Mechanical and Structural Properties of Maltodextrin/Agarose Microgels Composites

Chrystel Loret[1*], William J. Frith[2] and Peter J. Fryer[3]

[1] Unilever Foods and Health Research Institute, PO box 114, 3130 AW Vlaardingen, The Netherlands
[2] Unilever Corporate research, Colworth House, Sharnbrook, Bedford MK40 1DG, U.K.
[3] Centre for Formulation Engineering, Chemical Engineering, University of Birmingham, Edgbaston, Birmingham B15 2TT, U.K.

*E-mail: Chrystel.Loret@Unilever.com
Fax: +31.10.4606747

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Abstract:
We present results from a new approach to the study of multicomponent gels, which allows independent investigation of the effect of phase volume and droplet size of the dispersed phase on the mechanical properties of the mixed gel composites. The method involves preparation of agarose microgels with different sizes, which are then embedded in maltodextrin gel matrices with different gel strengths. The effects of both phase volume and droplet size on composite properties are dependent on the phase modulus ratio. The higher the phase modulus ratio, the larger is the reinforcement effect and the effect of droplet size on mechanical properties of the maltodextrin/agarose composites. The observed behaviour was compared with literature models for the behaviour of composite materials.

Zusammenfassung:
In der vorliegenden Studie wird eine neue Methode zur Untersuchung von phasenseparierten Mehrkomponentengelen vorgestellt, die es erlaubt unabhängig voneinander den Einfluss von Phasenvolumen und Tropfengröße der eingeschlossenen Phase auf die mechanischen Eigenschaften des Mehrkomponentengels zu untersuchen. In der hier vorgestellten Methode werden zunächst Agarosemikrogele unterschiedlicher Teilchengröße erzeugt und anschließend in Maltodextringele unterschiedlicher Gelstärke eingebettet. Der Einfluss von Phasenvolumen und Tropfengröße auf die mechanischen Eigenschaften der erhaltenen Komposite wird dabei vom Verhältnis der Elastizitätsmoduli der einzelnen Phasen bestimmt. Je größer dieses Verhältnis ist, desto größer ist der Versteiffungseffekt und der Einfluss der Tropfengröße auf die mechanischen Eigenschaften des Malto-dextrin/Agarose Gemisches. Das beobachtete Verhalten wird mit theoretischen Modellen für die resultierenden Eigenschaften von Kompositen verglichen.

Résumé:
Nous présentons des résultats issus d'une nouvelle méthode de préparation pour l'étude de gels multicomposés, laquelle permet de dissocier l'effet du volume et de la taille des particules de la phase dispersée sur les propriétés mécaniques des gels multicomposés. Des microgels d'agarose de taille différente ont été préparés puis inclus dans une matrice gélifiée de maltodextrine avec des rigidités différentes. L'effet tant du volume de phase ainsi que de la taille des particules dépend du ratio des modules des phases. L'augmentation du ratio des modules entre les phases dispersée et continue accentue l'effet de renforcement ainsi que l'effet de la taille des particules sur les propriétés mécaniques des composites de maltodextrine/agarose. Le comportement observé a été comparé à des modèles de la littérature décrivant le comportement de matériaux composites.

Key words: biopolymer mixtures, maltodextrin, agarose, microgels, mechanical properties, microscopy

1 INTRODUCTION

Previous studies have shown that using phase separated maltodextrin/agarose mixed gels to study the effect of phase volume and droplet size on the mechanical properties of food composites were made difficult because of problems with fractionation of maltodextrin [1]. It also proved impossible to control the inclusion size independently of the phase volume. Another approach to understand the effect of the inclusion of one ingredient in a matrix of another is to prepare filled gels, which consist of a gel matrix with inclusions of pre-made microgel particles [2]. A few studies have been conducted using filled gels to model food composites [3 - 6]. Ring and Stainsby [3] used different fillers to show that the small

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posite by increasing its modulus and stress at failure and decreasing its strain at failure. This effect is more pronounced if the difference in modulus between filler and matrix is large. The effect of phase modulus ratio on the true strain at failure is less pronounced, with a bigger decrease of the true strain at failure only at high phase volume for composites with high phase modulus ratio.

Despite the multitude of models proposed to describe the behaviour of the relative modulus with phase volume, none was able to fit the data correctly. However, these models described the effect of phase modulus ratio well. For fracture properties, the Ross-Murphy models describe well the behaviour of the true strain and stress at failure as a function of phase volume. If the filler modulus is much higher than that of the matrix, the behaviour of the true strain at failure can be well described by the simple relation: $\epsilon = 1 - \phi_f$. The Ross-Murphy model (Eq. 17) describes relatively well the behaviour of the true stress at failure as a function of agarose microgel phase volume for maltodextrin/agarose composites with low phase modulus ratio. The introduction of the maximum packing fraction helps the description of the behaviour of the true stress at failure as a function of phase volume for composites with high phase modulus ratio.

By including agarose microgels of different sizes in maltodextrin gels of different strengths, the effect of droplet size on large deformation properties of maltodextrin/agarose composites was studied for different phase volumes of agarose microgels. The effect of droplet size on mechanical properties of maltodextrin/agarose composites depends on both the phase modulus ratio and the phase volume. It was found that higher the phase modulus ratio, the bigger was the reinforcement effect, i.e. higher apparent elastic modulus and the true stress at failure and smaller the true strain at failure. This effect was observed at lower phase volumes for composites with high phase modulus ratio. For the system with a small modulus ratio between filler and matrix, no effect of droplet size could be observed. Contrary to previous studies, the composites with the larger droplets had the bigger reinforcement effect. They were stronger and stiffer.

These observations are very relevant for the food industry. To develop products with new textures by mixing two biopolymer gels together, certain conditions need to be fulfilled. To see an effect of reinforcement of the filler, the stiffness of the filler needs to be higher than to the matrix. This modulus ratio between filler and matrix also determines the phase volume at which the filler must be included. The larger the phase modulus ratio, the less filler has to be incorporated to see a reinforcement effect.

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