Experimental Report

21/10/2014

Proposal: **8-05-416** **Council:** 10/2012

Title: Anomalous water diffusion in biological tissue

This proposal is a new proposal

Researh Area: Biology

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Samples: sucrose solution

Instrument	Req. Days	All. Days	From	To
IN13	12	9	26/02/2013	07/03/2013
IN5	3	2	01/03/2013	03/03/2013

Abstract:

A univocal interpretation of the physics driving water diffusion in cellular tissue is not yet achieved and different theoretical approaches currently exist to explain the deviation from pure Gaussian-like behavior. It is however commonly observed in up to date diagnostic imaging technique (MRI), which is widely used to detect pathologies such as ischemia and tumors. Neutron scattering plays here a unique role being able to observe water diffusion at atomic scale even in extremely complex systems. We thus propose a joint MRI-neutron scattering experiment on optimally chosen phantoms in order to validate the complementarities of such techniques.

Exp. Report n. 8-05-416
Dates of exp.: 01-03/03/2013 (IN5), 26/02/2013-07/03/2013 (IN13)
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Water is the major constituent of biological tissues (> 70%). Interacting with cell membranes during their random motion, water molecules can serve to probe tissue structure at microscopic scale, and thus, provide unique information on the functional architecture of tissues. In particular, the diffusion magnetic resonance imaging (dDMRI), uses water diffusion as a tool to investigate, at the micron scale, the occurring of common pathologies such as ischemia, tumors etc [1,2]. However, at micron scale, the cellular contributions are averaged with consequences on the correct interpretation of the diagnostic images obtained through dMRI.

We have shown that water diffusion may also be used by neutron scattering techniques [3,4], with the benefit of reducing the probed distance to the scale of the macromolecular separation.

In order to validate the complementarity of neutron scattering and dMRI, we have undertaken pioneer joint reference experiments on phantoms. The choice of phantoms is driven by the aim of getting rid of the extreme complexity of cellular tissue and, in particular, to be able to perform neutron scattering and dMRI experiments with the same sample conditions, and not influenced by the physiological degradation of cellular tissue after death.

Different phantoms were chosen, from vegetables at different water and fiber contents to water solutions at different sugar concentrations to mimic variable degrees of water confinement and anysotropy.

Here below (tab. 1) we report the list of the samples investigated through dMRI and elastic and quasi-elastic neutron scattering.

Vegetables	***Water content (%)***	***Fiber content (in 100g)***
Mushroom	92.45	1
Lemmon peel	81.6	10.6
Potato	81.6	2.4
Scallion	79.8	n. d.
Garlic	58.6	2.1
Date	21.32	6.7
Sugar solutions	***Water content (%)***	***Sugar content (%)***
0%	100	0
10%	90	10
15%	85	15
20%	80	20
25%	75	25
30	70	30

Tab. 1. List of samples investigated through dMRI and elastic and quasi-elastic neutron scattering.

dMRI scans were performed at the Grenoble Institute of Neuroscience (Inserm / UJF U836) in Grenoble using a 7T animal MRI scanner equipped with a gradient coil capable of reaching 600mT/m in 120µs. dMRI data were collected with multiple b values.

Elastic and quasi elastic neutron scattering data were acquired on IN13 and IN5, respectively, at 10 (IN13, IN5) and 70 (IN5) microeV energy resolutions. Although data analysis is still under progress, preliminary results show that we were able to discriminate and quantify at atomic scale free and restricted water diffusion processes (which are the dominating contributions to the global tissue dynamics) in the phantoms and characterize them through diffusion coefficients and residence times. In fig. 1 we report the comparison of experimental data acquired on IN5 at 10 microeV resolution for the right hemisphere of bovine (published data, [3,4]) and scallion tissues. The comparison is of particular interest since the samples count for the same water amount. In order to control and neglect multiple scattering events, the transmissions were kept below 84% by choosing appropriate sample thicknesses (due to the high water content thus strong neutron absorption).

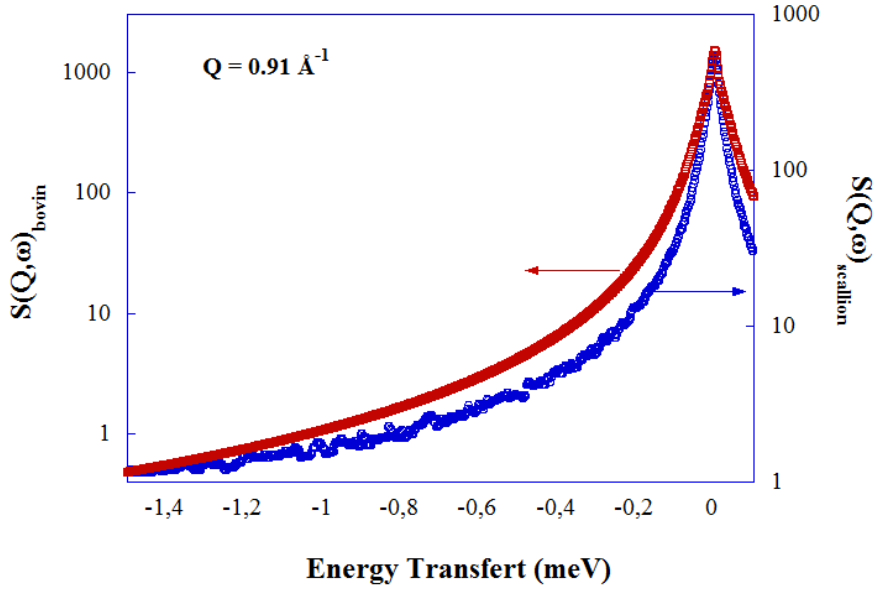

Fig. 1. Comparison of experimental data acquired on IN5 at 10 microeV resolution for the right hemisphere of bovine and scallion tissues.

The curves show evident different water behavior. Deeper investigation suggests the coexistence of free and restricted water pools to be independent from the macromolecular complexity. On the other hand, the relative weight to the global scattering signal varies sensibly. Indeed, limited to the scallion sample shown in fig.1, the analysis in terms of combined rotational and translational motions, as proposed by the Sears [5], suggests that the population of the restricted dynamics water pool is 3 times higher than the one of the bovine right hemisphere with consequent lower content of free-like water molecules. Moreover, the diffusion coefficients and resident times of the restricted roto-translational diffusion are strongly different while keeping unchanged the free-like water dynamics. Data analysis is still under progress for all the samples.

<u>References</u>

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