

Structural Characterization of Single Calcium Alginate Beads by 2.35 T MRI and MRS Methods

M. Bascelli¹, A. Fracassi², L. A. Pajewski¹, A. Sotgiu², and M. Alecci²

¹Department CICM, University of L'Aquila, L'Aquila, Italy, ²Department SdS, University of L'Aquila, L'Aquila, Italy

1. Purpose

Alginate gel beads are used in material science, food industry, pharmacology, medicine and their properties depend on many parameters, including origin and purity of the alginate, fabrication method, bead size, gelling ion composition [1]. MRI was previously used to characterize alginate solutions, gel phantoms, and single beads [2 – 4].

Here we report the combined use of MRS and MRI at 2.35 T to study the microscopic structure of single alginate gel beads. We show that beads of about 3.5 mm in diameter present T2 map heterogeneity that can be attributed to polymer concentration gradients formed during the gelling process.

2. Material and Methods

Sodium alginate powder was dissolved in deionized water at 0.3, 0.5, 1.0, 1.5, 2.0, 2.5 % (w/v). The beads were made by dripping the alginate solution into a large volume 2% (w/v) CaCl₂ solution and left for 24 hours before MR measurements. Images were obtained with a 2.35T Bruker-BioSpec equipped with a transmit-only birdcage RF coil and a receive-only surface RF coil (2.5cm diameter). T2 maps were obtained by acquiring RARE images (Figure 1) (TE=50,75,100,125ms; TR=15s; FOV=25*25mm; matrix=256*256; thickness=1.1mm; NEX=2) and pixel-based mono-exponential fitting. PRESS spectra of the alginate solutions and bead hydrogels at 0.5 and 2.0 % were acquired from a cubic voxel (1.5 mm) centrally positioned within the beads (diameter 3-4mm). For each PRESS spectrum the water component was removed by post-processing with the software jMRUI v3.0.

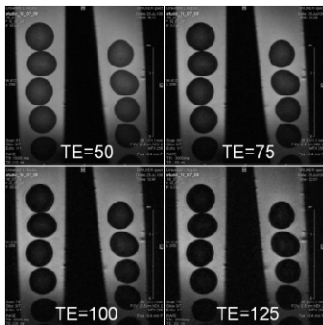


Figure 1: Coronal RARE images (TR=15 sec, FOV=25*25mm; matrix=256*256; thickness=1.1mm; NEX=2) of alginate beads at 2.5% (left) and 2.0% (right).

3. Results

Figure 2 shows the T2 map along the beads diameter at various alginate concentrations. For quantitative comparison the data were fit to a polynomial (6th order). The T2 map shows a smaller T2 values measured at the periphery of the beads and this can be explained by the reduced water mobility due to a more compact 3D gel structure. This increased density of intermolecular links is due to the higher [Ca⁺⁺] available during the gelling process at the beads periphery.

The 1/T2 values measured at the centre of the beads as a function of the [Ca⁺⁺] are reported in Fig. 3 and show an increasing trend due to a higher water proton exchange from bulk to the active hydroxyl sites on the alginate chains.

Our preliminary PRESS results (Figure 4) show the capability to detect the proton signal of the alginate polymers present in the solution and in the beads at two different concentrations. Following previous high resolution MRS study [5], our PRESS data should be useful to characterize the microscopic structure and dynamic properties of the hydrogels.

4. Conclusion

The combination of MRI and MRS methods is a useful tool that allows studying alginate polymer properties on single beads in a non-destructive and reliable way. This seems particularly useful for designing alginate hydrogels suitable as immobilization matrix and transport vehicle of viable cells [6 – 7].

5. References

- [1] Zimmermann H et al, Appl Phys-A 89:909-922 (2007)
- [2] Thu B et al, Biopolymers 53:60-71 (2000)
- [3] Simpson NE et al, Biomaterials 24:4941-4948 (2003)
- [4] Bascelli M et al, epos 597 ESMRMB 2008 (Valencia, SP)
- [5] Grasdalen, Carb. Res. 118:255 (1983)
- [6] Kong HJ et al, Biomaterials 24:4023-4029 (2003)
- [7] Foroutan P et al, Proc. Intl Soc. Mag. Reson. Med. 15:1339 (2007)

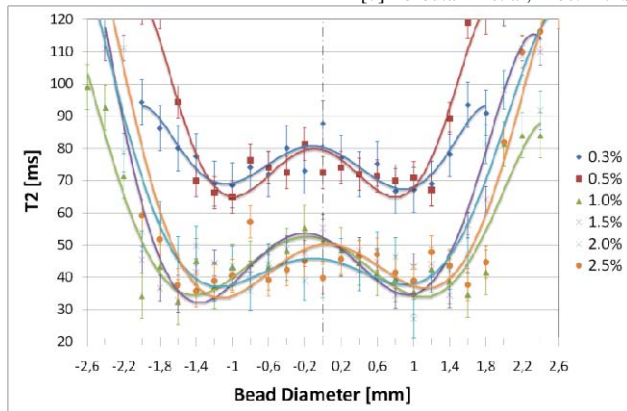


Figure 2: T2maps vs bead position along the diameter.

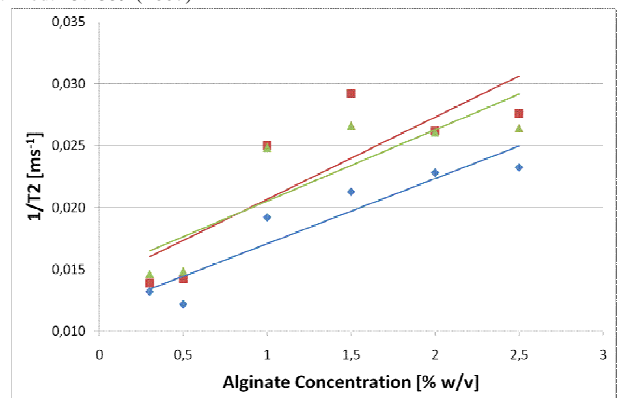


Figure 3: 1/T2 vs alginate concentration at the centre (◆), left (■) side and right (▲) side of the beads.

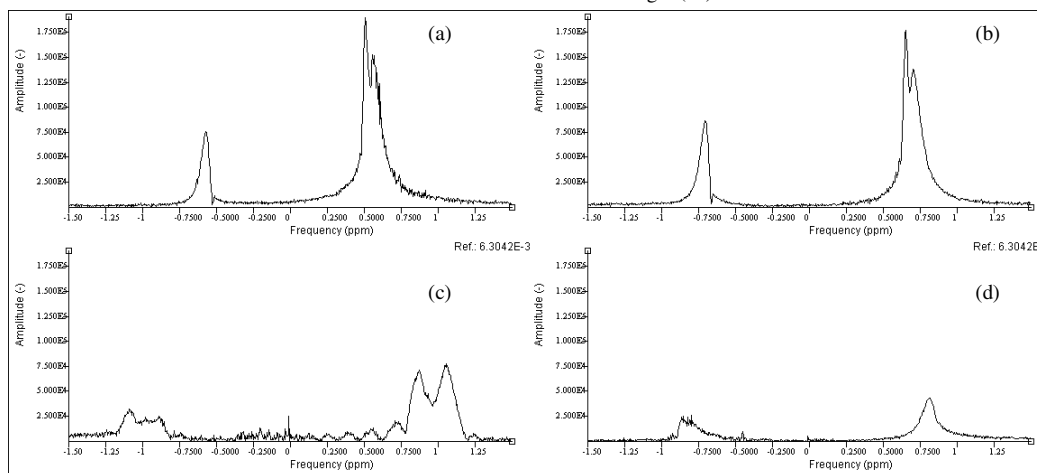


Figure 4: PRESS spectra (TR=5s; TE=25ms; span 600 Hz; NEX=80): (a) sodium alginate solution at 0.5% w/v; (b) sodium alginate solution at 2.0% w/v; (c) calcium alginate gel bead at 0.5% w/v and (d) calcium alginate gel bead at 2.0% w/v.