Diffusion Tensor Imaging (DTI) Studies of the Grape Berry

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1. Introduction

One of the most notable developments in the past decade in the field of nuclear magnetic resonance imaging (MRI) has been the development of diffusion tensor imaging (DTI). This technique has proven to be a powerful tool for neurological imaging, particularly when studying neural fibre tract networks [1; 2]. Outside of neurological imaging however the application of DTI has been largely unexplored. DTI has to potential to provide information on anisotropic diffusion within complex botanical systems such as the pericarp of the fruit of the grape vine (*Vitis vinifera* L).

2. Translational self-diffusion theory

Translational self-diffusion (henceforth referred to as diffusion) is the undirected and incoherent motion exhibited by an ensemble of molecules, such as water [3]. In a restriction free environment, the diffusion of water is isotropic and can be characterised by a single diffusion coefficient. When freely diffusing water molecules encounter physical boundaries within a restricted environment, the mean square displacement of these molecules is reduced. As diffusing molecules will travel further in directions less hindered, an apparent directional preference for diffusion can be introduced in restricted environments (i.e. anisotropic diffusion). Rather than using a single scalar diffusion coefficient to characterise anisotropic diffusion, a diffusion tensor is used instead. The diffusion tensor is a symmetric 3×3 matrix with real positive eigenvalues. The three eigenvectors of the tensor describe three orthogonal axes from which the mean square displacement spatial profile can be determined in three-dimensions (i.e. the diffusion ellipsoid) [4].

3. Diffusion tensor imaging in grapes

Water is an important determinant of fleshy fruit development and composition, as it is the medium by which solutes are transported into and throughout the fruit pericarp. Primary water and solute transport is facilitated by the xylem and phloem vessels of the vascular network [5], but less is known of how water is transported beyond the vascular tissue. Large expanses of cells in the fleshy pericarp have no direct connection to the vascular network: water and solutes must be delivered to these cells by other means, such as water flow and diffusion processes [6]. The focus in the present study is diffusion driven non-vascular water transport and tissue structure within the grape berry determined from the diffusion profile measured using MRI techniques and comparisons between berries at different stages of development.

4. Conclusions

Qualitative analysis of cv. Shiraz grape berries has revealed a strong relationship between the internal morphology of the fruit and the direction of diffusive transport. An anisotropic diffusion pattern is associated with major tissue regions of the pericarp – diffusion tangential to the berry surface in the exocarp and radial diffusion in the berry mesocarp. The nucellus of the seeds demonstrated highly anisotropic diffusion that appears isotropic after the tissue is replaced by the liquid endosperm. Diffusion in the seed embryo was isotropic.

These results indicate that DTI is a novel technique for studying diffusion based water transport in plants. DTI has the potential to increase the understanding of passive water transport processes in high water content structures and organs of plants, such as fruits, roots, petioles and stems.

References

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