

MECHANICAL AND STRUCTURAL PROPERTIES OF MALTODEXTRIN/AGAROSE GEL COMPOSITES

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ABSTRACT:

When two biopolymers are mixed together, they will normally phase separate to give two distinct phases. If the biopolymers are gelled during this phase separation, for instance by reducing the temperature, one phase is trapped in this other one and an emulsion-like composite structure is obtained. In this study, we investigated the effect of volume fraction and droplet size of this dispersed phase on the mechanical properties of maltodextrin/agarose gel composites, where agarose is the dispersed phase. Mechanical properties of the different composites were investigated under large deformation using a rheometer with a vane geometry. These composites were also observed by confocal microscopy, allowing conclusions to be drawn regarding the microstructural origins of the observed mechanical behaviour.

ZUSAMMENFASSUNG:

Das Mischen zweier Biopolymer Lösungen führt häufig zur Trennung in zwei distinkte Phasen. Wenn es durch Temperaturniedrigung während der Separation möglich ist eine der beiden Phasen in ein Gel zu überführen, so erhält man einen emulsionsähnlichen Einschluss der zweiten Phase in der Ersten. In der vorliegenden Arbeit wird der Einfluss von Volumenanteil und Tropfengröße von Agarose als eingeschlossener Phase auf die mechanischen Eigenschaften eines Maltodextrin/Agarose Gemisches untersucht. Die mechanischen Eigenschaften der Komposite wurden unter großer Deformation in einem mit Drehschaufel-Geometrie ausgerüsteten Rheometer untersucht. Rheologische Charakterisierung von Mischungen unterschiedlichen Zusammensetzungen in Verbindung mit konfokaler Mikroskopie lassen Rückschlüsse auf die strukturellen Ursachen der beobachteten mechanischen Eigenschaften zu.

RÉSUMÉ:

Quand deux biopolymères sont mélangés, dans la plupart des cas, il y a une séparation de phases. Si durant cette séparation de phases, les deux phases gélifient, par exemple par une réduction de la température, l'une reste attrapée dans l'autre et une structure de type émulsion est obtenue. Ce travail étudie l'effet du volume de la phase dispersée ainsi que la taille des particules sur les propriétés mécaniques de gel composites de maltodextrine/agarose, où l'agarose se trouve dans la phase dispersée. Les propriétés mécaniques des différents composites ont été étudiées par de la rhéologie en grande déformation avec un rhéomètre équipé d'une géométrie type "vane". Les composites ont également été observés par microscopie confocale. La combinaison des deux techniques a permis d'avancer des conclusions utiles à la mise au point de microstructures constituées de mélanges de gels.

KEY WORDS: maltodextrin, agarose, biopolymer mixture, phase separation, mechanical properties

1 INTRODUCTION

Investigations of biopolymer interactions in gels have become increasingly critical for the food industry. An understanding of the behaviour of mixtures of biopolymers is necessary for modelling and improving conventional foods, controlling the functional properties of foods with added biopolymers and for developing novel formulated foods. Moreover, since it is difficult to acquire food approval for new polysaccharides,

the food industry has turned to mixtures of proteins and polysaccharides to generate new textures or new applications.

When two biopolymers are mixed together, they generally separate into two distinct phases due to their thermodynamic incompatibility. Each phase is enriched in one biopolymer and depleted in the other. This behaviour of mixtures of biopolymers in aqueous solutions is characterised by a phase diagram, which defines the

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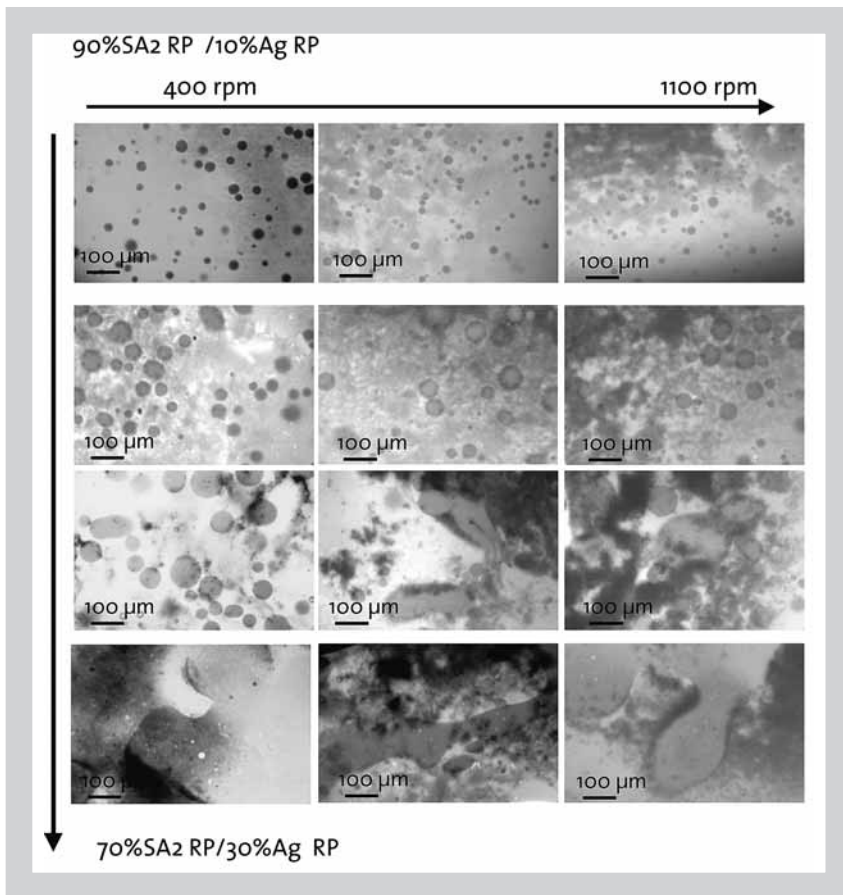


Figure 13: Effect of phase volume and mixing speed on the microstructure of maltodextrin/agarose gel composites. The composites were obtained by mixing in different ratios and speeds, the rich phases from the phase separation of 12.5 % SA2 / 5 % Ag (Confocal microscope observation).

a bicontinuous network is seen. This difference in microstructure results in a difference in the mechanical properties of the composites. Composites mixed at 400 rpm with 25 % agarose rich phase volume are weaker than composites with the same phase volume mixed at 800 or 1000 rpm. In contrast, the strain at failure is not affected by the mixing conditions. From this observation, it can be concluded that the slower the solutions are mixed, the higher is the phase volume of the dispersed phase that can be included in droplet form. Moreover, as can be seen in Fig. 12 for samples prepared at 800 and 1000 rpm, when a bicontinuous network is formed, increasing the phase volume of agarose rich phase, increases the modulus and stress at failure of the composites and decreases the strain at failure, resulting in a stronger and less deformable mixed gels. Further increase of agarose rich phase volume should result in a phase inversion with the agarose rich phase becoming the continuous phase. It is interesting to note that the range where neither of the biopolymer rich phases dominates the microstructure is quite large.

4 CONCLUSIONS

Maltodextrin and agarose rich phases from the phase separation of 12.5 % maltodextrin / 5 % agarose were mixed in different proportions and mixing conditions to prepare gel composites

with different mechanical and structural properties. As an alternative to the more usual compression or tensile testing approaches, the vane method was used for investigating large deformation behaviour, and proved particularly useful for the testing of very weak samples.

It proved difficult to evaluate the separate influences of phase volume and droplet size in these studies since the two properties proved to be intimately linked in that the droplet size depended mainly on phase volume and hardly at all mixing conditions. These results show that rheological measurements on their own may not be sufficient to understand the behaviour of this type of material and that structural analysis (e.g. microscopy) should always be coupled with rheological studies.

Despite this, interesting conclusions can be drawn. An effect of phase volume on mechanical properties of maltodextrin/agarose was only observed at high agarose rich phase volume when the composite structure changed from a droplet structure to a bicontinuous network. This formation of a bicontinuous network resulted in an increase of the modulus and shear stress at failure but in no change in the shear strain at failure. The formation of this bicontinuous network depended on the mixing conditions. Increasing the speed of mixing reduced the phase volume range where “emulsion-like” structure can be obtained. When a bicontinuous network was formed, an increase in the phase volume of agarose rich phase gave a stronger, stiffer and less deformable composite. This is a very interesting observation for the processing of mixed biopolymer gels in general.

To summarize, it seems that, depending on the proportions in which the two biopolymers are mixed together as well as the speed at which they are mixed and gelled, the structure of the mixed gels can go from a phase separated network to a bicontinuous network, with very different mechanical properties. Additionally, it seems that coalescence in biopolymer liquid mixtures is sufficiently rapid that it can be the determining factor regarding the microstructure of the final gelled composite. In other words it is quite possible that the gelation kinetics of the biopolymers in the mixture are likely to be so slow compared to the rate of coalescence that the influence of processing history on the final gelled microstructure may be minor.

In order to study independently the effect of phase volume and droplet size of the dispersed phase on maltodextrin/agarose gel composites, a different method of preparation of the mixed gels was developed. The results are discussed in forthcoming part of this article.

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