# SHRINKAGE PHENOMENON IN CHERRIES DURING OSMOTIC DEHYDRATION

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***Abstract***
*During the process of cherry osmotic dehydration, it is produced the output of water from the cells and the input of soluble solids, modifying the shape, volume and the surface of cherrys in different ways, producing the phenomenon of shrinking. Three formulations were made: witness: 100% sucrose, T1 treatment with 75% sucrose lactitol 25% and T2 and 50% sucrose, 50% with lactitol, in order to study the loss of moisture, and shrinking phenomenon. To the obtained data, a polynomial equation of third degree was adjusted. There are few but important works of osmotic dehydration that include the shrinkage phenomenon.The aim of this work it is to analyze the shrinking phenomenom in cherries by osmotic dehydration. The experimental model was compared with the Lozano, Ochoa y Ratti's Models for drying cherries in convective conditions with hot air. The models validated the behavior of osmotic dehydration in the trial conditions.*

**Keywords:** Shrinkage, cherries, osmotic dehydration, volume, surface

Received: 21.09.2019 Received in revised form: 25.02.2020 Accepted: 28.02.2020

## 1. INTRODUCTION

The food texture is defined as the sum of reologic as structural features (geometrics and surface). They are perceived through mechanics, tactails, visual and hearing receptors (ISO 1981; Jowitt, 1974).
The integrity of fruit cells can be attributed to the adhesion of cell walls and the strength of the primary wall. The adhesion between the walls has been described as the most critical factor than those, which influence the perception of the texture of the fruit (Diehl y Hamman,1980).
Osmotic dehydration is a technique that partially removes water from the tissues of food by immersion in a hypertonic solution without damaging the food and affecting its quality (Pointing et al, 1966; Mascheroni, 2002). Some soluble solutes of food are lost by being washed away by water. Likewise, there is a gain of soluble solutes by the food from the solution. Significant changes in the volume and structure of the food are observed. As well as variations, havebeing perceived in the values of the diffusion and mass transfer coefficients during the course of the process.

The changes that occur on the surface of the fruit are related to the driving force of osmodehydration. Of this, several variables depend and among them the ability of many surfaces, such as the cell wall, to absorb water due to the electrical attraction that water molecules exert on proteins and polysaccharides (Zapata Montoya & Castro Quintero).
Osmotic dehydration involves the dehydration of cellular tissues. As the process progresses, the cells evolve from a structure in highly organized equilibrium to a more disordered set of fundamental constituents, due to the deformation of the material. Thus, transport mechanisms and properties are strongly dependent on the nature of the material, its moisture content and temperature, and consequently, its change in dimensions.
Depending on the type of geometry and size that the product presents, the area per unit volume will vary depending on the action of the osmotic solution. Different studies showed that if you have smaller products (the surface per unit volume increases) the water loss rises; on the contrary, if you have pieces of fruit, or another food, of larger size (the surface per unit of volume decreases) the water loss is less.

Knowing the dimensions and shape of the fruit and its modifications during processing, is important for its handling and for the design of the machinery with which it can be processed (Giner, 1989).

As Ochoa (2007) said: "the theoretical approach for shrinkage considers the mechanical forces, and account for material stresses and deformations during drying". This approach would be complicated when applied to foodstuffs because of the multiphase and cellular nature of foods tissues, (Crapiste, et al., 1988; Ratti, 1991, 1994). Some authors studied this phenomenon of shrinking indrying of foods with convective heat air and microwave drying (Raghavan&Venkatachalapathy, 1999). They have proposed fitting equations to experimental data (Ketelaarset al.(1992), Abaloneet al. (1994), Pezzutti (1994), Arnosti, et al. (2000), Mulet, et al. (2000), Moreira et al.(2000), Prado et al. (2000), Ochoa et al. (2002a, 2002b). They have presented data and models in the literature to evaluate the changes of volume and surface area.

Ratti (1994) has indicated that for some foodstuffs, e.g., carrots and pears, the $V/V_0$ versus $X/X_0$it functionis linear in the whole range of water content. This author proposed a model that Ochoa applied to sweet cherries with good results (Ochoa et al. 2002a, 2002b).

The use of variable porosity and volume due to shrinkage during drying improved notably the predictions of the simulation model, showing that shrinkage should not be neglected in the modeling. For other products such as potatoes, garlic,and this author considered that the shrinkage of biological materials under dehydration must also be taken into account when used in the macroscopic balances (Ratti and Crapiste2009).

A general model has been presented by Ochoa et al. (2007) to study the shrinkage in sour and sweet cherry for drying convective. Lozano et al. (1983) also proposed a model to study the shrinking phenomenon.

During the osmotic dehydration, the shrinkage phenomenon occurs too, similar as in dehydration by convective heat air conditions. These phenomena of diffusion modify the shape and the surface in one way or another, producing shrinkage phenomenon due to loss of water that the fruit undergoes, modifying its volume and area. The fruit also undergoes modifications in the weight depending on the characteristics of the dehydrating agent used, the nature of the fruit, temperature, concentration and other intrinsic variables to the system. However, there are few but important studies about shrinkage phenomenon in osmotic dehydration. Silva et al. (2012) studied convective drying conditions in pineapple. Internal changes occur in pineapple`s structure, and diffusion model depends in a shrinkage variable and a variable effective diffusion coefficient, as a better solution.

According to Silva et al. (2014a,b) shrinkage produces internal changes in the structure of the product that affects the effective mass diffusivity. Silva et al.(2014a) have studied the osmotic dehydration of guava slabs using numerical solutions of the one-dimensional diffusion equation with boundary condition of the first kind. They used two models: model 1 disregards the shrinkage of the product and assumes that effective mass diffusivity constant during the process; model 2 takes into account shrinkage, considering effective mass diffusivity as variable.

Farias Aires et al. (2017) studied osmotic dehydration in apples with sucrose at different temperatures, using a model that considers shrinking and variation of process parameters. Silva Júnior et al. (2016) studied the same phenomenon in osmotic dehydration of banana slices.

Almeida Farias Aires et al. (2018) have described a three dimensional numerical solution of the diffusion equation in apples with parallelepiped shape, considering phenomenon of shrinking.

Based on the evidence named above on how shrinkage affects the diffusion phenomenon, the aim of this work is to study experimentally the volume and surface area changes during the osmotic dehydration in whole sweet cherries without pit and to analyze the evolution during the process. The experimental data were

modeled by a polynomic equation and compared with the Lozano, Ratti and de Ochoa's modelsas the first approximation.

## 2. MATERIALS AND METHODS

Bin Sweet cherries of the cultivar (2.4 cm, weight: moisture content: 98% ±; soluble solids: 0.1 °Brix; pH: 4.2), produced in Mendoza, Argentina, were used in the present study case. A multiple impregnation process was used by the slower method. This involves placing the fruit in a solution of relatively low initial concentration, which was increased gradually until reaching the desired final concentration, leaving them a 24 hour period between each concentration. Sixkg of cherries were used. The sweetener solution was added to them in sufficient quantity to cover all of them (ratio of 1:1.2 solid-liquid). The experiment was maintained in constant stirring. The process began with an initial sweetener solution with a nominal soluble solids concentration of 25°Brix in order to prevent wrinkling of the fruit. The prepared syrup was boiled, and cooled until it was 60°C. This temperature was maintained during all the process. The cherries were placed into the solution. Syrup over the cherries was left for a period of 24 hours until the next impregnation. At this point, a withdrawals sample and measurements were made. This process was repeated successively, with the purpose of reaching the soluble solids concentration in a nominal amount of 10°Brix at each new impregnation. It was repeated until the sweetener solution got a minimum concentration of 55°Brix in the flesh. Five impregnations were carried on in full. The syrup mass was kept constant until the last impregnation. The experiment was carried out with cherries, six kg assays were performed in triplicate with sample treatments: Witness samples: 100% sucrose, T1: sucrose 75% - lactitol 25%, T2: sucrose 50% - lactitol 50%. The candying was done in five stages from 25° to 65°Brix. Coloration was done between the third and fourth impregnation with erythrosine and amaranth to 0.0238 and 0.019% respectively and 2% citric acid, reaching pH 3.5. Cherries were packaged in glass flasks of 360 cc and they were autoclaved at 121°C for 10 min using a high-pressure steam sterilizer.
The following parameters were measured in triplicate: soluble solids with Atago refractometer in solutions and fresh during the process, and the moisture in an oven dried at 100 ± 5°C for 24 hours.

### 2.1. Sampling for syrup and flesh

Three sample portions from different parts of syrup, which was mixed to obtain a homogenate system, were taken. The measurement was performed in triplicate and the mean was calculated. Measurements in the flesh were carried out on three cherries (replicates) from different parts of the system, following the same steps above. The three separate samples were allowed to stand for 1 minute on absorbent paper to remove syrup in excess, then they were crushed and only one portion of liquid was obtained in order to measure the Brix value. The sampling frequency after each impregnation was: 1)Every 1 hourbetween to measure weight with an analytic scale Radwag AS/220/C/2 with a precision of $10^{-5}$gand 2) dimension with caliper Palmer Helios (1:50mm).

### 2.2. Shrinkage

In order to measure the shrinking 30 cherries, they were place nylon net.Assuming that the cherry looks like a sphere, three diameters were measured at the coordinates of r, θ,φ. This gave rise to diameters D1, D2 and D3 respectively. These dimensions were measuredwith a caliperPalmer Helios (1:50mm) every time, and weighted a scale Radwag AS/220/C/2 with a precision of $10^{-5}$g during the 5 days of the process, the first 6 hours of treatment.

### 2.3. Mathematical treatment

With the length measurements, the radius of cherries was calculated. With these, their volume "V" (1) and surface "S" (2) area were calculated using the Microsoft Excel® program. In addition, the relative weight loss percentage "Wr" (3) of the cherries was also calculated.

These equations were used:

$$V = \frac{4}{3}\pi r^3 \quad (1)$$

$$A = 4\pi r^2 \quad (2)$$

Wr= (Wi-Wt)/Wi x 100 (3)

This was done taking into account that cherries resemble a hollow sphere, whose sphericity is calculated using the equations of Wadell (1932) "φ1" (4) and Sneed & Folk(1958) "φ2" (5):

$$\varphi 1 = \frac{D1}{MAX(D)} \quad (4)$$

$$\varphi 2 = \sqrt[3]{\left(\frac{D3}{D1}\right) x \left(\frac{D2}{D3}\right)^2} \quad (5)$$

φ1 - sphericity according to Wadell
φ2 - sphericity according to Sneed & Folk
W - cherry weight (g)
Wi - initial cherry weight (g)
Wtcherry weight over time (g)
Wr - relative weight loss percentage (%)
MAX(D) - maximum diameter value
D1- cherry diameter 1 (mm2), measured in the r coordinate
D2 - cherry diameter 2 (mm2), measured in the θ coordinate
D3 - cherry diameter 3 (mm2), measured in the φ coordinate
Avg. – average;

On the other hand, the volume (6), surface (7) and moisture (8) variation rates were calculated using the Microsoft Excel® Solver plug-in, whose equations are described below:

$$Volume\ rate = \frac{V}{Vo} \quad (6)$$

$$Surface\ rate = \frac{S}{So} \quad (7)$$

$$Moisture\ rate = \frac{X}{Xo} \quad (8)$$

S - surface ($mm^2$); $V_o$ - initial volume ($mm^3$)
V - volume ($mm^3$); $X_o$ - initial moisture (%)
X - moisture (%)

Then the moisture and volume variation rates were adjusted by a 3rd degree polynomial (9), represented by the following equation:

$$y = ax^3 + bx^2 + cx + d \quad (9)$$

This polynomial type model was compared with the Ratti (10), Ochoa (11) and Lozano (12) model, using the following equations:

$$\frac{V}{Vo} = 0.2407 + 0.7534\frac{X}{Xo} \quad (10)$$

$$\frac{V}{Vo} = 0.7598\left(\frac{X}{Xo}\right)^3 - 0.6698\left(\frac{X}{Xo}\right)^2 + 0.5299\left(\frac{X}{Xo}\right) + 0.3795 \quad (11)$$

$$\frac{V}{Vo} = 0.161 + 0.816\frac{X}{Xo} + 0.022\,e^{\frac{0.018}{X+0.025}} + \left(0.209 - \frac{0.966}{Xo + 0.796}\right)\left(1 - \frac{X}{Xo}\right) \quad (12)$$

## 3. RESULTS AND DISCUSSION

Table 1 shows principal dimensions of cherries used in trials. The cherries had an average diameter of 21.13 mm, surface 1402.91$mm^2$, volume 4941.72$mm^3$ and sphericity 0.89by Wadell (1932)and 0.86by Sneed & Folk (1958)and a weight of 6.59200g.

The dimension of cherries were diminished during the process due to the loss of water, modifying its volume, surface and weight according to the increase of loss moisture and the imput ofsoluble solids into flesh. We have considered the cherry asa small sphere because the sphericity calculated by Wadell and Sneed &Folk's Models were average0.88 and average 0.83 respectively.

Figure 1 shows the decrease in moisture in cherries. It can be observed as a function of the treatment time. In all treatments, the moisture content at the initial time was 98%.

The same behavior was diminishing with the course of the time by the exit of water that happens in the phenomena of osmotic dehydration, when these are placed in a hypertonic solution of syrup.

**Table1. Principal dimensions of cherries used in trials**

| Treatment | D1 (mm) | D2 (mm) | D3 mm) | S (mm2) | V (mm3) | Φ1 | Φ2 | W (g) |
|---|---|---|---|---|---|---|---|---|
| T0 | 21.41 | 22.56 | 19.98 | 1421.41 | 5039.12 | 1.00 | 0.86 | 6.9770 |
| T1 | 20.83 | 21.29 | 22.25 | 1555.30 | 5767.62 | 1.00 | 0.77 | 6.3568 |
| T2 | 21.42 | 22.57 | 20.00 | 1422.89 | 5046.98 | 1.00 | 0.86 | 6.4423 |

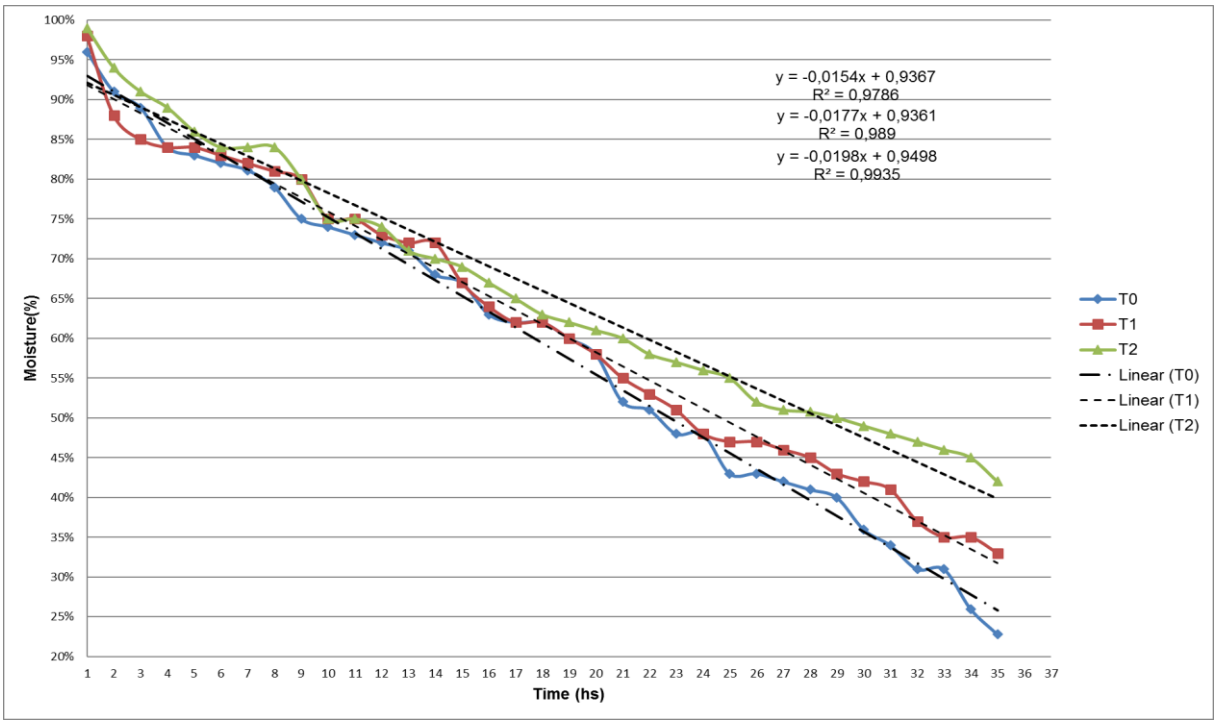


**Figure 1. Comparison of moisture loss for the three formulations and their evolution over time**

For all the treatments, the Witness: 100% sucrose, T1: sucrose 75% lactitol 25% T2: lactitol 50- sucrose 50% were adjusted an equation of the type y: ax +b, being $R^2$: 0.9925 for the Witness: sucrose 100%; $R^2$: 0.989 for T1: 75% sucrose lactitol 25% and $R^2$: 0.9786 for T2 treatment: 50% lactitol 50- sucrose. Although, they behaved in a similar way, it can be observed that theWitness treatment, 100% sucrose, had a final value of 23% moisture, the T1 of 35% and the T2 of 44%.

It could indicate that the sucrose has a greater osmodehydrating power when it is found alone in solution than when it is combined with lactitol in different concentrations or proportions. The difference of osmotic dehydration between the different treatments was an average of 10% at the end of it treatment. This could suggest a different form of diffusion of the sucrose molecule relative to that of lactitol. Table 2 shows the decrease of weight during the process.

**Table 2. Cherries weight reduction during the process**

| Times (hours) | T0 | T1 | T2 |
|---|---|---|---|
| 0 | 6,9770 | 6,3568 | 6,4423 |
| 6 | 6,2091 | 5,9503 | 6,2770 |
| 13 | 6,02113 | 5,87550 | 6,24786 |
| 20 | 5,93117 | 5,80250 | 6,17133 |
| 27 | 5,81376 | 5,72280 | 6,14297 |
| 34 | 5,69488 | 5,54670 | 6,03618 |

In the first 13 hours of trials, all the treatment lost the most of the weight. As a Witness: 100%suc. diminished about 86%of its weight; the T1 diminished about 92%of its weight and the T2 diminished about 97%of its weight. This was due to the exit of water and other substances that were not identified. During the rest of the process, the loss of weight it was very little. For the witness:100%suc. diminished about 14%of its weight, T1 diminished about 8%of its weight and T2

diminished about 3%of its weight. This datacould be indicating that the influence of the nature of the substance, where the cherries were immersed, modifies the intrinsic behavior of porous matrix. Maybe, simultaneously with the loss of moisture, the matrix of cherries wasmodified.Likewise, other authors found in other fruits, that moisture loss occurs, due to the open structure of tissues.

The cellular membranes are not completely semipermeable. Different materials such as solutes from the solution to fruit tissues and solutes from the vegetables or fruits to solution diffuses in the samedirection together with the water. Structural changes in tissues occur simultaneously to the moisture transport. The first few layers of cells are usually assumed to die in response to damage that occurs at the microscopic and macroscopic levels during dehydration (Mavroudis et al., 2004; Ferrando and Spiess, 2001). This hypothesisis consistent with the Alzamora et al.'s (1997) studies showed that osmotic dehydration of strawberry resulted in lysis of plasmalemma, tonoplast and middle lamella membranes (Alzamora et al. 1997). Owing to water loss, protein denaturation takes place resulting in damaged membranes (Salisbury and Ross, 1997). The cell walland cell membranes damage leads to decreased iability and finally cell death (Ferrando and Spiess, 2001).

However, cell death does not always occur.Lewicki and Porzecka- Pawlak (2005) showed that osmotic dewatering caused changes in the size and shape of fruit cells. Sometimes these effects were not enough to break cell walls or to split middle lamella. (Lewicki and Porzecka- Pawlak 2005). The loss of weight modifies the volume and surface of the cell of the cherries in different ways.

Nevertheless, the mechanisms of moisture transport during osmotic dehydration of fruit and vegetable tissues are not completely understood. The three most important pathways for mass transfer were proposed as apoplasmic transport (external to cell membranes) symplasmic transport (internal to the plasma membrane) and trasmembrane flux (Marcotte et al., 1991).

Figure 2 shows the decrease of volume for the three treatments. The behavior was adjusted by a polynomic equation $ax^3 + bx^2 + cx + d$ being $R^2 = 0.9903$ for witness, $R^2 = 0.9895$ for T1: suc. 75% - lact 25% and $R^2 = 0.9889$ for T2: lact 50- sucrose 50%.

The loss of volume was similar for the Witness: suc. 100%, It beganwith aloss volume rateof 1 and decreased to 0.91 after 6hours,0.81 after 12 hours, 0.79 after18 hours, 0.73 after 24 hours, 0.69 after 30 hours and finally 0.61 after 35 hours.

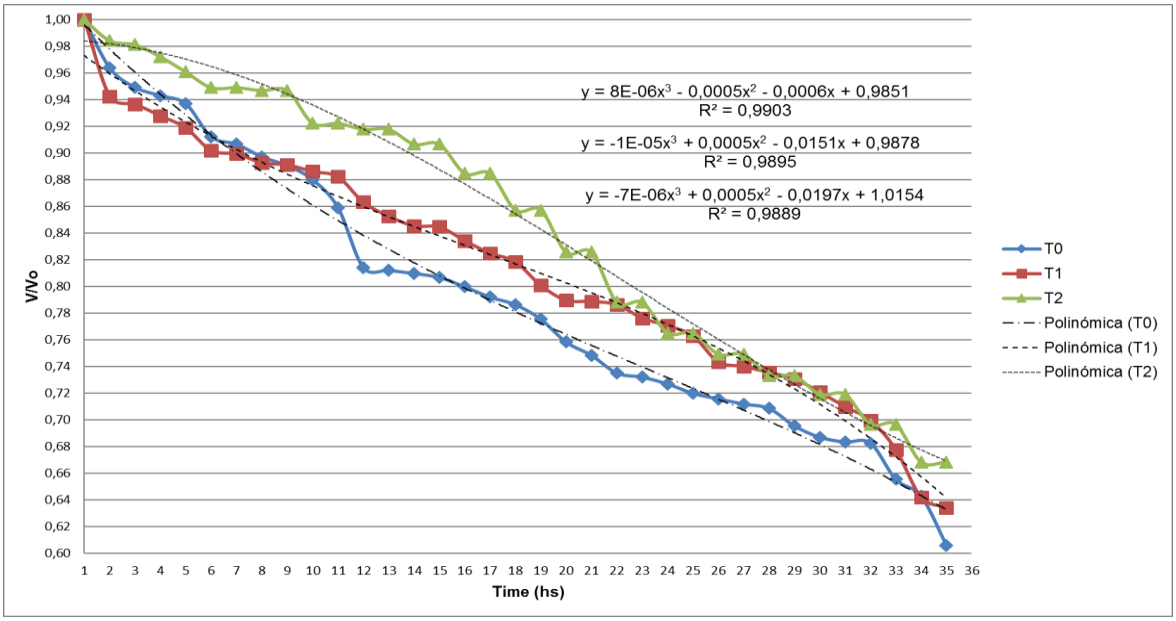


**Figure 2. Evolution of dimensionless volume loss in relation to time for the three formulations**

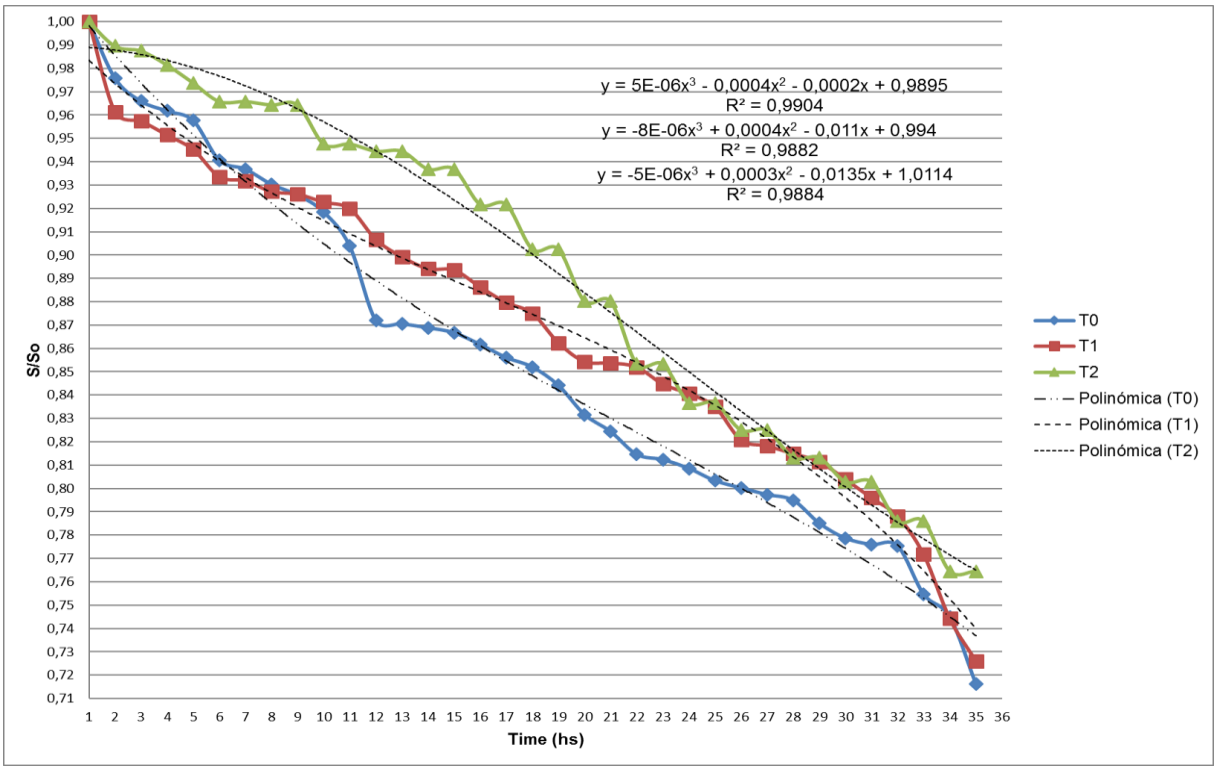


**Figure 3. Evolution of dimensionless surface loss in relation to time for the three formulations**

The loss of volume in T1: suc. 75% - lact. 25% was decreasing slightly less than the Witness. It began with a loss volume rate of 1 and decreased to 0.90 after 6hours, 0.86after 12 hours, 0.82 after 18 hours, 0.77after 24 hours, 0.72 after 30 hours. Finally 0.63 after 35 hours.

The loss of volume was similar for the T2: lact. 50- suc. 50% was decreasing more than theWitnessat the beginning until the 24 hour but it was slower the last 12 hours. It began with a loss volume rate of 1 and decreased to 0.95 after 6hours, 0.92after 12 hours, 0.86 after 18 hours, 0.77after 24 hours, 0.72 after 30 hours.Finally, 0.67 after 35 hours.

The decrease in volume was increasing as time passed and the loss of moisture,also increased. It was higher for the Witness respect to T1 and T2.Maybe it suggests a different form of diffusion of the sucrose molecule relative to that of lactitol.

Figure 3 shows the decrease of surface for the three treatments. The behavior was adjusted by a polynomic equation $ax^3 + bx^2 + cx + d$ being $R^2$: 0,9904 for Witness, $R^2$: 0,9889for T1: suc. 75% -lact. 25% and $R^2$: 0,9884 for T2: lact. 50- suc. 50%. The loss of surface was similar for the Witness: suc. 100%, It began with a loss volume rate of 1 and decreased to 0.94after 6hours,0.87after 12 hours, 0.86 a las 18 hours, 0.81after 24 hours, 0.79after 30 hours and finally 0.72after 35 hrs.

The loss of surface in T1: suc. 75% - lact. 25% was decreasing slightly less than the Witness. It began with a loss volume rate of 1 and decreased to 0.94after 6hours, 0.91after 12 hours, 0.88after 18 hours, 0.84 after 24 hours, 0.81after 30 hours. Finally 0.73 after 35 hours.

The loss of surface was similar for the T2: lact. 50 - suc. 50% was decreasing more than the Witness at the beginning until the 24 hours but it was slower the last 12 hours It began with a loss volume rate of 1 and decreased to 0.97after 6hours, 0.94after 12 hours, 0.92after 18 hours, 0.85 after 24 hours, 0.81after 30 hours. Finally 0.76after 35 hours.

The decrease in surface was increasing as time passed and the loss of moisture,also increased. It was higher for the Witness respect to T1 and T2. It could indicate that the sucrose has a greater osmodehydrating power than lactitol and affects in different ways the cherry cells. The volume and surface influence its final texture due to a differential diffusion of water that gets out of flesh cherries.

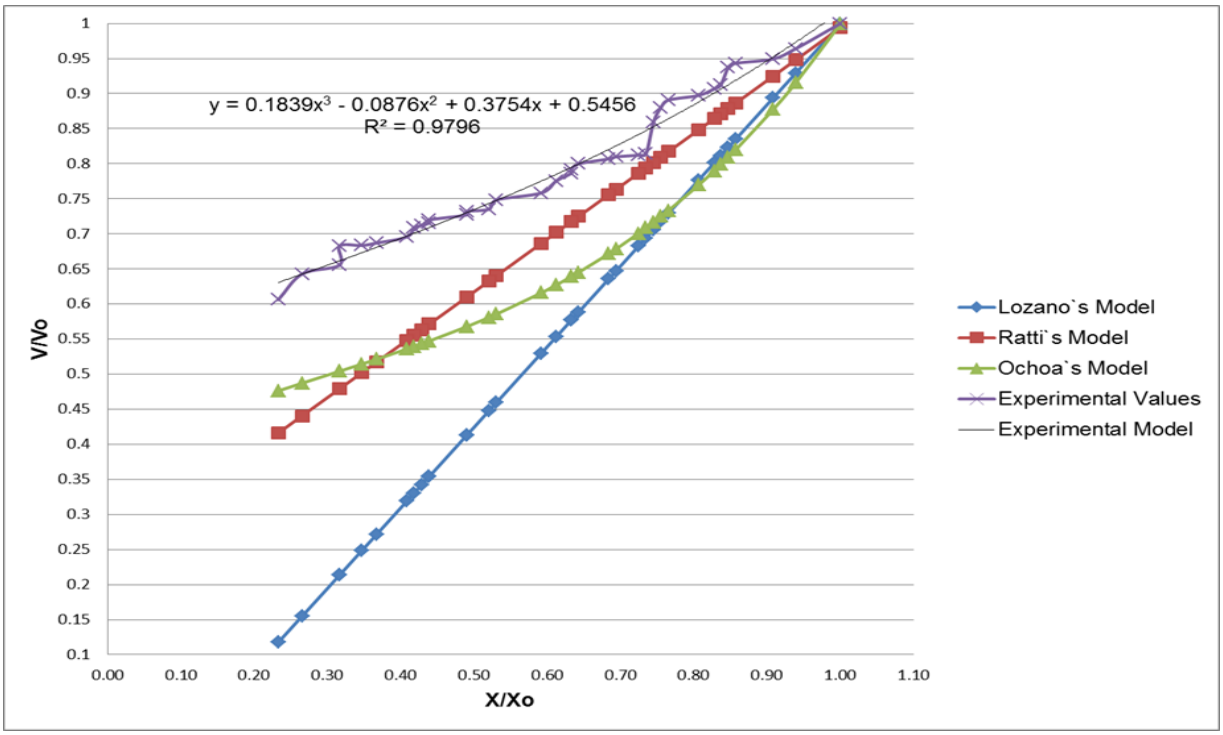


**Figure 4. Experimental data fitting compared to the model of Lozano, Ratti and Ochoa for T0**

Figure 4 represents variation rates volume V / $V_0$ versus variation moisture rates for the Witness: 100% suc. for the adjustment of the third order polynomial equation y = 0.1839x3 - 0.0876x2 + 0.3754x + 0.5456 with a high degree of adjustment: $R^2$: 0.9796. It has been compared to the Model Lozano, Ochoa and Ratti'sModels.

For Witness: 100% suc., it can be seen that for the same moisture rate $X/X_0$ = 1,at the initial time, started from a volume rate of Experimental Polynomic Model, Ochoa and Lozano's Models $V/V_0$ = 1, while the Ratti's model had a $V/V_0$ = 0.99. Then for a moisture rate $X/X_0$ = 0.83 the volume rate for the Experimental model was $V/V_0$= 0.91, 0.86 for Ratti's model, 0.79 for Ochoa's model and 0.80 for Lozano's model.

For a moisture rate $X/X_0$ = 072 the volume rate of Experimental model was $V/V_0$= 0.81, 0.79 for Ratti's model, 0.70 for Ochoa's model and 0.68 for Lozano's model. For a moisture rate $X/X_0$= 0.63 the volume rate of Experimental model was $V/V_0$= 0.79, 0.72 for Ratti's model, 0.64 for Ochoa's model and 0.58 for Lozano's model. For a moisture rate $X/X_0$ =0.49 the volume rate of Experimental model was $V/V_0$= 0.73, 0.61 for Ratti's model, 0.57 for Ochoa's model and 0.41 for Lozano's model.

For a moisture rate $X/X_0$ = 0.37 the volume rate of volume rate for the Experimental model was $V/V_0$= 0.69, 0.52 for Ratti's model, 0.52 for Ochoa's model and 0.27 for Lozano's model. Finally for a moisture rate $X/X_0$ =0.23 the volume rate of volume rate for the Experimental model was $V/V_0$= 0.61 for the Experimental model the volume rate $V/V_0$ is = 0.42 for Ratti's model, 0.48 for Ochoa's model and 0.12 for Lozano's model.

In other words, in this case, all the models had similar behavior than the Experimental model, until that the moisture rate was $X/X_0$=0.63. When the moisture rate for the Experimental model was $X/X_0$= 0.49 approximately, it continued being slightly similar for Ratti and Ochoa's models, but not for Lozano's model. For a moisture rate of $X/X_0$ = 0.37 the volume rate for the Experimental model was $V/V_0$= 0.69. At this point Ratti and Ochoa's model converged in a volume rate of $V/V_0$ = 0.52 and from there, the Ochoa's model became more similar to the Experimental model than the Ratti's model up to the end. Lozano's model was the one that least behaved to the Experimental model.

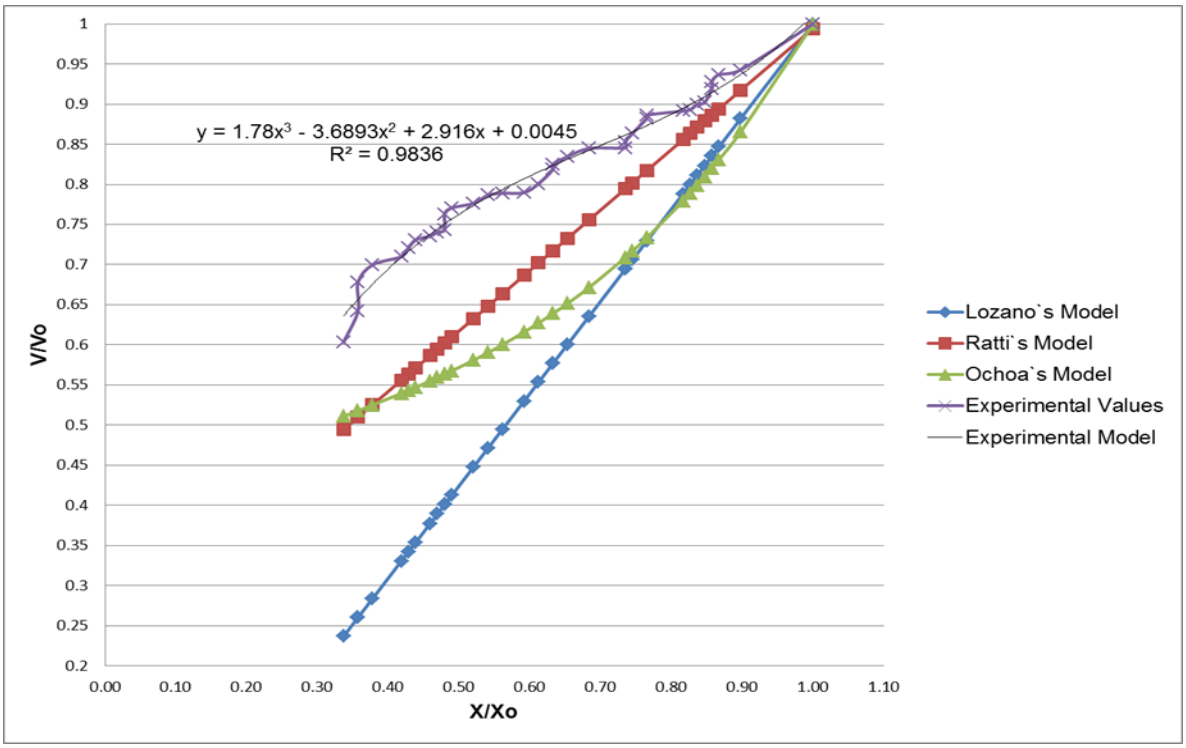


**Figure 5. Experimental data fitting compared to the model of Lozano, Ratti and Ochoa for T1**

Figure 5 represents variation rates volume $V/V_0$ versus variation moisture rates for the T1: sucrose 75% lactitol 25%, for the adjustment of the third order polynomial equation $y = 1.78x^3 – 3.6893x^2 + 2.916x + 0.0045$ with a high degree of adjustment: $R^2$: 0.9836. It has been compared to the Lozano, Ochoa and Ratti'sModels.

For T1: suc. 75% - lact. 25%, it can be seen that for the same moisture rate $X/X_0 = 1$ the volume rate were $V/V_0 = 1$ for the Experimental, Model, Ochoa and Lozano's Models, while the Ratti's model had a $V/V_0 = 0.99$. Then for a moisture rate $X/X_0 = 0.85$ the volume rate for the Experimentalwas $V/V_0$= 0.90, 0.88 for Ratti's model, 0.81 for Ochoa's model and 0.82 for Lozano's model. For a moisture rate $X/X_0 = 0.74$ the volume rate of Experimental model was $V/V_0$= 0.86, 0.80 for Ratti's model, 0.72 for Ochoa's model and 0.71 for Lozano's model.

For a moisture rate $X/X_0 = 0.63$ the volume rate of Experimentalmodel was $V/V_0$= 0.83, 0.72 for Ratti's model, 0.64 for Ochoa's model and 0.58 for Lozano's model. After that for a moisture rate $X/X_0$ =0.52 the volume rate of Experimental model was $V/V_0$= 0.78, 0.63 for Ratti's model, 0.58 for Ochoa's model and 0.45 for Lozano's model.

Then, for a moisture rate $X/X_0 = 0.44$ the volume rate of volume rate for the Experimental model was $V/V_0$= 0.73, 0.57 for Ratti's model, 0.55 for Ochoa's model and 0.35 for Lozano's model. Finally for a moisture rate $X/X_0$ =0.34 the volume rate of volume rate for the Experimental model was $V/V_0$= 0.60, 0.49 for Ratti's model, 0.51 for Ochoa's model and 0.24 for Lozano's model.

In other words, all the models had similar behavior until the moisture rate was $X/X_0$= 0.86-0.74 approximately. After that, the Experimental model was slightly similar for Ratti's model.

At the moisture rate $X/X_0$= 0.63 for the Experimental model, the Ochoa's models began an approach to Ratti'smodel. Finally, the Ochoa's model ended up with almost the same value for the Ratti's model. In this case, Lozano's model was the one that least resembles to the experimental model.

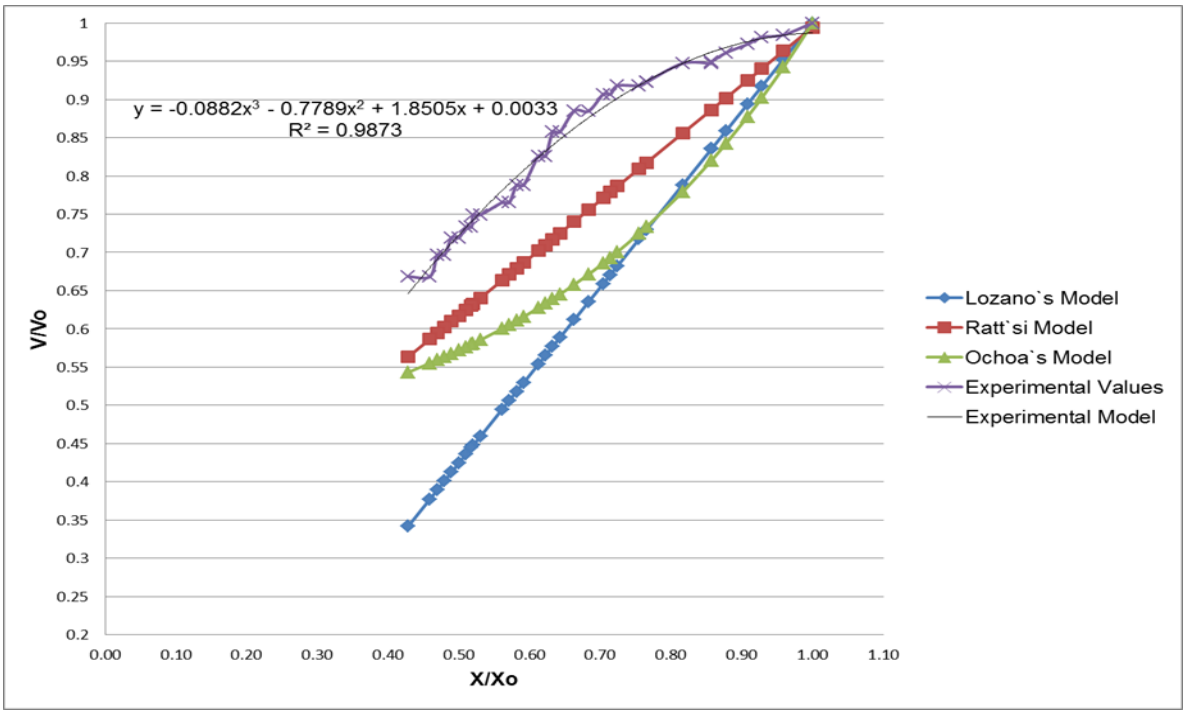


**Figure 6. Experimental data fitting compared to the model of Lozano, Ratti and Ochoa for T2**

Figure 6 represents variation rates volume $V/V_0$ versus variation moisture rates for the T2: lact. 50 – suc. 50%, for the adjustment of the third order polynomial equation $y = -0.0362x^3 – 0.9069x^2 + 1.9434x – 0.0124$with a high degree of adjustment: $R^2$: 0. 9873 It has been compared to the Lozano, Ochoa and Ratti'sModels.

For T2: lact. 50% - suc. 50%,it can be seen that for the same moisture rate $X/X_0 = 1$,at the initial time, started from a volume rate of Experimental Polynomic Model, Ochoa and Lozano's Models $V/V_0 = 1$, while the Ratti's model had a $V/V_0 = 0.99$. Then for a moisture rate $X/X_0 = 0.87$ the volume rate for the Experimental model was $V/V_0$= 0.96, 0.90 for Ratti's model, 0.83 for Ochoa's model and 0.85 for Lozano's model. After that, for a moisture rate $X/X_0 = 0.76$ the volume rate for the Experimental model was $V/V_0$= 0.92, 0.81 for Ratti's model, 0.73 for Ochoa's model and 0.72 for Lozano's model. For a moisture rate $X/X_0 = 0.66$ the volume rate of Experimental model was $V/V_0$= 0.88, 0.74 for Ratti's model, 0.65 for Ochoa's model and 0.61 for Lozano's model. Then for a moisture rate $X/X_0 = 0.58$ the volume rate of Experimental model was $V/V_0$= 0.79, 0.67 for Ratti's model, 0.61 for Ochoa's model and 0.51 for Lozano's model. For a moisture rate $X/X_0$ =0.51 the volume rate of Experimental model was $V/V_0$= 0.73, 0.62 for Ratti's model, 0.57 for Ochoa's model and 0.43 for Lozano's model. Finally for a moisture rate $X/X_0 = 0.42$ the volume rate of volume rate for the Experimental model was $V/V_0$= 0.67, 0.56 for Ratti's model, 0.54 for Ochoa's model and 0.34 for Lozano's model.

In this case, all models behaved similarly up to the moisture rate of $X/X_0 = 0.76$. Then, the Ochoa's Model began to approach the Ratti's Model until it almost converged with the Ratti's Model in the final moisture rate $X/X_0$ = 0.42. However, for this case, the Lozano Model was also different in relation to the experimental model.

## 4. CONCULSIONS

The shrinking phenomena of cherries in osmotic dehydration with different formulations was quantified.

The Witness suc.100% was the treatment with greater osmodehydrating power in front the T1: suc.75% - lact. 25% and the T2: suc.50%-lact.50%. The difference of osmotic dehydration between the different treatments was an average of 10% at the end of its treatment respectively.

In the first 13 hoursof trials all the treatment lost the most of its weight.
The osmotic dehydration with the different formulations used in the trials modified the volume and surface of cherries "increscento"during the time of process. Itwas shown in a decrease of volume rate and surface rate.
The behavior of volume rate was adjusted by a polynomic equation $ax^3 + bx^2 + cx + d$ being $R^2$: 0.9903 for witness, $R^2$: 0.9895 for T1: suc. 75% - lact. 25% and $R^2$: 0.9889 for T2: lact. 50% - suc. 50%. It was higher for the Witness in comparison to T1 and T2 respectively.
The behavior of surface rate was adjusted by a polynomic equation $ax^3 + bx^2 + cx + d$ being $R^2$: 0.9904 for witness, $R^2$: 0.9889 for T1: suc. 75% - lact. 25% and $R^2$: 0,9884 for T2: lact. 50% - suc. 50%. The diminish of surface rate, was higher for the Witness infront to T1 and T2 respectively.
In all the treatments the Experimental Polynomic Model showed the best adjust for the data as the first approximation to model the shrinking phenomena. This had a high degree of adjustmet with $R^2$: 0.9836 for the Witness suc. 100%,$R^2$:0.9836 toT1: suc.75%-25% lact. and $R^2$: 0. 9873 to T2: lact. 50% - suc. 50%. This model was a good and first approximation to describe the phenomena of cherry shrinking by osmotic dehydration in the trials conditions.
The Ratii and Ochoa's models were an acceptable option to validate the datas, but it is important to consider them as models of the shrinking phenomenon in convective conditions. The Lozano's model was the worst option to the datas in this case.

## 5. ACKNOWLEDGEMENT

CONICET, UTN FRM Argentina; EstablecimientoCarletii S.A (donor of cherries). Ingredion (donor polyalcohols).
This Project was financed by Secyt PID ALUTIME 0004413TC "Study of the phenomenon of diffusion during osmotic dehydration in fruits and preserves with low digestibility carbohydrates".

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