pre-treatment The L (Luminosity) and b * (yellow blue) parameters decreased ($p \leq 0.05$), the combined pretreatment was the one that eliminated the most water and reduced drying time, however, the osmotic dehydration pre-treatment was the best kept the appearance characteristics of dehydrated mango flakes. [4]

Food industry is the processing of perishable foods, such as fruits, which allows to maintain not only their nutritional and organoleptic quality, but also their bioactivity. To preserve these foods for long periods of time, one of the processes applied is dehydration. Since during these treatments chemical and physical changes can occur in the constituents of fruits, it is necessary to have quality indicators that provide us a tentative retrospect idea of these changes. In this work, different parameters (humidity, water activity, indicators of the Maillard reaction, vitamin C, carbohydrates, rehydration capacity and solids losses through leachate) have been evaluated in twelve common and exotic commercial dehydrated fruits, in order to evaluate the quality of the products found in the market. [5]

The dehydration is one of the most used methods for the conservation of fruits and vegetables, by means of its use, it is possible to extend the period of storage while preserving the product's quality. The objective of this work is to evaluate the kinetic behavior of the main properties of the fruit pump (Carica papaya L, Maradol Roja) during the agroindustrial processes of osmotic dehydration (DO) and hot air flow (DAC). The fruit was cut into cubes (pieces) of 2.5 x 2.5 x 1.0 ± 0.02 cm (width, length and thickness) and dehydrated by DO (60 ° C for 10 hours) and DAC (60 ° C for 5 hours). During the dehydration process, the variation of the mass, the firmness and the percentage of weight loss (Pp) of the fruit in both methods was monitored and for the statistical processing Startgraphics Plus version 5.1 Software was used. As a result, no significant differences were found within the evaluated properties (mass, weight loss and firmness) between the DO and DAC, therefore, very similar results were obtained by both methods; however, otherwise, in the dehydration time for both methods, significant differences were found between said properties. [6]

The papaya is a tropical fruit that has therapeutic, nutritional and cosmetic qualities. The physicochemical characteristics of the papaya influence the degree of consumer acceptance. One way to preserve the fruit is dehydration; Different concentrations of osmotic solutions (glucose - calcium chloride) are proposed to perform the dehydration of cubes of the Maradol papaya variety, evaluating the changes of the physicochemical characteristics of the papaya (Brix degrees, water activity, color, cutting force), in different time intervals until completing 1080 minutes, through an analysis of variance where the best byproduct result was identified within the proposed working conditions, performing calcium analysis before and after the dehydration process and submitted to a sensory panel to determine the level of acceptance. It was found that the best physicochemical characteristics of papaya cubes were presented when treated with a solution of 65 degrees Brix with a time of immersion of 300 minutes, presenting significant gains in calcium content and a high degree of acceptance by the sensory panel. [7]

Here is a project with the instrumentation of a solar dehydrator, which consisted in the installation of a photovoltaic system as power supply, fans for forced air flow regulated according to the relative humidity outside and inside of the equipment, which allows optimized drying time of the product and increase the production of dehydrated food. As shown in figure 1. [1]

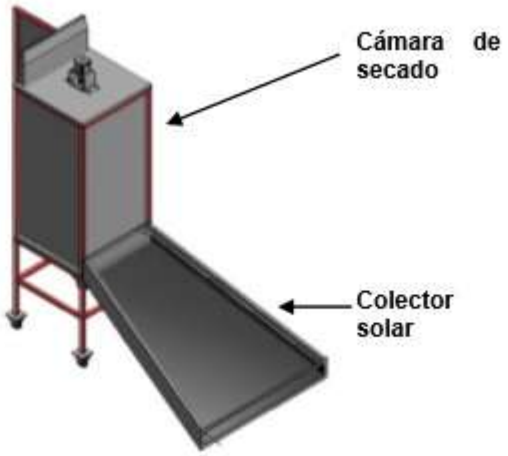

Figure 1: Solar Dehydrator

A study for regional companies which are dedicated to the dehydration of fruits by means of electrical equipment indicate that the dehydration is done by "trial and error", which means the product is not homogeneous, therefore, there is a need to study a temperature control which will improve the quality of the product. The adequate control of the temperature variable will allow the study of the quality of the product in relation to the components that these contain (nutrients and vitamins). [2]

The food industry is considered one of the economic activities with the greatest participation in Colombia, which, in order to continue with its production process, have faced waste problems due to lack of infrastructure and food preservation methods that do not alter the physical-chemical properties of the merchandized product. Therefore, there has been a need to develop methodologies aimed at extracting water without altering its nutrients and thus prolonging the of fruit degradation period. In the present article, the exposed results of the analysis in temperature and humidity are necessary to achieve an efficient dehydration process of the *Annona Muricata*, which presents a high water content (83 per 100 grams of fruit). The development of this project is focused on allowing fruit producers to have the capacity to offer tropical fruits of rapid degradation to national and possibly international markets. Whose results are observed in the conservation of food for long periods of time, reducing losses, promoting consumption and economic development for the agricultural producer. [3]

The prototype shows the development of a sustainable instrumented solar dehydrator, which uses photothermal energy for the dehydration of food and photovoltaic energy for the actuators as well as instrumentation which allows the drying process to be far more efficient. In addition, the automatic control of the process variables are used in the determination of times of dehydration of different foods, as well as the study of the organoleptic properties of the food after the dehydration process. [4]

3. Methodology

In this project, a solar dehydrator is used as shown in figure 2 with the following dimensions: 2 meters of base per 1 meter of height, having a height of 62 cm in the lower part, with 1 meter in the upper part, resulting in a slope of 79 °. It consists of 1 tray of mosquito netting where the apples are placed at a height of 12 cm with respect to the base of the dehydrator. In addition, in its upper part has a glass of 2 meters long by 1 m. wide by 4 mm thick. The material of the bed is polyurethane to maintain the temperature inside the solar dehydrator. IJISR expects researchers, graduate students, developers, professionals and others to make use of this publication of the journal for the development and research of accepted scientific papers which will be available free online with full text content once the final versions are received and will be indexed on the main academic databases [2] - [4].

Figure 2: Solar Dehydrator

The components used in this project (shown in Figure 3) are; 3 type "J" thermocouples, with a temperature range between 0 ° to 750 ° C. with an MAX7566 Analog to Digital signal converter. Electronic circuit with four relays, the function of the first three is to have the thermocouples connected, which will be activated one by one to send the signal to the Max7566 converter, this converter then sends the signal to the *Arduino*. The fourth relay is responsible for the activation of a fan which will have the function of maintaining a homogeneous temperature. The matrix keyboard allows access to the menu programmed in the *Arduino* which will allow different options according to what is shown in the programming language; this menu is shown in an LCD also called a *display*. To save the desired data at certain times, a flash memory is used, with this stored information in the memory the behavior of the internal temperature of the solar dehydrator is analyzed and plotted.

Finally, the set of electronic components are connected to the *Arduino*, which will have the necessary programming for the proper functioning of; control, display and save readings of dehydrator temperatures; as shown in the figure3.

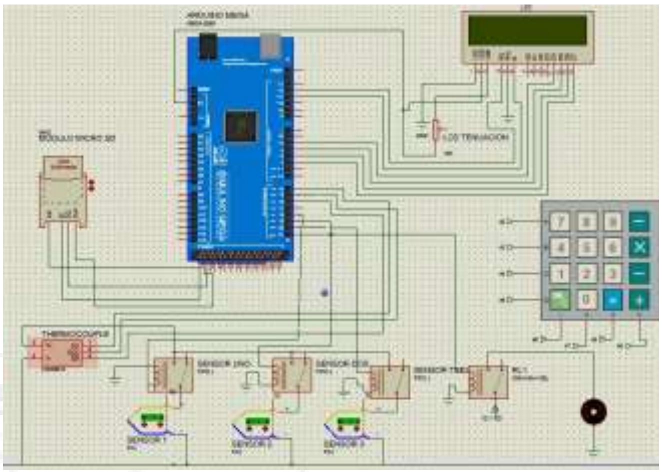

Figure 3: Solar Dehydrator’s Electronic diagram

For all these electronic instruments a cabinet was designed which guards and keeps them free of dust and water which can affect the system as show in the figure 4.

Figure 4: Electronic components cabinet

The program development of is carried out in *Arduino* which is a microcontroller designed to facilitate programming, is a low cost controller in comparison to other industrial type controllers, this microcontroller allows us to perform readings of both *analog* and *digital* inputs, for the particular case of this project, it is programmed to obtain readings from the thermocouples through the MAX7566.

The flow chart applicable to the developed project is shown in Figure 5:

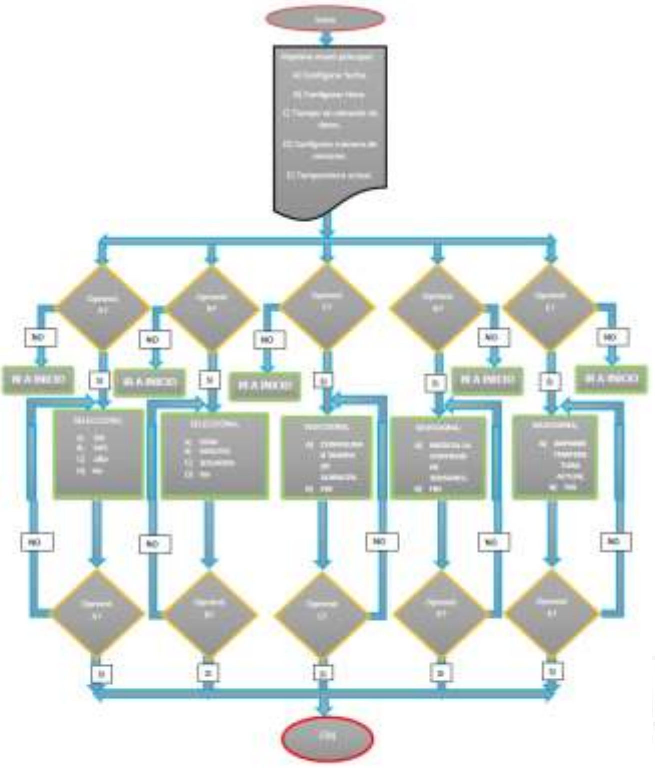

Figure 5: Control logic flow diagram

According to the flow diagram; the program starts confirming that the memory is inserted; shows the memory has set-up correctly and starts the readings. First a document named TEST1.TXT is created, then, the main menu of options is presented on the LCD screen, displaying the following options:

A) Set date.
B) Set Time.
C) Time in data warehouse.
D) Configure number of sensors.
E) Current temperature.

When selecting subsection *A)*, it will give the option to enter day, month and year by means of the matrix keyboard, in option *B)* will allow to enter minute and second hours through the matrix keyboard. In *C)* it will allow inserting a time value to program the time to store temperature data. Once the document * *.txt* has been created correctly and the warehouse time has been configured, the data storage will start, a warehouse of every second being predefined.

Pressing the *D)* key will allow entering a maximum of 3 sensors, when selecting the current temperature option, it will display on the LCD the temperature obtained from the three sensors, and by pressing the *# (Octothorpe) key*, will end each option as completed.

In this section we present the temperature tests performed on the dehydrator, these reflect the solar dehydrator's behavior in their three respective areas. The temperature of the three thermocouples is shown in the following graphs, where we can see in their measurement of each individual thermocouple and the measurement. Comparison of the thermocouples is shown in fig. 6

***Figure 6.** Solar Dehydrator's thermocouples data comparison chart*

As we can see in figure 6, temperature readings of the thermocouples are taken with a measuring instrument in order to compare the data obtained with the temperature control and the readings of the measuring instrument.

a) rea 1 **b) Area 2** **c) Area 3**

Figure 7: Temperature comparison of with multimeters in each area of the dehydrator

4. Conclusions

In this paper we present a temperature control proposal for the solar dehydrator, which is developed with an *on / off* control type, according to the graphs shown, without a control in this design of the solar dehydrator, the temperature will rise above 65 ° in all three areas where the thermocouples are located, this violently affects the dehydration of the product, and there for causing calcination of the fruit. Which is why, a control was proposed which could maintain and homogenize the temperature all throughout the panel allowing to comply with what is required in the proper dehydration process.

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