Contemporary Engineering Sciences, Vol. 11, 2018, no. 12, 583 - 599
HIKARI Ltd, www.m-hikari.com
https://doi.org/10.12988/ces.2018.8248

Design and Construction of a Vacuum Osmotic Dehydrator Applied to Tropical Fruits

Luis Alberto Gallo-García, Leonor Hernández Miranda and Diofanor Acevedo-Correa

Research Group Innovación y Desarrollo Agropecuario y Agroindustrial
Universidad de Cartagena, Av. Consulado, Street 30 No. 48-152, 130015
Cartagena de Indias, Colombia

Abstract

Vacuum impregnation is a unitary operation that allows the occluded gas in the porous structure of a food to be partially exchanged for an external liquid phase in contact with it. The main objective of this work was to design and build an osmotic vacuum dehydrator applied to papaya, melon and mango, coupled with temperature control, vacuum pressure and stirring rate. Firstly, the vacuum pressure, temperature and stirring rate control system for the osmotic dehydration equipment was designed. Afterwards, the analysis and calculations of the materials used for the design of the osmotic dehydration equipment were carried out. Finally, the operation of the osmotic dehydration equipment was constructed and validated, studying the osmotic dehydration kinetics of these fruits. The design was able to control temperature, stirring rate and vacuum pressure, and the prototype can be used for dehydration of papaya, melon and mango.

Keyword: Moisture kinetics, equipment design, temperature control, vacuum pressure and stirring rate

1. Introduction

Dehydration of agricultural products leads to longer shelf life, reduced shipping and packaging costs as a result of reduced weight and volume, and increased market diversification. Among the dehydration treatments, osmotic dehydration (OD) has attracted the attention of many food product developers, due to its good quality preservation results. It can be carried out to obtain various types of products, such as minimally processed or intermediate wetted products, or as a pre-treatment prior to drying or freezing [1].

An alternative for man to make more and better use of food is to conserve it by reducing the water content. Currently, there is a broad trend towards the development of food preservation techniques that make it possible to obtain products of high nutritional quality while maintaining their sensory characteristics [2]. The OD process is characterised by dynamic periods and equilibrium periods. The kinetics of the OD process is determined by the approximation to equilibrium, by the initial differential osmotic pressure between food and osmotic agent and by the diffusion rates of water and solute [2], and these are controlled by the transport of moisture in the product and by the structure of the fruit (porosity). Water can be diffused 10 to 100 times faster than solutes (glucose, sucrose, fructose, etc.) in a temperature range between 45°C and 70°C through the cell membrane [2], in turn improves DO kinetics, making vacuum during the whole process of DO or vacuum pulses (VPOD), in which occurs a hydrodynamic mechanism (HDM), which consists of the gas present in the pores expands and exits gradually. Once the system pressure has been restored, the pressure gradient acts as a driving force by causing compression of the remaining gas and allowing external dissolution to occupy this space [2, 3] and increasing the area of interfacial contact, causing an increase in the mass transfer rate[2].

In the OD process, two main diffusion flows countercurrently through the cell walls occur. An important flow of water exits the product into the hypertonic solution and simultaneously flows in opposite directions from small concentrations of the dehydrating solution to the product [2, 4, 5]. The osmotic process is affected by the physicochemical properties of the solutes used, because the efficiency of dehydration is possibly affected by the molecular weight, ionic state and solubility of the solution in water. The selection of the solution could be considered according to the following factors: (i) the impact of the solution on the sensory characteristics of the product, (ii) the relative cost of the solution in relation to the final value of the product, and (iii) the molecular weight of the solution. Some of the most commonly used solutes are sodium chloride, sucrose, glucose and corn syrup [5].

The aim of this research was to design and build a vacuum osmotic dehydrator applied to papaya, melon and mango. To carry out the design and construction of this equipment, all the necessary information was first consulted and compiled, a sketch and calculations of the equipment were also carried out, then the electrical and electronic components were classified and selected, and a software was designed to calculate the variables such as temperature, vacuum pressure and stirring rate. Then the construction and assembly of the equipment was carried out, in addition to functional and start-up tests as well as the validation of the prototype.

2. Methodology

For the design of the equipment, it was necessary to take into account the control of the variables involved in the process: the density and viscosity of the osmotic agent used in the dehydration process was considered, taking as a reference the density and viscosity of the glucose (0.8 g/mL and 665 cP), as well as the maximum speed reached by the solution taking into account previous research [6]. The design of this prototype was carried out using CAD software as a tool.

2.1 *Design of the osmodehydrator prototype*

The equipment is designed as a shaken tank type without jacketed, heated by means of a clamping resistor and has a control panel with three variables (temperature, stirring rate and pressure) of great influence on the final conditions of the product. This control is digital and each variable is independently controlled. The tank was constructed in stainless steel AISI 304 caliber 14 with a thickness of 3 mm film. The vessel and agitator dimensions (Figure 1) [8, 9] were determined for a capacity of 26 L, the dehydration tank followed the standards for stirring tanks shown in Figure 1.

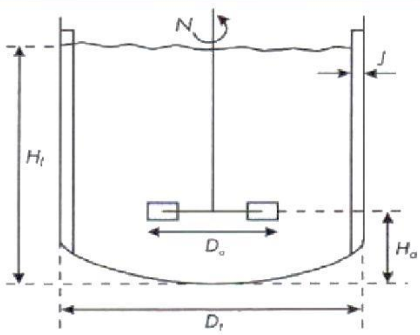

Figure 1. Standard stirring system
Barboza et al., [9].

The variables to be taken into account when designing a standard stirring system can be seen in the Figure 1, where: N = Rotation speed; D_t = Tank diameter; D_a = Diameter of the agitator; H_l = Height of the liquid; H_a = Distance from the base of the agitator tank; J: Width of the baffle plates. The capacity was based on design priorities, the requested volume was 20L, but the safety factor was taken into account due to errors in the mathematical model, theory of faults used or characteristics of the materials used, this safety factor depends fundamentally on: application of the current regulation, level of designer confidence or failure of the material (ductile, fragile) form [10]. The equipment was designed taking into account the equations for the volume of a cylinder.
Therefore, the dimensions chosen for the equipment were in accordance with the expected capacity to store 26L of osmotic solution.

2.2 Selection of agitator type and electric motor

For the design and calculation of the agitator, the dimensions of the tank selected were taken into account, as well as the variables that influence the power consumed by it: D: tank diameter (m); Da: agitator diameter (m); H_l: liquid height (m); J: width of the baffle plate (m); E: height of the liquid to the bottom of the tank; viscosity of the fluid (Pa*s); density of the fluid (kg/m^3); N: speed of stirrer rotation (rps). The calculation of the consumed power was done through dimensional numbers, relating in a graph the number of Reynolds and the number of power. These graphs depended on the geometric characteristics of the agitator and whether or not deflector plates are present.

Reynolds number = inertia stress / shear stress. Which is expressed by the Equation 1:

$$N_{Re} = \frac{D_a^2 N\rho}{\mu} \tag{1}$$

Taking into account the impeller design of a standard turbine [8 ,9, 11], we have: di = H/2, impeller diameter; W = H/5, impeller width; L = H/4, blade length; C = H/6 to H/3, being *C* height from the impeller to the bottom of the tank, with these conditions was obtained: di = 32.1 cm / 2 = 16.05 cm agitator diameter, for impeller width W = 32.1 cm /5 = 6.42 cm; L = 32.1 cm / 4 = 8.025 cm; C = average value of the interval, i. e. H / 4 = 8; C = 8.025 cm. A motor with the ability to reach speeds of 150 rpm (2.5 rps) was then selected; bearing in mind that 1cP = 10^{-3} kg/m. s, then 665 cP = 0.665 kg/m. s, glucose density (0.8 g/mL = 800 kg/m^3), equation 1 remained so [9, 12], replacing these values was obtained:

$$N_{Re} = \frac{(0{,}08025m)^2 * 2{,}5\ ^{rev}/_{s} * 800kg/m^3}{0{,}665\ ^{kg}/_{m.s}} = 207.24 \quad (2)$$

From the ratio graph N_{Re} vs N_{Po}, and following curve 4 for diagramming a power curve, for tank without baffle plates (Figure 2).

N_P=2.8

Clearing the Power Number Formula

$$P = N_P * N^3 * D_a^5 * \rho \quad (3)$$

Substituting, it was obtained the following:

$$P = 2.8 * \left(\frac{2.5\ rev}{s}\right)^3 * (0.0802m)^5 * \frac{800\ kg}{m^3}$$

$$P = 0.116\ ^{kg}/_{m^2s^3}$$

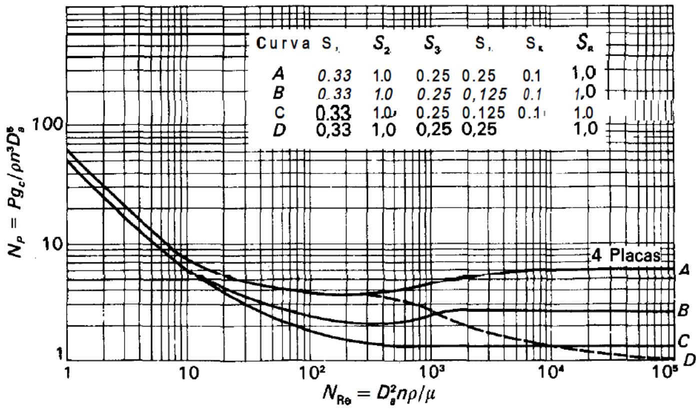

Figure 2. Power curve for agitation of low or moderate viscosity liquids

On the other hand, the power to overcome inertia was calculated taking into account the torque needed to raise the angular velocity from 0 to 150 rpm, equation 4 [9].

$$P = T \times \omega \quad (4)$$

Here, T = torque to overcome inertia and ω = angular speed of the agitator. T = 0.43 hp, therefore, an electric motor of 1 hp power was selected.

2.3 *Calculation of clamp type endurance power*

The calculation of the resistance power was done in accordance with the energy conservation method, taking also into account the increase in fluid temperature from 28°C to 80°C over an estimated time of 15min. Equations 5 (energy conservation method), 6 (energy storage) and 11 (power to heat the fluid) were used for this:

$$E_{ent} = E_{st}$$

$$E_{alm} == \mu_0 \Delta U_f \tag{5}$$

$$Pot = \frac{E_{st}}{t} \tag{6}$$

Here E_{inp} is the energy input to the system; E_{st} is the stored energy; μ_0 is the mass of the solution; U_f is the internal energy differential; Pow is the power to heat the fluid and *t* is the estimated heating time. Now the initial resistance had a necessary power of Pow = 4.83KW. Based on the calculations, a clamp-type resistor made of ASI 316 series stainless steel was designed with a power of 8kW.

2.4 Microcontroller selection

The control system consists of an electronic card for processing and data acquisition of the monitored variables, this card was implemented with microcontrollers of the PIC family (integral proportional controller). For the selection of the microcontroller, a comparison was made between two microcontrollers (PIC16F877A and DSPIC33FJ128) easily available on the market, among other factors, after this and according to the requirements of the project, it was concluded that the DSPIC33FJ128 is the microcontroller that best fits the needs, since it has more inputs and outputs PWM, motor control by PWM, among other features such as increased program memory capacity and RAM, working speed (40 MIPS), clock and calendar in real time.

2.5 User-machine interface

For the selection of the control strategy of the osmotic vacuum dehydration equipment for tropical fruits, the different types of control (ON/OFF, P, PD and PID) according to each of the variables to be controlled and their importance in the process were taken into consideration. For the temperature control system, an

ON/OFF control with hysteresis was selected which allowed a maximum error above and below the reference value within the working range of 30 - 80 °C. For vacuum pressure control, an ON/OFF control with hysteresis was also applied; allowing a minimum adjustable error within the control band (14.7 psi- 7.7 psia) according to the user-selected range [10].
For the control of the solenoid relief and drainage valves, an ON/OFF control was used since they only require an opening or closing command when the process requires it, either because the pressure must be relieved or balanced, or at the end of the test drain the solution inside the tank, and this control strategy, unlike other osmodehydration equipment, allows a safe process by not doing it manually. Finally, a Derivative Integral Proportional Integral Control (PID) was selected to control the speed of the agitator motor since it transmits a more precise behavior of the speed with which the fruit and solution are being mixed [13].

2.6 Cabinet 1: Power (CP)

The power cabinet is located on the right side of the structure and consists of the following elements: Connection terminals, breaker Totalizer 220 VAC, breaker Totalizer 110 VAC, solid-state relay for vacuum pump, solid-state relay for P-001, frequency converter for agitator motor, 24 volt DC power supply unit (VDC).

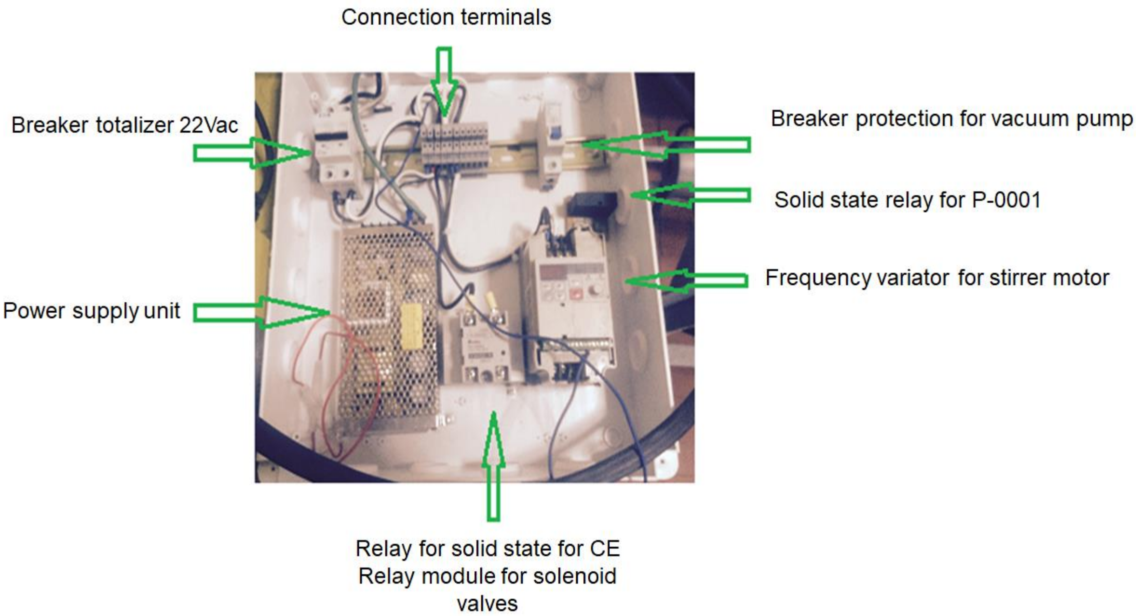

Figure 3. Power cabinet

2.7 Control cabinet (GC)

The main control cabinet, located on the left side of the structure, consists of the following elements: Exbee module for wireless data transmission, main control card, 12 VDC power supply, relay modules for solenoid valves.

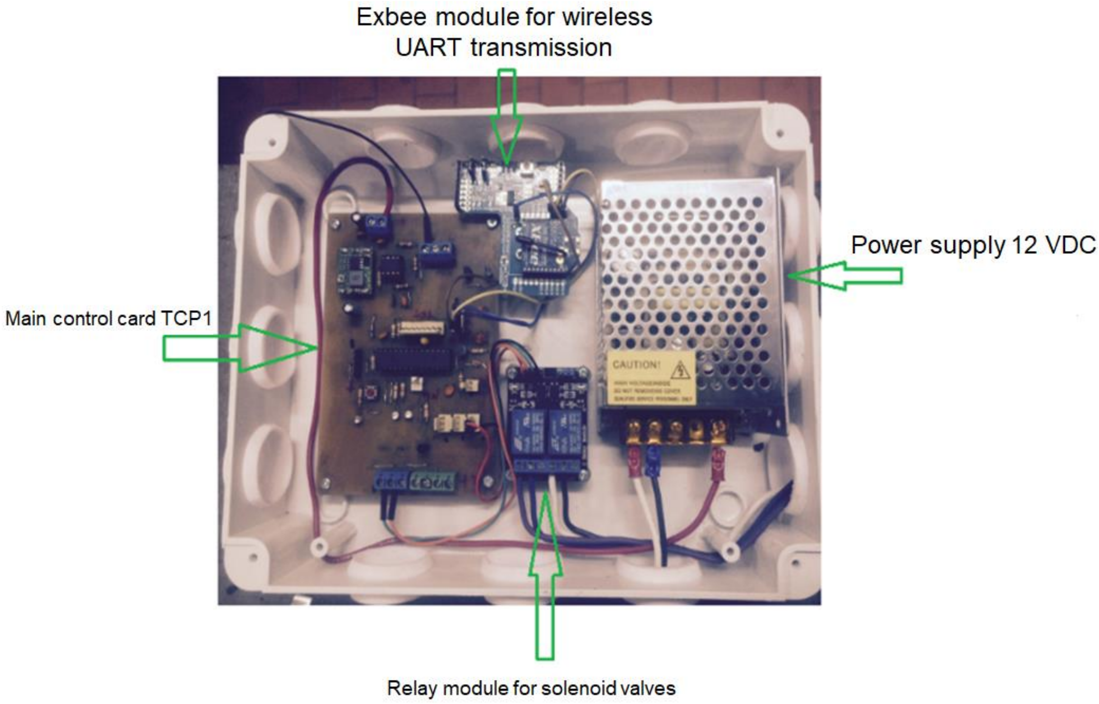

Figure 4. Control cabinet

3. Results

3.1 Equipment Construction

The dehydrator tank is the main base of the prototype as it is the one in charge of supporting the whole fruit dehydration process, with measures of 300mm diameter and 360mm high, in stainless steel AISI 304, it is supported with a base plate that has 1.5m^2 approximately, the temperature sensors, solenoid valves, pressure transmitter, manual safety valves, clamping resistor and pressure indicator are fixed on it. With respect to the part of the tank seal to conserve the vacuum, the lid has a special nitrile gasket for food processing [14], which helps to maintain the vacuum pressure with losses of approximately 1 psia every 3min approximately. In addition to this, it has six fixing points which are manually adjusted to provide watertightness and greater sealing. The construction and assembly of the equipment was carried out by means of fasteners (screws) in order to make maintenance easier. Figures 5 and 6 show the prototype already built.

Figure 5. Osmodehydrator tank

Figure 6. Vacuum osmotic dehydrator

3.2 Application of operation of the vacuum osmotic dehydration equipment

In order to set up the control system, a series of tests were implemented on each particular circuit in order to adjust the variables and constants for each particular control. The following variables were used: vacuum pressure, temperature, stirring rate, switching on and off of solenoid valves.

3.3 Function test for vacuum pressure

For this variable the following elements intervened: tank, absolute pressure transmitter, absolute pressure indicator, main control card (tcp1) taking into account the voltage that handled the 3.3 VDC tcp1 (microcontroller voltage), the reference of pressure ranges (14.7 psi to 7.7 psi), the characteristics of the transmitter that handles a 24 VDC voltage with 4 to 20 mA output current, the complete sealing of the tank and the pressure indicator being connected correctly, the following adjustments were made: after having the signal emitted by the transistor conditioned so that the tcp1 circuit is able to read it, a 246 data recorded in an Excel table was taken to facilitate the calculation of the equation entered in the DSPIC code to interpret the data emitted by the transmitter.

Table 1. Vacuum pressure and voltage data

Pressure	Voltage
7.00	2.99
7.08	2.99
7.10	2.99
7.20	2.99
7.21	2.98
7.25	2.98
7.29	2.98
7.33	2.98
7.37	2.98
7.40	2.98
7.42	2.98
7.45	2.97
7.47	2.96
7.50	2.94

Once the equation of Table 1 has been obtained, the DSPIC code for data acquisition from the transmitter was performed, as well as the code for display in the HMI control.

3.4 Temperature control set-up

Bearing in mind that the DS18B20 sensor used is a digital temperature sensor with one-wire communication (single cable) and that the dSPic has several digital inputs (Pin 6, Pin 1). The control hardware can be connected directly to the microcontroller without the need for an adaptation stage. The reference temperature was taken as the ambient temperature (28°C) and every time the user requires it, type the temperature set point in the HMI panel, it will activate the solid state relay so that the electrical resistor can then be put into operation.

3.5 ON/OFF control tests of solenoid valves

The control only took into account the working time of the process, given by the user of the equipment, by a digital output (pin 12) of the dSPic, then a relay module was commanded that had the function of switching the 24 VDC signal for the operation of the solenoid valves.

3.6 Equipment performance testing and process simulation

The ON/OFF control with temperature hysteresis functioned satisfactorily according to program logic and design assumptions, finally the system was left with a temperature error of ± 10°C from the user-selected range, i. e. at 10°C below the user-selected range, the resistance receives the heating signal and 10°C above receives a shutdown signal. The ON/OFF control with vacuum pressure hysteresis was carried out with an error of ± 0.5 psi, keeping the vacuum pump suction in the tank due to the tightness of the vacuum pump. This way if the vacuum pressure is 0.5 psi below the range selected by the operator, it receives the signal to turn the pump on and once it is 0.5 psi above the range it will receive a command to turn off.

The control of the pressure relief and drain solenoid valves (VAP and VDS) respectively responded adequately by opening and closing in the established times of less than three seconds by means of the program logic, that is to say; once all the values selected by the operator for each of the variables have been reached, it initiates a time delay for 15 min. Upon completion of this time, the pressure relief valve receives command to open in order to balance pressures or break the vacuum in the tank, and immediately restarts the system at the initial cycle.

The PID control of the stirring rate manifested precision at the time of tuning the constants Kp, Ki and Kd; in order to have greater accuracy in the speed with which the solution is shaken so as not to affect the integrity of the fruit. The constants were tuned by the trial and error method, looking for the critical point in each of them. Finally, the system remained with the following constants Kp = 5, Ki = 8.24 and Kd = 0. Constants can later be modified to experiment with various plant behaviors or prototypes. The communications module implemented worked properly since it transmitted and received the process variables in real time to exercise control actions according to the programmed logic. In the first instance, an osmotic solution was prepared with commercial sugar, with a concentration of 65°Brix, measured with a digital refractometer, and once the 15L of the solution had been prepared, it was deposited in the tank of the osmodeshydrating equipment. Immediately the equipment cover was closed, the resistor and the stirring motor were switched on. When the resistance reached the selected working temperature, i. e. 45°C, the motor was switched off and the resistance, then 1Kg of melon cut into $2cm^3$ cubes was deposited, consequently the resistance was switched on, then the motor and then the vacuum pump. All selected controls had a range set point selected by the operator. Every 15 min the process was stopped and the sample weighed on a scale to observe the weight loss. The operation was performed for 1h, repeating the previous test.

3.7 Vacuum osmotic dehydration of mango, melon and papaya

Fresh papaya, melon and mango fruits were selected, removing those that presented physical damage, or by insects or mechanical manipulation, choosing products with a first quality grade, according to the Colombian Technical Standard NTC-1270 given by ICONTEC (1993) [15]". Once the selected fresh products were obtained, they were peeled and cut into cubes of two centimetres on the side, immersed in the sweetening agent (sucrose), 55 °Brix and 30°C for five hours, with steady stirring and vacuum pressure of 9 psi, making an osmotic dehydration kinetics. For each time period of one hour the humidity was determined. With these values, the amount of water removed during the process (released by the fruit) was calculated, all analyses were carried out in triplicate.

Table 2 shows the moisture content of the fruits during the first five hours of dehydration, with their respective standard deviation. It is detailed that for all times there were significant statistical differences between each fruit ($p<0.05$), this is because, as time went by, the moisture content of the fruit decreased due to the pressure gradient that existed between the pressure of the system and the osmotic solution (hydrodynamic mechanism). Studies carried out by Chavarro-Castrillón et al., [20], on the osmotic dehydration kinetics of papaya, reported that there was greater loss of water and weight in the papaya samples, possibly this behavior is due to the high porosity (11.36%) which allows the water contained inside the cells to escape through the pores more easily.

This behaviour shows that the dehydration rate is only favoured because during the vacuum pulse the air trapped in the pores of the sample is removed, and when atmospheric pressure is re-established, some solutes are quickly incorporated into the food by the exchange between the gas or internal liquid in the pores and the external solution through hydrodynamic mechanisms and the internal pressure of the cell is increased, a pressure gradient is generated between the inside and outside of it [21].

Table 2. Results Percentage moisture content of mango, melon and papaya

Time	Mango	Melon	Papaya
0	0.823 ± 0.23^{a}	0.905 ± 0.22^{a}	0.922 ± 0.65^{a}
1	0.737 ± 0.13^{b}	0.832 ± 0.27^{b}	0.836 ± 0.55^{b}
2	0.656 ± 0.35^{c}	0.727 ± 0.36^{c}	0.754 ± 0.54^{c}
3	0.594 ± 0.52^{d}	0.651 ± 0.64^{d}	0.686 ± 0.58^{d}
4	0.542 ± 0.33^{e}	0.588 ± 0.37^{e}	0.618 ± 0.68^{e}
5	0.495 ± 0.45^{f}	0.516 ± 0.66^{f}	0.541 ± 0.2^{3f}

Figure 1 shows the osmotic dehydration kinetics of papaya, melon and mango. It is evident that the fruit that lost most moisture was mango, followed by papaya and melon. This may be due to the structure of each fruit, which pressure causes pores in the food matrix to expand and water to flow out of the fruit more quickly. Research carried out by Martínez et al., [16], during osmotic mango dehydration, reported that after five hours, the samples reached a range of water activity between 0.957 and 0.963, consistent values if we take into account that water losses are around 40%. Osmotically dehydrated treatments with vacuum pulses obtained faster kinetics in solutes gain and water loss, especially in scalded samples [16]. During osmotic dehydration of various fruits and vegetables, physiologically active compounds are transferred from external hypertonic dissolution to the interior of plant tissue by a process usually controlled by the phenomenon of diffusion.

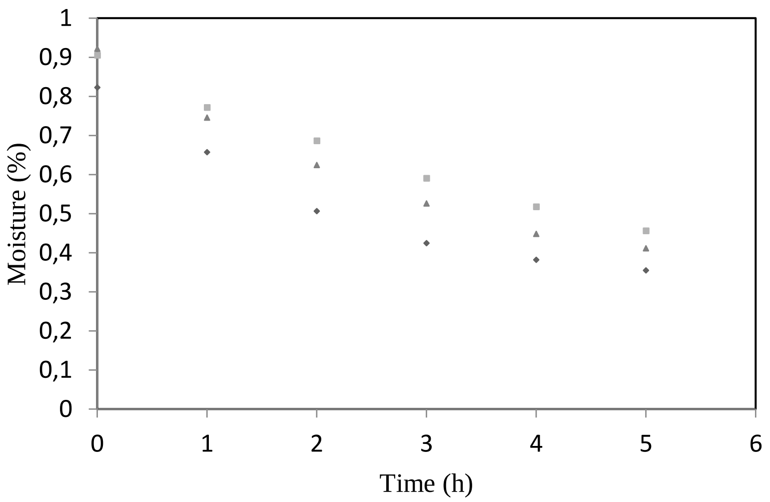

Figure 7. Kinetics of osmotic dehydration of papaya, melon and mango.

The kinetics of material transport during the osmotic dehydration (OD) processes, as well as the properties of the final product, are also affected by the previous application of a vacuum impregnation operation [13, 17], the greatest loss of water by the food in the osmotic drying process occurs in the first six hours, with the two initials being the highest rate of water removal. This kinetic trend was also reported by Nowakunda et al., [18] in osmodehydration of banana slices, which indicated that bee honey has the greatest capacity to reduce water activity, mainly due to its high concentration of fructose (40-50 % by weight) [13, 19]. Also Chaparro et al., [22], claimed that during osmotic melon dehydration, processing time and vacuum pressure were the most significant factors explaining water loss in melon fruits. The most influential combination treatment was vacuum time pressure treatment, which was inversely associated with water loss, which is attributed to the hydrodynamic mechanism that occurs just when atmospheric pressure in the system is restored. In the case of vacuum pressure, the maximum value of water loss occurred at the maximum vacuum level attributed to the removal of air from the pores increasing the potential for mass transfer between the external medium and the sinus of the fruit.

4. Conclusions

The vacuum pressure, temperature and stirring rate control system of the osmotic vacuum dehydration equipment fulfilled the PID and ON/OFF control functions with hysteresis required by the user. Solenoid valves, pressure gauges and temperature sensors reported reliable data during operation. In addition, the validation carried out with vacuum-hydrated osmodehydrated fruits proved to be an effective technology in the development of fresh fruits. This equipment could be used to carry out various investigations in the dehydration area of tropical fruits of the Caribbean Region.

References

[1] L. Oliver, N. Betoret, P. Fito, M.B. Meinders, How to deal with visco-elastic properties of cellular tissues during osmotic dehydration, *Journal of Food Engineering*, **110** (2012), no. 2, 278-288. https://doi.org/10.1016/j.jfoodeng.2011.04.028

[2] D. Torres, D. Salvador, R. Baltazar, R. Siche, Optimización de las condiciones de deshidratación osmótica de espárrago (*Asparragus officinalis*)

utilizando la metodología de superficie de respuesta, *Agroindustrial Science*, **3** (2013), no. 1, 7-18.
https://doi.org/10.17268/agroind.science.2013.01.01

[3] P.D. Rocca, *Secado De Alimentos Por Métodos Combinados: Deshidratación Osmótica Y Secado Por Microondas Y Aire Caliente*, Diss., Universidad Tecnológica Nacional, Facultad Regional Buenos Aires: Ciudad Autónoma de Buenos Aires, 2010.

[4] M. Castelló, P. Fito, A. Chiralt, Changes in respiration rate and physical properties of strawberries due to osmotic dehydration and storage, *Journal of Food Engineering*, **97** (2010), no. 1, 64-71.
https://doi.org/10.1016/j.jfoodeng.2009.09.016

[5] R.R. Bambicha, M.E. Agnelli, R.H. Mascheroni, Optimización del proceso de deshidratación osmótica de calabacita en soluciones ternarias, *Avances en Ciencias e Ingeniería*, **3** (2012), no. 2, 121-136.

[6] W.L. McCabe, J.C. Smith, P. Harriott, *Operaciones Unitarias en Ingeniería Química*, Cuarta edición, McGraw-Hill, España, 1991.

[7] Colombia. Ministerio de Salud. Decreto 3075: por el cual se reglamenta parcialmente la Ley 09 de 1979 y se dictan otras disposiciones. Bogotá (Colombia) 1997, 47 p.

[8] N. Chopey, *Handbook of Chemical Engineering Calculations*, Section 12, Liquid Agitation. Dickey, Third Edition, México: Mc Graw-Hill, 1986.

[9] J.E. Barbosa, D.C. Villada, S.A. Mosquera, Diseño y construcción de un equipo osmodeshidratado para el desarrollo de nuevos productos agroalimentarios, *Biotecnología en el Sector Agropecuario y Agroindustrial*, **11** (2013), no. 1, 37 – 46.

[10] J.M. Marín, *Apuntes de Diseño de Máquinas*, Segunda edición, 22-23. Club Universitario, San Vicente Alicante, 2008.

[11] C.J. Geankoplis, *Procesos De Transporte y Operaciones Unitarias*, Tercera edición, Compañía Editorial Continental, México, 1998.

[12] S.L. Bonilla, *Diseño De Un Equipo De Deshidratación Osmótica Con Pulsos De Vacío (DOPV) De Tamaño Industrial, Y Generación De La Propuesta Económica Para La Construcción Del Equipo*, Diss., Universidad de la Sabana, Facultad de Ingeniería de Producción Agroindustrial, Chía, 2004.

[13] G. Barbosa, H. Vega, *Deshidratación de Alimentos*, Zaragoza (España), Acribia, 2000.

[14] Flexitallic, Soluciones de sellado. Criterio de diseño para juntas de sellado, 2014. http://www.flexitallic.com/uploads/files/broDesignCriteria-spanish.pdf

[15] Instituto Colombiano de Normas Técnicas, Industria alimentaria: papaya. Bogotá, D.C.: ICONTEC, 1993. (Norma Técnica Colombiana; NTC-1270). https://tienda.icontec.org/wp-content/uploads/pdfs/NTC1270.pdf

[16] J. Martinez, A. Calero, A.A. Aponte, A. Chiralt, P. Fito, Efecto del Escaldado sobre la Deshidratación Osmótica del Mango, *Revista Ingeniería y Competitividad*, **4** (2011), no. 2, 27-33. https://doi.org/10.25100/iyc.v4i2.2310

[17] M.M. Ríos, C.J. Márquez, C. Velásquez, H. José, Deshidratación osmótica de frutos de papaya hawaiana (*Carica papaya* L.) en cuatro agentes edulcorantes, *Revista Facultad Nacional de Agronomía, Medellín*, **58** (2005), no. 2, 2998-3002.

[18] K. Nowakunda, A. Andrés and P. Fito, Osmotic dehydration of banana slices as a pretreatment for drying processes, *Proceedings of the 14th International Drying Symposium (IDS 2004)*. São Paulo, Brazil: The Symposium, (2004), 2077-2083.

[19] C.P. Londoño, Estudio palinológico de miel procedente del apiario "Los Charchos" (Santa Bárbara). Diss., Facultad de Ciencias Agropecuarias, Universidad Nacional de Colombia, 1998.

[20] L.M. Chavarro-Castrillón, C.I. Ochoa-Martínez, A. Ayala-Aponte, Efecto de la madurez, geometría y presión sobre la cinética de transferencia de masa en la deshidratación osmótica de papaya (*Carica papaya* L., var. Maradol), *Food Science and Technology (Campinas)*, **26** (2006), no. 3, 596-603. https://doi.org/10.1590/s0101-20612006000300018

[21] L.A. Melo, H. Ordóñez, O.B. López, Efecto de la presión y de la temperatura durante la deshidratación osmótica del mango Tommy Atkins en solución de sacarosa, *Noos (Colombia)*, **9** (1999), 127-139.

[22] L. Chaparro, N. Soto, T. García, J. Gutiérrez, J. Palmero, Efecto de la presión de vacío, sólidos solubles totales y tiempo de procesamiento sobre la deshidratación osmótica de rebanadas de melón, *Bioagro*, **22** (2010), no. 3, 223-228.

Received: March 3, 2018; Published: March 29, 2018