HOW TO REDUCE THE ENERGY COSTS OF FOOD AND DAIRY PRODUCTS TO SPRAY DRYING?

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The most frequently used technique for dehydration of dairy products is spray drying. This is an effective method to preserve biological products as it does not involve prolong exposure of materials to severe heat treatment. Due to the variety and complexity of the concentrates to be dried, a more rigorous understanding of spray-drying based on physico-chemical and thermodynamic properties is necessary. At the same time, the current state of the art did not allow easy determination of the parameters of spray-drying of dairy products prior to drying, except from performing several complex and expensive experiments with pilot-scale spray-dryer. Nevertheless, recent advances in the understanding of product behavior toward water transfer with the development of a desorption method makes it possible to give several answers to the following question: What is the best strategy to anticipate the behavior of concentrate toward drying and to improve the process, the economy and the quality of the dairy powders?
The strategical approach can be developed on the knowledge of the thermodynamic parameters of the spray dryer coupled to physico-chemical characteristics of the concentrate. The software SD2P® (Spray Drying Parameters Simulation & Determination) developed by Schuck et al. (2009) is a way, among others, to predict the value of these parameters when they are not known. The combined results provide more precise determination of spray-drying parameters (including inlet/outlet air temperature, mass/powder flow rate, powder temperature, etc.), powder state during spray-drying (stickiness) and the cost of spray-drying with respect to weather conditions. Several cases will be presented to show the interest of this strategy in order to anticipate the spray-drying parameters and the powder behavior.

INTRODUCTION

Drying (consisting of lowering water activity by water elimination) 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 (skim and whole milk, whey, various fractions resulting from membrane filtration and chromatographic separation) 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.
There have been few scientific or technical studies on the powder quality obtained from spray drying related to the process parameters, physico-chemical composition or microbiology of the concentrates. Manufacturers have acquired expertise in milk and whey drying processes through an empirical approach. However, due to the variety and complexity of the mixes to be dried, more rigorous methods based on physico-chemical and thermodynamic properties have now become necessary.
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 (Schuck et al., 2007), residence time distribution (Jeantet et al. 2008), surface composition and surface temperature (versus drying time). 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), Patel et al. (2005a,b) and Lin et al. (2005, 2006, 2007) 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 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.

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. 1.). 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).

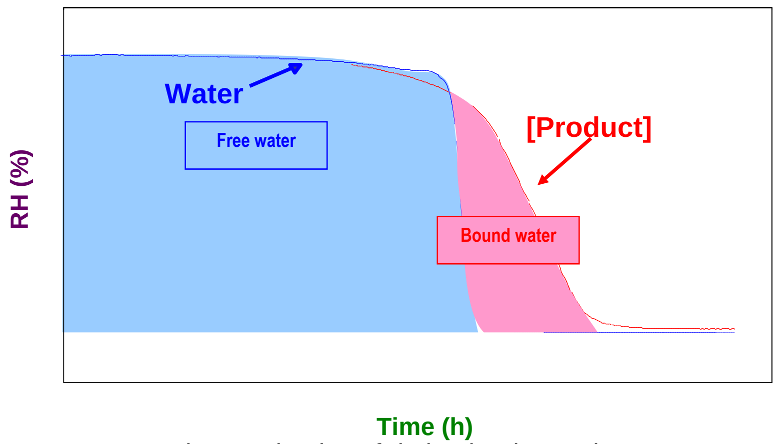

Fig. 1.: Kinetics of drying by desorption

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.). When the drying kinetic of a concentrate is similar to the drying kinetic of pure water, no ΔE is required. 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.
The calculation method to determine ΔE was computerized to obtain new software (SD^{2}P®, Spray Drying Parameter Simulation & Determination) and registered at the '*APP*' *('Association pour la Protection des Programmes'*) under the following identification IDDN.FR.001.480002.003.R.P.2005.000.30100.
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. 2. 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.

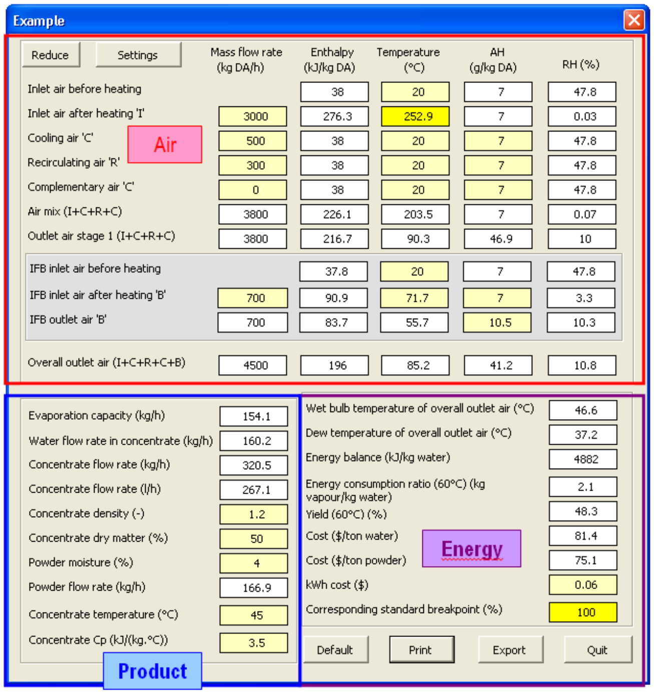

Fig. 2.: Synthesis page

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 □E). 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” (SD^{2}P®) registered under the following identification: IDDN.FR.001.480002.003.R.P.2005.000.30100.

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