MECHANISM OF TRANSFER OF MASS IN THE PROCESS OF DRYING OF A COLLOIDAL SUBSTANCE

Resumen / ***Abstract***

La operación de secado de sustancias coloidales para la elaboración de alimentos y otros productos es parte importante de un proceso químico que requiere facilitar la manipulación de este tipo de sustancias ya sea como producto intermedio o como producto final, que debe cumplir con ciertos parámetros de calidad. Industrialmente las necesidades en el secado de sustancias coloidales exigen el estudio de este proceso con la intervención de análisis del material terminado. En el estudio del proceso de secado se encuentran múltiples factores que afectan el desarrollo de proceso contribuyendo a la complejidad del mismo y, específicamente en el secado de las sustancias coloidales. El abordar la problemática que integra el proceso de secado de este tipo de sustancias hace pertinente el análisis de estos problemas y el análisis y control de las variables que los afectan.

The operation of drying of colloidal substances for the elaboration of foods and another type of products is important part of a chemical process that requires to either facilitating the manipulation of this type of substances as intermediate product or as final product that should fulfill certain characteristics of quality. In the study of the drying process they are multiple factors that affect the development of the process contributing to the complexity of the same one and specifically in the drying of the colloidal substances such problems are had as; the quantity of the elimination of the liquid that is in the colloid, the drying temperature, the time of drying duration and the quality of the finished product that it requires, certain texture, certain dispersion and a certain emulsion point. Approaching the problem that integrates the process of drying of this type of substances makes pertinent the analysis of these problems and the analysis and control of the variables that affect them.

Palabras clave ***/ Key words***

Proceso de secado, procesos químicos

Process of drying, chemical process

INTRODUCTION

The operation of drying of colloidal substances for the elaboration of foods and another type of products is important part of a chemical process that requires to either facilitating the manipulation of this type of substances as intermediate product or as final product that should fulfill certain characteristics of quality. Industrially the necessities in the drying of colloidal substances, demand the study of this process with the intervention of analysis of the product that can be named the easiness of manipulation of the dry substance for a later treatment among other or to allow the satisfactory use of the final product, that which can reduce process costs when increasing the capacity of other teams and facilities when conserving the product during their storage and their transport.

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DEVELOPMENT

The process of drying of colloidal substances in the elaboration of foods for a later treatment or eat finished product brings get problems therefore in the requirement of the properties that should complete the colloid, it has been considered necessary to carry out a study on the drying of this type of substances in the search of new techniques by means of the analysis of the internal and external variables that intervene in the process for their optimization and their control with the purpose of satisfying the specifications of the wanted product.

Basically the first stages of this study understand the establishment of the mechanism of transfer of mass of the liquidate coming from the colloid when it is carried out the drying and in order to improving the results it is looked for to simulate and to optimize the process, to continue with the proposal and the design of a control system, with the analysis and technical implementation of control and of drying for this type of substances.[1]

This way, during the carried out investigation, the variables have been analyzed that influence in the behavior of drying of this type of substances, being that the main external variables are the temperature, the humidity, the ventilation of the air, the thickness of the sample, the state of subdivision of the colloidal substance, the agitation of the same one, and the contact between the hot surfaces and the humid substance.

The effect of the transmission of heat in the colloid and the transfer of mass of the water in the drying, is exercised directly in the external variables, as the temperature whose process consists on passing to the external surface and from her to the interior of the colloidal substance, giving place to the transfer of the water through the colloid. These variables affect the development of the process and, specifically in the drying of the colloidal substances they are problems that can be named among other; the quantity of the elimination of the liquid that is in the substance, the drying temperature, the time of drying duration and the quality of the finished product.

In this problem, this investigation proposes the good treatment in the drying of a colloidal substance with the optimization of the conditions that govern the behavior of the process and whose treatment requires the control of the factors that affect the drying, and that they influence directly in the speed of the same one and in the obtaining of a product with good quality the optimization of the drying, demands the easiness of manipulation of the dry substance since for a later treatment or to allow the satisfactory use of the final product, to reduce costs of transport, to increase the capacity of other teams and facilities and conserving the product during its storage and its transport.[2]

Inside the methodology settled down in the investigation, in the first part of the project three stages have been developed that understand the experimental part of the process, with the obtaining of data that they help to the analysis and establishment of the mechanism of transfer of mass of the water through the colloid by means of the mathematical pattern that him or it represents them.

STAGE I. DRYING TESTS

To carry out the experimental part of the drying of the alginatos, they were carried out different tests with different drying conditions and samples with different thickness and different content of humidity of water in dry and humid base. In such a way that when exposing the sample to the drying through air, the weight of the sample you could measure like a function of the time, being held to conditions of transfer of heat, of temperature of the air, of circulation speed and of humidity for each one of them, constituting this way constant conditions of drying.

When the alginatos undergoes the drying operation, two fundamental processes and the factors that govern the intensity of each one of these processes take place they are those that determine the intensity or speed of the drying process: 1. The transmission of heat to evaporate the water. 2. The transfer of mass in internal humidity and it dilutes evaporated.

Independently of the mechanism, the transmission of heat goes first by the external surface of the sample to dry off and from her to the interior of the colloid, causing the transfer of mass of the water in two forms: A) Of liquid or vapor or both inside the colloid. B) Like vapor from the humid surface of the colloid. In turn, it is considered that the transfer of mass of the water in the colloid, you could base on two mechanisms: a) Internal mechanism of the circulation of the water. b) In the effect of the external conditions that you/they affect the process, like they are the drying temperature, the content of humidity in the colloid, the ventilation that is used in the drying, the type viscosity of the colloid and their subdivision state.

Through the study of the mechanism of the internal circulation of the liquidate in the colloid the internal conditions that affect the process, settle down while with the study of the external conditions, results of the behavior of the drying can settle down by means of the analysis of the intensity of the operation. In the study of the internal circulation of the liquid in the drying of the alginatos, some mechanisms have been identified that it follows the transfer of mass depending on the structure of this colloid for the different viscosities with which it has been worked in the experimental part: 1. For diffusion of the water in the colloid when their structure you could consider homogeneous, in alginatos of low viscosity. 2. For diffusion of the water in the colloid and for capillary circulation of the liquid in alginatos of high viscosity to have granular and porous consistency. 3. For the circulation of the water caused by the graveness in colloids of high viscosity. 4. For the circulation of the water, originated by a series of vaporizations and condensations for alginatos with medium high viscosities and you lower. 5. For the circulation of the liquid due to the contraction gradients and pressure, also for alginatos of any type of viscosity.

However, for calculations it has been considered that mechanism that prevails in a range of the cycle of the process and that particular mechanism that it prevails it is determined studying the gradients of internal humidity of the colloid. In the study of the drying process based on the effect that produce the external variables, they settle down the different periods of drying by means of the experimental data that are obtained along the process like it is the temperature of the hot air, the temperature of humid bulb of the air that they circulate in the dryer, the weight of the load and the temperature of the load in the course of the time of the drying, being calculated the content of humidity of the load in function of the time.[3]

This way, the results are an indicator of the different mechanisms that prevail in the process and they are useful in the analysis and modelización of these behavior types that it suffers the colloid in the drying besides the calculation of the good time that should undergo this operation, the necessary drying intensity and the wanted drying proportion.

STAGE II. PERIODS OF DRYING INTENSITY

The behavior of dry intensity is dividend in tree periods or sections: The first section represents the mechanism where the heating of the load prevails by means of the air that circulates in the dryer. The second section represents a period of constant intensity of drying. The third section of the curve represents the period of falling intensity that varies with regard to the time of drying.

In the point in which finishes the period of the constant speed, begins to diminish the intensity of the drying and they're the critical content of humidity is located. In this point the movement of the liquid toward the surface of the solid becomes insufficient to replace the liquid that this being evaporated. The above-mentioned means that the critical content of humidity depends on the easiness of the movements of humidity inside the colloid and the thickness of the sample. For of the structure that presents that colloid as continuous the drying process. Therefore the experimental races of the drying of this type of substances provide these data difficult to calculate in theoretical form. Next the behavior of the drying process settles down to detail for each some of the sections of the obtained curves.

FIRST PERIOD OF DRYING INTENSITY. GROWING SPEED

When drying humid colloidal substances as the alginatos, by means of the air with temperature and humidity fix, a pattern of such behavior is obtained that, immediately after the contact among the sample to dry off and the air, a state of uncertainty is presented in the temperature of the colloid, it stops later on to spread to be adjusted until reaching a stable state. The temperature of the sample to dry off and the drying proportion can increase or to diminish until reaching the condition of stability, that which is reflected in the measure of the temperature of the humid surface of the colloid, registering an approach to the temperature of humid bulb of the air and the evaporation of the water, giving beginning to the period of constant speed. The temperatures inside the colloid that dries off will also spread to equal the same temperature of the humid bulb. Once they are reached, are a stable state and the drying proportion remains constant, beginning the following period of drying.

Therefore in this period the heating of the sample prevails by means of a sudden heating until reaching the temperature of the humid bulb of the air, being reached approximately from 10 to 20 minutes of drying.

SECOND PERIOD OF DRYING INTENSITY. CONSTANT SPEED

This period of constant speed is characterized for that the evaporation process is presented from the surface of free water on the surface of the colloid and the intensity of the drying determines it the speed with which she/he spreads the vapor of water through the movie of air in the surface of the colloid leaving her and entering in the main mass of the current of air. This constant intensity of evaporation on the surface of the colloid spreads to maintain the surface to a constant temperature, registering, experimentally the approach to the temperature of humid bulb of the air. However if the heat arrives to the evaporation surface for some radiation mechanism, conduction or convection or for combination of them, the constant temperature is reached between the temperature of the air and the temperature of the humid bulb producing a bigger constant intensity. Therefore one could say that the magnitude of the constant intensity of evaporation is function of three external variables: Of the coefficient of transmission of heat or of the coefficient of transfer of mass, of the exposed surface to the hot air in the drying and the difference between the temperatures or the humidities of the currents of air and the humid surface of the colloid.

THIRD PERIOD OF DRYING INTENSITY. FIRST PERIOD OF FALLING SPEED

The period of falling intensity begins when it finishes the constant period when arriving to the critical content of humidity being the following thing: If this it is smaller than the required final content, the period of constant intensity constitutes the whole drying process and while if the initial content of humidity is smaller than the critical content, the whole drying process will be understood among the period of falling intensity.

In this third period the superficial drying is not presented saturated, continuing immediately after the critical point, with a decrease of the drying intensity due to the decrease of the humidified surface of the colloid, presentation dry areas of the colloid and reduction of the evaporation intensity for unit of the total surface. Therefore, the humidified surface of the colloid, it is lineal function of the content of water and the variables that influence in the period of constant intensity, producing similar effects on the drying speed in that area.

Then the proportion of flow of hot air that influences in the constant speed of drying becomes less important as the drying proportion diminishes. This way, the portion of the surface that

his saturated dries off for transfer of heat by means of convex on from and due to the mass of the water toward the current of constant gas or still dries off without it exists inside the sample diffusion toward the current of the air. For the colloids as the alginatos, in this period, it is still observable the considerable content of water; although the drying speed continues diminishing, you can predict an infinite process of movement of iquid inside the colloid.

FOURTH PERIOD OF DRYING INTENSITY. SECOND PERIOD OF FALLING SPEED

In this last period, the internal circulation of the liquid prevails, nfluencing in the drying intensity until contained first floor of humidity. It is in this period, where it exists the possibility that he circulation of the liquid is governed by some such mechanisms as, the diffusion, the capillarity and the gradients of pressure due o the contraction that suffers the colloid.

When the diffusion of the liquidate it governs or it controls he period of falling intensity you can adopt a diffusion equation, considering that the content of humidity is in balance and the colloid has an uniform distribution of the initial humidity.

Because the humidity in the alginatos remains, it doesn't care how long it is the time in that undergoes the drying for the same conditions, it is considered that you arrive to a balance among he contained vapor in the drying means that is the air for this case. This point is the content of humidity in balance of the colloid. The quantity of humidity retained by a colloid in balance with the humid air depends on the structure of the substance, of he temperature of the air and of the content of humidity in the air.

The above-mentioned means that the sample of the colloid oses humidity for evaporation from the surface in an abrupt way n such a way that the water doesn't move with enough speed rom the center of the sample until the surface, being the quickest evaporation that the movement of the water, causing hardening of the sample with repellency to the humidity and the drying is even obstructed it dares it stops although the content average of water of the sample is still very high. Next the graphs of the determination of humidity are shown for two hours of drying of some samples with low viscosity (figures 1 and 2).

STAGE III. DETERMINATION OF MODEL MATHEMATICAL

The determination of the profile of humidity through the time of drying of the alginatos is carried out the calculation of the finite differences that consists on selecting the intervals of time appropriately in the time of drying and the distance intervals in the surface of the sample, in such a way that the humidity on the dot for an interval of time later can settle down by means of arithmetic stockings among humidities in the two adjacent distance intervals in the beginning of the interval of time. These arithmetic stockings provide acceptable results as for conditions that it requires the drying of the alginatos and the prediction of the content of humidity that even has at one time the substance certain of drying.

Finally a lineal partial equation is obtained: $\partial X/\partial t = K_g \{\partial^2 X/\partial X2\}$. He solution of the problem of transfer of mass of water can be represented by the previous functions which are represented the function of the behaviour of the change of the humidity of the colloid by the loss of water, in function of the Thickness "x" in the tray yen the course of the time "t".[4]

That agreement to the function considered for X(x, 0) = f(x), and to the interval where it is completed, different functions can be obtained in series of Fourier that represent the change at one time in the humidity of the colloid t>0 and for any position in the tray during the time that the drying lasts (figure 3).[5]

The variation in the humidity of the colloid through the time due to the process of transfer of the water toward the exterior in the operation of the drying, is represented through a series of Fourier whose significance is the change in the humidity of the colloid, this change is given by means of harmonic oscillations originating sinusoides in the continuous propagation of waves taken place by the decrease in the humidity in the colloid.

$$\frac{X' - X_{E'}}{X_c - X_{E'}} = X(x,t) = 2\sum_{n=1}^{\infty} A_n e^{-} K_g t \left(\frac{n^2\pi^2}{\lambda^2}\right) \text{sen}\left(\frac{n\pi}{\lambda}\right) x$$

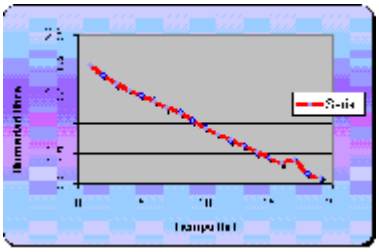

Fig. 1 *Changing of humidity with time.*

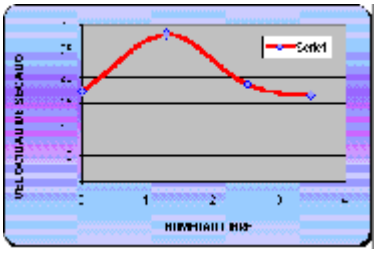

Fig. 2 *Intensity of dry with humidity.*

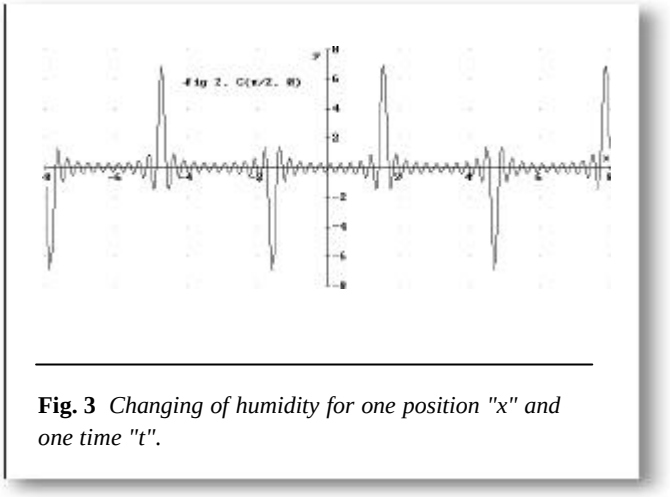

Fig. 3 *Changing of humidity for one position "x" and one time "t".*

CONCLUSIONS

Starting from the experimental data the curves of drying intensity have been obtained as well as the profile of humidities for several samples during the process, being able to predict the behavior of the drying of the colloidal substances and the mechanism that it follows the transfer of mass of the water in their evaporation toward the surface.

Likewise it has been obtained, the mathematical pattern that prevails in the diffusion of the water and with it the variables and the constants that determine it. This way it is had information for the stage of the optimization of the drying process by means of the simulation through the program ASPEN.

With the data obtained in the optimization, you will proceed to determine the following stages of the project that consist on to design and to build a control system for the process of drying of colloidal substances that follow the behavior of the alginatos and this way to fulfill the specifications of a product with requirements and necessities specifies.

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