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HOW TO ANTICIPATE THE BEHAVIOUR OF FAT-FILLED POWDER TO SPRAY DRYING



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INTRODUCTION & OBJECTIVES

Drying is an effective method for preserving biological products, since it does not involve severe heat treatment and it allows storage at an ambient temperature. Large amounts of liquid dairy products and food are dried in order to produce feeds, food and ingredients. Most of these powders are spray-dried. This process consists in spraying the concentrated liquid in droplets of about 50 μm into a large drying chamber containing air heated at around 200°C. The temperature of the product itself lies between the wet bulb temperature and the temperature of the outlet air, i.e. it remains below 100°C. Since drying occurs within a few seconds, thermal damage is limited.

Improvement in the quality of new dairy and food powders can be obtained only with the integration of new parameters such as glass transition temperature, water activity, residence time distribution, surface composition and surface temperature. The latter consists of drying modeling based on heat and mass transfer and balance equations. Two approaches can be considered: an overall approach, developed by Schuck et al. (2005), in which the model results in a mass and energy balance over the entire dryer, which can be a black box between both ends that which efficiently predicts the settings and overall performance of the spray dryer before production starts for varying weather /product conditions, and a micro approach developed by Chen and Lin (2005) which considers the drying kinetics and balance at the droplet level to determine information regarding the condition of the droplet (temperature / water content) as it dries. This reaction engineering approach makes it possible to model the drying droplet of various dairy products and is a new and interesting approach for improved control of the surface temperature of the droplet and subsequently the powder. This model can be used to predict certain aspects of powder quality / functionality. Whatever the approach used, one difficulty remains: i.e. how to take into account the water availability in the product, except for pure water.

The aim of this study was to propose a new and useful method of drying by desorption in order to determine major drying parameters according to food components in relation to their interactions with water (bound and free water) and linked to water transfer kinetics.

MATERIAL & METHODS

Concentrates were dried at 45°C (constant temperature) in a device (Rotronic, Bassersdorf, Switzerland) which consists of a 2 compartment cell, one (the smallest) containing the product (about 160 mg) and the other containing an excess of zeolite. The mass ratio is approx 100 g zeolite to 1 g product. Water transfer takes place because of this vapor pressure gradient, in a similar way to the water transfer that occurs during drying. The main difference is in the kinetics of the transfer, which here

takes 2 hours compared to a few seconds during spray drying. This device was described by Schuck et al (1998) (Figure 1.). One relative humidity (RH) sensor (Rotronic, Bassersdorf, Switzerland) over the 2 compartments makes it possible to plot RH in the cell as a function of time.

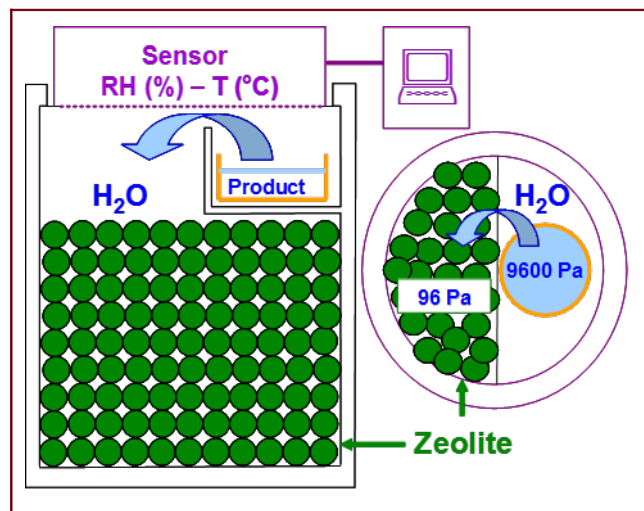


Fig. 1. Schematic device for drying by desorption.

RESULTS AND DISCUSSION

The main aim of this study was to develop a method to simulate the transfer conditions (energy and water) of spray-drying. Typical curves were registered with the water activity meter on water, dairy and food concentrates (Fig. 2.). These curves showed that the relative humidity (RH) from the pressure sensor as a function of time can be represented by a sigmoid equation (Schuck et al., 1998).

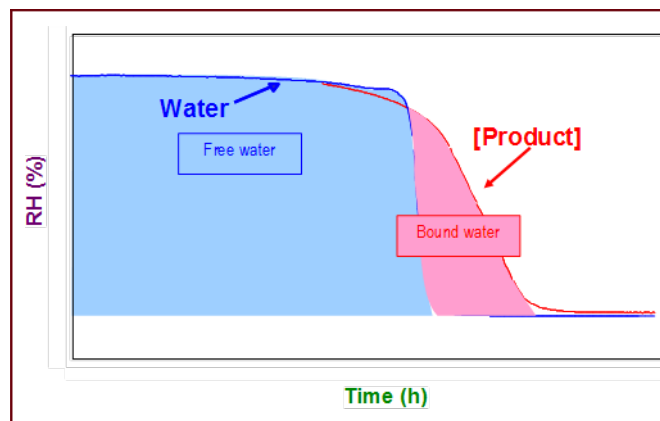


Fig. 2. Kinetic of drying by desorption

Two phases can be identified on the curves obtained for pure water and milk concentrates:

Initially, at the beginning of desorption, there was a constant RH (ie rate of drying) phase. This constant phase corresponds to free water evaporation. The second phase was the falling rate period, which was very short for pure water and much longer for milk concentrates, whatever the total solid content. We assumed that this corresponded to the evaporation of bound water, which involves extra energy (ΔE) in order to overcome binding (indirectly the bound strength of water). The area under the curve of each part thus represents the amounts of free and bound water desorbed, respectively. ΔE is calculated as a function of the drying kinetics according to the desorption curves (Fig. 2.). If the drying kinetic is two slower, energy requirement is two higher than for pure water. The difference with the latent heat of evaporation required for pure water determines ΔE . Analysis of the desorption curve combined with knowledge of the temperature, total solids, density and specific heat capacity of the concentrate, air flow rates, theoretical water content in relation to water activity and relative humidity (RH) of the outlet air, the current weather conditions, cost per kWh and the percentage of drying in the integrated fluid allowed determination of enthalpy, T (Temperature), RH (including ΔE) for each air, concentrate and powder flow rate, energy specific consumption, energy and mass balance, yield of the dryer and cost (in € or in \$) to remove 1 kg of water or to produce 1 kg of powder. All these results are summarized in Fig. 3. This figure is a representation of the software delivery and can be broken down into three parts:

Air: Summarizing all the parameters concerning air entering and leaving the drying chamber (temperature, absolute humidity, relative humidity, mass flow rate).

Product: Summarizing all the parameters concerning the concentrate (mass water flow rate, volume, temperature, total solid content and c_p) and powder (mass flow rate and moisture content).

Energy: summarizing economic (kWh cost, cost per ton water removed or per ton of powder produced) and energy (droplet temperature during spraying, dew point temperature at the air outlet, energy balance, energy consumption ratio and yield) results for the equipment.

Reduce	Settings	Mass flow rate (kg DA/h)	Enthalpy (kJ/kg DA)	Temperature (°C)	AH (g/kg DA)	RH (%)
Air Flow						
Inlet air before heating			48,2	35	5	14,2
Inlet air after heating T'		3000	279,3	267,4	5	0,02
Cooling air 'C'		500	38	25	5	25,3
Recirculation air 'R'		300	32,9	20	5	34,2
Complementary air 'C'		0	78,8	65	5	3,2
Air mix (I+C+R+C)		3800	232,8	209	5	0,04
Outlet air 1 stage (I+C+R+C)		3800	216,7	90,4	46,9	10
IFB (Inlet/Fan/Belt) Flow						
IFB inlet air before heating			37,8	25	5	25,3
IFB inlet air after heating B'		700	92,8	78,7	5	1,8
IFB outlet air 'B'		700	84	55,8	10,6	10,3
Overall outlet air (I+C+R+C+B)		4500	196,1	85,3	41,3	10,7
Energy and Cost						
Evaporation capacity (kg/h)		165,1	Wet bulb temperature of overall outlet air (°C)		47,2	
Water flow rate in concentrate (kg/h)		169,7	Dew temperature of overall outlet air (°C)		37,2	
Concentrate flow rate (kg/h)		339,3	Energy balance (kJ/kg water)		4535	
Concentrate flow rate (l/h)		282,8	Energy consumption ratio (60°C) (kg vapour/kg water)		1,9	
Concentrate density (-)		1,2	Yield (60°C) (%)		52	
Concentrate dry matter (%)		50	Cost (\$/ton water)		75,6	
Powder moisture (%)		4	Cost (\$/ton powder)		69,8	
Powder flow rate (kg/h)		176,7	kWh cost (\$)		0,06	
Concentrate temperature (°C)		20	Corresponding standard breakpoint (%)		100	
Concentrate Cp (kJ/kg.°C)		3,5				

Fig. 3. Synthesis table for spray drying parameters

CONCLUSIONS

This study shows that drying by desorption is an excellent tool to determine the major spray-drying parameters in relation to biochemical composition according to water availability, and to their desorption behavior (calculation of the ΔE). The experimental device differs from the spray-drying installation in terms of duration of drying, temperature of drying, surface / volume ratio, etc. However, for these reasons some computational tools have been developed to improve the method by taking this into account. Validation tests (> 100 products) indicated that this method could be applied to a wide range of food products and spray-dryer types. For reasons of calculation speed and reliability, this method has been computerized and it can already be used in the determination of parameters of spray drying for food products. The name of the new software is "Spray Drying Parameter Simulation and Determination Software" (SD2P®) registered under the following identification: IDDN.FR.001.480002.003.R.P.2005.000.30100.

By variation of drying parameters and concentrate parameters with the help of the INRA software (SD2P®) for prediction, the results showed

- the high interest to increase, the total solid of the concentrate and the temperature of the inlet air before heating,
- of the integrated fluid bed for easy or difficult product to spray dry,
- of the dehumidification the air (to increase the production or/and to have regular spray drying parameters or/and to decrease the powder temperature),
- to invest in order to reduce the energy cost, because a little increase in unitary energy cost has a high effect on the energy and total cost of dairy powder production.

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