

Low field NMR research on the state of water at superchilling and freezing temperatures and the effect of salt on the freezing process of water in cod mince

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The quantity and state of water is an important factor in the quality assessment of fish and fish products. Low-field Nuclear Magnetic Resonance (LF-NMR) was used in this study to evaluate the quality and quantity of water in fresh cod mince and to study the effect of salt content on the water properties and freezing process of cod mince. This is a technique that has not been applied to food science in Iceland prior to this study, despite its many applications. One of the objectives of the study was therefore to study the application possibilities of low field NMR on food research in Iceland as well as to strengthen the relationship between the Icelandic Fisheries Laboratories (IFL) and international research centres.

The quantity of water was measured with a multi-pulsed Magnetic Field Gradient Spin Echo (m-PFGSE) pulse sequence and the results were compared with results from drying measurements. Relative Free Induction Decay (FIDR) measurements were used to follow the freezing process of the cod samples. These showed that increased salt content lowers the initial freezing point and affects the freezing process significantly. The FIDR measurements were also used to follow the change in the salt concentrations as the samples froze. They showed that the salt concentration increases in the remaining unfrozen muscle water as more of the water freezes and that the salt concentration increases faster as the initial salt content is higher. Proton relaxation times of the samples were measured with Carr-Purcell-Meiboom-Gill (CPMG) and Inversion Recovery (IR) pulse sequences. The transverse relaxation times measured by CPMG were processed with a bi-exponential model and the longitudinal relaxation times with a mono-exponential model. The measured relaxation times showed a strong correlation to the corresponding salt concentrations and water holding capacity (WHC). The study showed that low-field NMR is a useful tool in the evaluation of the quality and quantity of water in cod.

Key words: Low field Nuclear Magnetic Resonance (LF-NMR); superchilling; freezing; cod (*Gadus morhua*); transverse relaxation; longitudinal relaxation; free induction decay; water; water populations; salt; ice formation.