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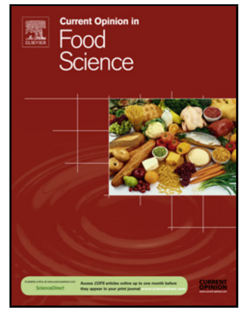

Title: Progress in understanding of supplemented state diagrams of hydrophilic food materials

Author: R.G.M. van der Sman

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Progress in understanding of supplemented state diagrams of hydrophilic food materials

R.G.M. van der Sman

Wageningen-Food Biobased Research, the Netherlands

ruud.vandersman@wur.nl

Highlights

- Thermodynamic theory allows for complete prediction of phase diagram of many food materials
- Advances for theory of ternary systems has made significant progress, especially systems involving crystallization/dissolution of carbohydrates
- Experimental evidence of multiple glass transitions, suggests phase separation of ternary systems into biopolymer-rich and plasticizer-rich regions

Since decades food scientists have been using supplemented state diagrams for finding the storage conditions for food stability, and for the design of food structuring processes involving phase transitions such as baking. Only, recently thermodynamic theories have been developed allowing for complete prediction of the phase transitions and glass transitions. Interpretation of experimental and numerical results on the state changes of food materials during processing by means of the supplemented state diagram has led to more precise understanding of the physical mechanisms governing optimal processing. In this paper I will review current developments in theory and experiment. More and more work is investigating ternary systems, consisting of a biopolymer, water and a second plasticizer like a carbohydrate. Investigations of their glass transitions indicate multiple glass transitions, suggesting phase separation into biopolymer-rich and plasticizer-rich regions. This has yet to be confirmed by theory. Theory has shown good advancement in the prediction of crystallization/dissolutions of ternary mixtures of two carbohydrates and water.

Introduction

Since the pioneering work of Slade and Levine [1, 2], and of Karel and Roos [3, 4], food scientists have been using supplemented state diagrams, to infer conditions for stable storage of food, or conditions for changes in food structure via inducing phase transitions. The supplemented state diagrams show the phase transitions of food materials together with transition to jammed states, like the gel state or glassy state. Recent developments in the field of pharmacy has shown that stability of biopolymeric systems can only partly be explained by the glass transition [5, 6]. The glass transition is linked to the so-called alpha-relaxations which determine the large-scale mechanical stability of the system. Stability of proteins against denaturation and chemical reactivity is much more determined by the so-called beta-relaxations, which also drive the diffusion of solvents. Near the glassy state the diffusion becomes decoupled from the viscosity, which can be related the glass transition. In the field of food science this aspect is not yet well debated. Hence, in this review I restrict myself to developments with respect to the use of supplemented state diagrams to understand food structuring via phase transitions.

In the recent years much progress has been made in the prediction of the phase transitions using thermodynamics, to which the author has made significant contributions. Due space constraints this review is limited to recent studies, advancing the understanding of hydrophilic food materials - which are traditionally the subject of investigations with supplemented state diagrams. Hence, I only briefly note interesting new developments in understanding phase behaviour of non-traditionally-investigated systems like micro-emulsions [7], fat-based systems [8], and coacervates [9].

Hydrophilic food materials, such as proteins, polysaccharides, and carbohydrates, interact with water mainly via hydrogen bonding, which largely determines their state/phase behaviour. Earlier I have shown that their glass transition can be correlated to the volumetric density of hydrogen bonds [10]. Phase transitions of these materials and their mixtures can be described by extensions of the classical Flory-