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Assessment of physical characteristics and dissolution behavior of protein based powders

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Abstract

Proteins are main constituents of a broad range of food products in powder form, from dairy to dough-based foods. Water is the main responsible of physical properties modifications in powders and many scientific studies have been focusing on characterizing the role of water content and water activity in carbohydrates powders. This work deals with the assessment of physical properties and dissolution behavior of milk proteins powders and their interactions with carbohydrates (lactose). In the first part, micellar caseins, native and denatured β-lactoglobulin and Na-caseinate powders were selected and equilibrated at different water activities. In the second part, binary mixtures of proteins with lactose were prepared in different proportions (25:75 and 75:25). Sorption isotherms were built at 25°C and water adsorption kinetics was found to be faster in proteins than in carbohydrates. Thermal analysis (DSC) showed that micellar caseins and Na-caseinate exhibit a clear glass transition, while the measurement was not easy for BLG powders. In binary systems, proteins delayed lactose crystallization, up to a different extent depending on the kind of protein. Dissolution behavior was measured by conductimetry; the protein structure (native vs denatured) and its initial water activity played an important role, especially influencing powder's wettability. The presence of lactose strongly accelerated the dissolution process, in a more important way for BLG. Scientific findings could lead to improved powder engineering, in order to optimize dissolution behavior and storage stability of protein-based foods.

Keywords: milk proteins; powders; glass transition; lactose crystallization; dissolution

1. Introduction

Over the role of water in modifying the physical properties of food, especially in dehydrated powder form. Concepts like water activity, sorption isotherms or glass transition temperature constitute the basis of the

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so-called “water management”, and a continuous effort has been done to develop the appropriate techniques to assess these properties.

Tools like **state diagrams** have been developed for several materials (e.g. milk [1]), and can be used to prevent unwanted modification during storage - as caking - and/or to drive processing (drying, sintering, agglomeration) in an optimal way.

However, it should be noted that – even if a wide literature exists about water management in food powders – most studies focused on the characterization of carbohydrates compounds. Only few works dealing with proteins and their interactions with carbohydrates could be found [2], even if those are essential constituents in a broad range of food products, from dairy to dough.

Thus a better comprehension of the mechanisms of water transfer and its effect on physical properties of protein powders would help in understanding the behavior of complex food matrices, where carbohydrates, proteins, fats and micronutrients are present and interacting at the same time.

This study deals with the extension of the classical water management approach – developed for carbohydrates – to model protein-based powder systems. This requires adapting the existing experimental tools and mathematical models, to take into account some specificity of proteins like possible denaturation. Also concepts like glass transition should be discussed, as there is still an open debate about the existence and relevance of this property for proteins, which cannot easily be assimilated to polymers.

The work is performed on milk proteins’ powders (caseins and β-lactoglobulin). In the second part of the work, the investigation is extended to model systems containing lactose in order to assess the effect of interactions between proteins and carbohydrates.

The study focuses also on the characterization of rehydration behavior of protein-based powder systems. A fast rehydration is almost always a key requirement for powders, either for the final consumption either for further processing. Proteins could be responsible for longer dissolution times, as they are in general less soluble than amorphous carbohydrates. This work will help quantifying the dissolution time depending on the physical state of the proteins (native vs denatured), their structure and their interactions with carbohydrates.

2. Materials and Methods

2.1. Choice and preparation of powder samples

In the first part of the study, native BLG (Davisco, United States), micellar caseins (Sole-Mizo, Hungary) and Na-caseinate (Emmi, Suisse) powders were purchased and directly used for physical analysis without any further processing. Denatured BLG powder was prepared by heat treatment (92°C, 30 min) of an aqueous diluted solution (4% w/w), followed by spray drying (Tin = 180°C Tout = 80°C).

In the second part, eight binary systems were selected; they were composed by the four proteins used in part I mixed with lactose in two different proportions (25:75 and 75:25). Components were dissolved in aqueous solutions (20% w/w) and spray dried to produce the powders (Tin = 180°C, Tout = 80°C).

2.2. Physical properties assessment

Water content W_{wb} (%) was measured by thermogravimetry (Q600, TA, US), by applying a heating ramp at 2°C/min from 25 to 200°C. Water activity a_w was measured with Rotronic cells. Powders were equilibrated at 25°C at different a_w in desiccators with saturated salt solutions ($0.11 < a_w < 0.90$); values at equilibrium were used to build sorption isotherms. Water sorption kinetics at 25°C was measured with an automatic sorption device (SPS-11, Switzerland), by increasing progressively air RH from 10 to 80%, with 5% steps.