Characterization of sodium relaxation in food : a mandatory step to reach quantitative sodium images

Sylvie Clerjon, Guilhem Pagès, Nour El Sabbagh, Amidou Traoré, J.-M. Bonny

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a mandatory step to reach quantitative sodium images

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INRAE, QuaPA, F-63122 St Genes Champanelle, France
INRAE, PROBE research infrastructure, AgroResonance facility, F-63122 St Genes Champanelle, France

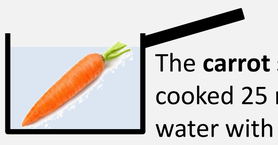
Sylvie Clerjon, Guilhem Pagès, Nour El Sabbagh, Amidou Traore, Jean-Marie Bonny

Local quantification of ^{23}Na in food is critical to
(i) understand the relations between salt distribution (and relaxation) and sensory properties
(ii) construct mathematical models to optimize the salting processes.

The challenge of quantitative sodium MRI deals with
(i) the poor sensitivity of sodium nuclei
(ii) the quadrupolar interactions
(iii) the short T_2 relaxation times
(iv) B_0 and B_1^+ inhomogeneities (similarly to other nuclei).

The present poster deals with the relaxation issues.

Sodium imaging quantification usually assumes that a single population is present in a voxel and that 3/5 of this population is invisible due to the short T_2 relaxation times compared to imaging TE. This hypothesis is true if all the sodium nuclei exhibit a biexponential super-lorentzian-like spectrum (type c) [1]. Even considering this invisibility factor, significant errors may persist [2]. That is why, we describe here an approach to check this assumption in different food matrices.



The **carrot** samples were cooked 25 min. at 100°C in water with 2% salt (weight).
For **relaxometry** 0.5g was collected after cooking.

The **fish** samples were salted on the upper side with 6% in weight of dry salt during 6 hours at 8°C.

Then, they underwent 6 hours at 24°C (smoking) and were stored at 5°C.
For **relaxometry**, a 16 g sample was collected 6 days after salting.

The **gel** sample used for spectroscopic analyses presented here was made with 20% of porcine pork in water and salted at 1,71 M.

A double quantum filter experiment (DQF) was first acquired on fish, gels and carrot. **All samples exhibit double quantum coherences** (i.e. slow motion sodium).
This information is not a sufficient prerequisite to ensure quantitative MRI. A **relaxometry** study of SQ coherences has been added to check if all sodium presents a biexponential behaviour, i.e. type c [1].

Fish samples

Relaxometry experiments were performed on a Bruker 9.4 T magnet with a 30 mm volumetric insert. A CPMG (TE=175 µs, 256 echoes, TR=500 ms) was recorded and the signal decay was fitted using a discrete biexponential model.

Reference gels

Relaxometry experiments were performed on a Bruker 9.4 T magnet with a 5 mm BBO coil. A CPMG (TE=160 µs, 4096 echoes, TR=400 ms) was recorded and the signal decay was fitted using a discrete biexponential model.

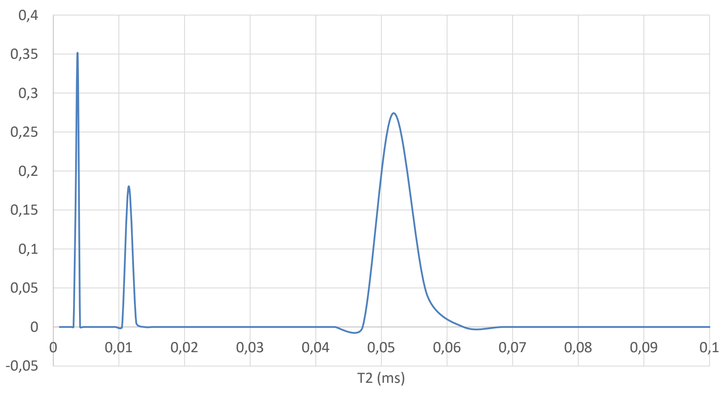
Carrot samples

	Fish	**Gel**	**Carrot**
T_{2fast}	5 ms	7.8 ms	4.6 ms
Amplitude (T_{2fast})	62.2%	3.6%	37.8%
T_{2slow}	48.3 ms	21.4 ms	24.9 ms
Amplitude (T_{2slow})	37.8%	96.4%	62.2%

The fish is the only sample exhibiting a biexponential behaviour with the theoretical amplitudes of 3/5 and 2/5 [1].

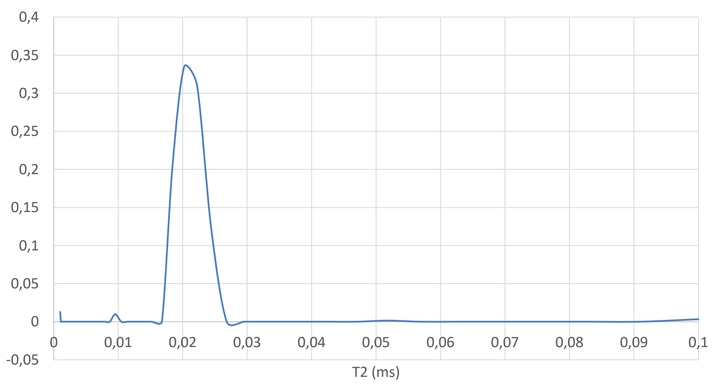
This first conclusion shows that biexponential discrete analysis is an unfair strategy for appreciating complex relaxation behavior. Hence, signal decay was then adjusted using a continuous inversion with L2-regularization [3].

Fish samples



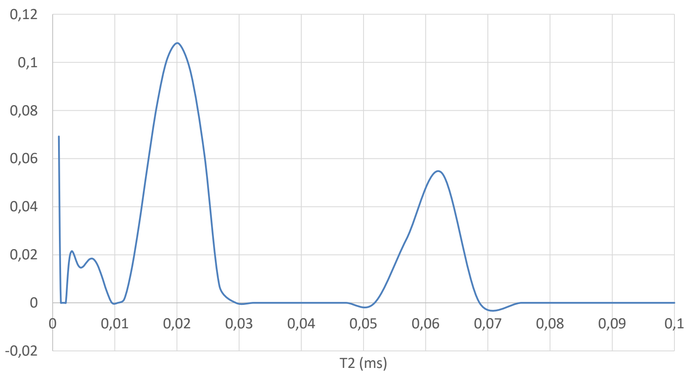
Fish sample exhibits short T_2 pools between 4 ms and 11 ms, and a slow population with a T_2 around 52 ms.

Reference gels



Gels exhibit a minor short T_2 pool at 10 ms and a slow population with a T_2 around 21 ms.

Carrot samples



Carrot sample exhibits more than two pools: 2 short T_2 pools between 2 ms and 9 ms, the main population around 24 ms and a free pool around 62 ms.

Key takeamays

- MR spectroscopy at high field allows to finely analyze the DQ and SQ relaxation of sodium in our food matrices
- SQ analysis reveals more complex relaxations than those suggested by DQ experiments
- Continuous inversion can be conducted on ^{23}Na decay. However it should be interpret with caution due to low SNR and the possible mix of several populations in heterogeneous systems (carrot, fish…)

Consequences for quantitative sodium MRI

- Reference gels and food matrices showed contrasted behaviors and thus probable different invisibility factors. These factor need to be evaluated to construct quantitative sodium images
- Because low SNR, adjustment using a continuous inversion with L2-regularization must be repeated on many samples for robust results
- Because food are heterogeneous, MR spectroscopy should be performed on several parts of the food (the edge, the core, the fat, the lean …)

Application to sensory properties

Fine analysis of sodium relaxation in food matrices is important
to build quantitative ^{23}Na MRI and then measure sodium location/diffusion in food
to characterize sodium-matrices interaction
because both location and interaction could be correlated with the sensory availability of sodium in food. One of the purpose of the ANR project Sal&Mieux is to demonstrate this correlation and to suggest solution to prepare food with less salt without altering the salty taste.

References
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