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Experimental characterization of hydrogel swelling under plant cell wall environment

C. Assor^{1,3}, F. Quignard², T. Alméras³ and O. Arnould³

¹UMR Ingénierie des Agropolymères et Technologies Emergentes, Sup'Agro, INRA, Montpellier, France

²Institut Charles Gerhardt - UMR 5253, Equipe Matériaux Avancés pour la Catalyse et la Santé, Montpellier, France

³Laboratoire de Mécanique et Génie Civil (LMGC), CNRS, Université de Montpellier, France
carole.assor@supagro.inra.fr

Pectins are one of the major components of primary cell walls and the middle lamella of dicotyledons (Carpita and Gibeaut 1993). Pectins play a central role in the control of cellular adhesion and thereby of the rheological properties of the wall. During the plant development, pectins are involved in several “active” phenomena as germination, growth cell acting on the cell turgor, cell wall matrix swelling and cell adhesion. A set of well-known enzymes modulate their structures to make their properties adapted to the plant requirements. Although there is an established literature on pectin structure and the way by which they are modulated by enzymes in the plant cell walls (Senechal et al., 2014), their interactions with other cell wall polymers and their mechanical behavior upon physiological conditions remain unclear. Some relevant experiments were carried out to characterize pectin swelling at high concentrations (>30% w/w) from samples under film and gel forms and different counterions under osmotic stress (Zsivanovits et al., 2004), but any were established under physiological conditions.

In this study, an original device was designed to characterize the mechanical behavior of hydrogels submitted to osmotic stress on conditions that mimic plant cell wall environment (Figure 1). Cylindric samples (10mm of diameter X10 mm of height) are placed in a stainless steel closed chamber in which water uptake, due to osmotic stress, occurs through a porous stone located at the bottom of the gel. At the opposite side of the sample, a force cell allows to measure the stress developed by the flow of water through the gel. As sample deformation is prevented by locking the longitudinal direction, the stress determined from the force cell correspond to the water pressure. The measurement of change in force during the time test duration allows determining the kinetic of water uptake as well as the maximum stress (Figure 2). The small sample size tested will permit both to characterize extracted polymers from the plant cell walls and to apply enzymatic treatments on polymers during measurements.

A set of tests was established on a model hydrogel made of alginates (with high (G) and low (M) galacturonate units ratio) at different content (1, 2 and 3% of their dry mass) formed in a 0,1M of various counterions solutions (cobalt, calcium and manganese). In parallel, the water uptake of these samples under free deformation conditions and characterization of their elastic properties were done. The integration of experimental results exhibits a good relationship between G' , P and ϵ that validate the device.

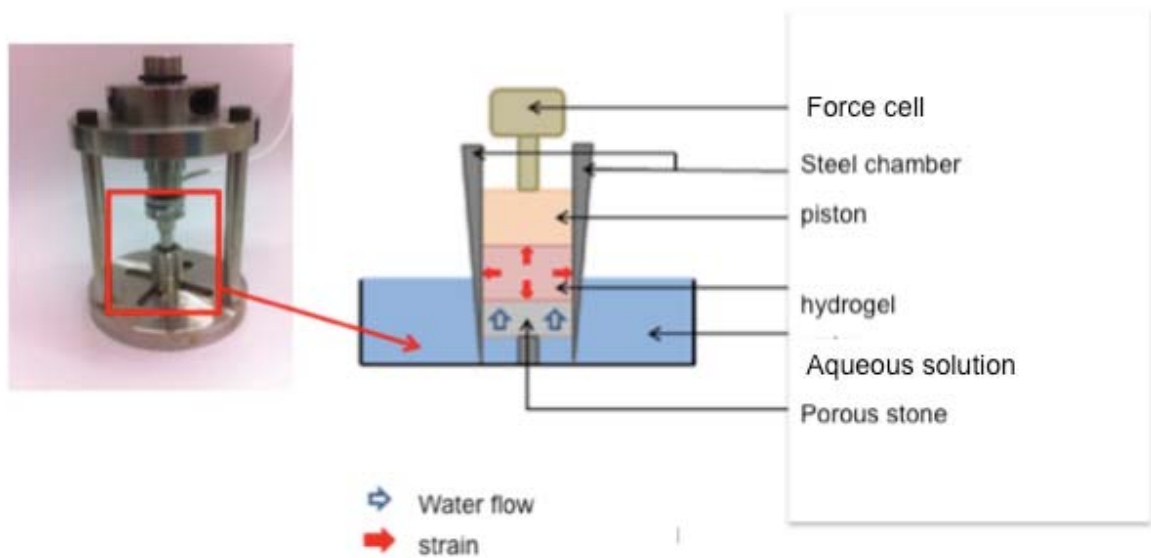


Figure 1: Experimental device develop to characterize swelling of hydrogel in aqueous solutions (Halle mécatronique, LMGC, Montpellier, France).

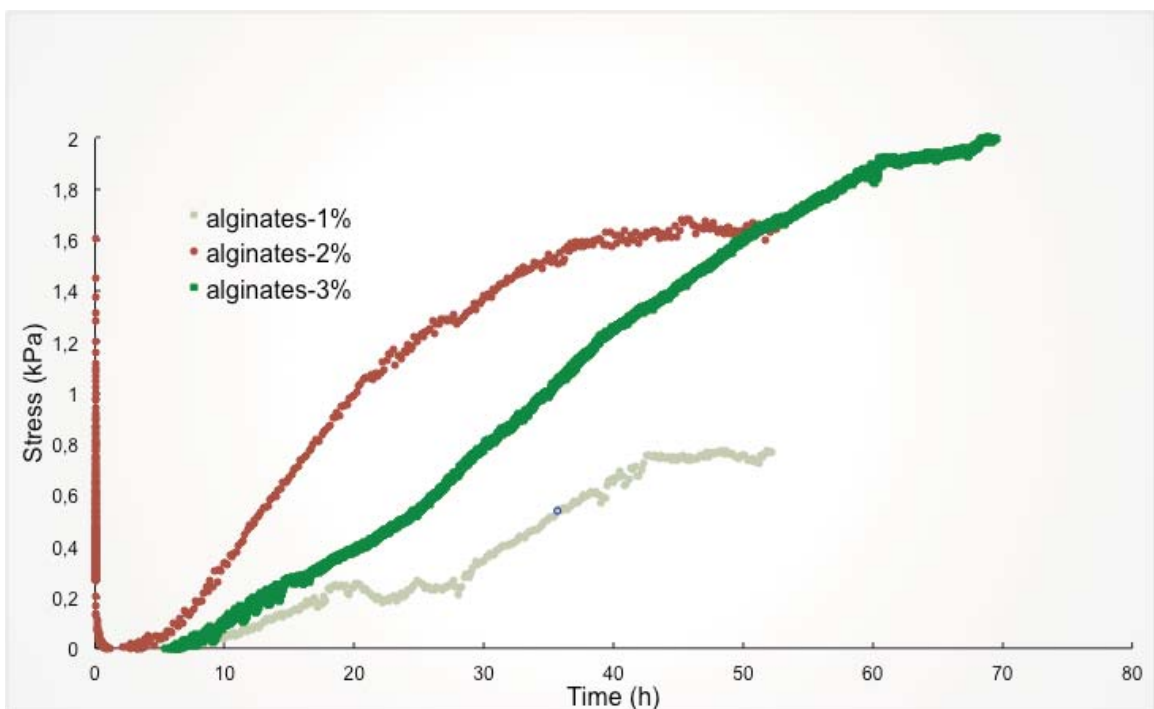


Figure 2: Evolution of the stress during water flow through the gel in the experimental device at different alginate ratios (Figure 1).

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