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Evaluation of the effectiveness of weak oscillating magnetic fields during freezing carried out in systems of different complexity

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ABSTRACT

The effectiveness of weak oscillating magnetic fields (OMFs) in improving freezing kinetics and reducing damage in frozen/thawed systems was assessed in ferric chloride solutions, lactate dehydrogenase (LDH), and hake mince infected with *Anisakis simplex* larvae. To do so, freezing experiments were performed in a lab-made magnetic freezer at different conditions (0, 0.33, 0.8, 1.5, and 7 mT at 50 Hz). Weak OMFs produced no significant effect on freezing kinetics of $FeCl_3$ solutions, LDH activity cryoprotection, water-holding capacity of the hake mince, or viability of *Anisakis simplex* larvae. Further studies are needed to evaluate the effectiveness of stronger OMFs in a wide frequency range.

Introduction

Magnetic freezing has attracted much attention in the last years due to its potential ability to improve the quality of frozen products. The commercialization of electromagnetic freezers has contributed to increase the interest of scientists and technologists. However, the scarce number of scientific works dealing with magnetic freezing have not been able to corroborate its claimed benefits, showing sometimes contradictory results.

The objective of this work was to contribute to clarify the potential effect of OMFs on freezing kinetics and quality of systems of different complexity.

Materials and Methods

A lab-made magnetic freezer composed of a conventional chest freezer and a 50-Hz oscillating magnetic field (OMF) generator (Fig. 1) was used. The sample was held at the middle of the air gap (10 x 10 x 4.2 cm^3) on the top part of the iron core of the OMF generator. The freezer temperature during the experiments was set at −23 °C and the OMFs applied were 0, 0.33, 0.8, 1.5, and 7 mT at 50 Hz.

Experiments were performed in triplicate in 3 systems of different complexity:

- 20 mL of freshly made $FeCl_3$ solutions (0.58 g in 0.1 M HCl)
- 100 µL of stock lactacte dehydrogenase (8 µg/mL in 20 mM potassium phosphate buffer, pH 7.5)
- Hake (*Merluccius merluccius*, L.) mince infected with 10 live *Anisakis simplex* larvae

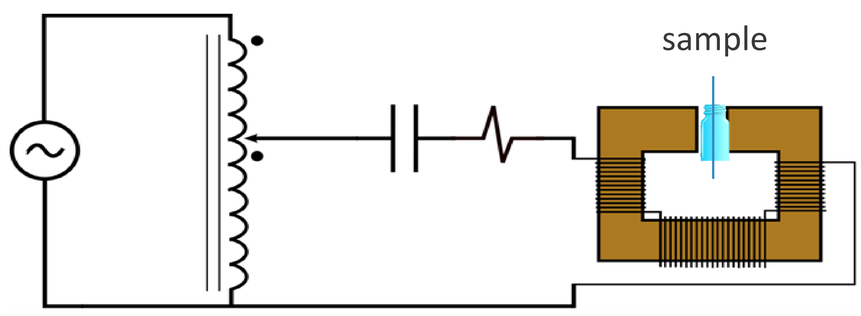

Figure 1. Oscillating magnetic field generator

Results and Discussion

Ferric chloride solutions

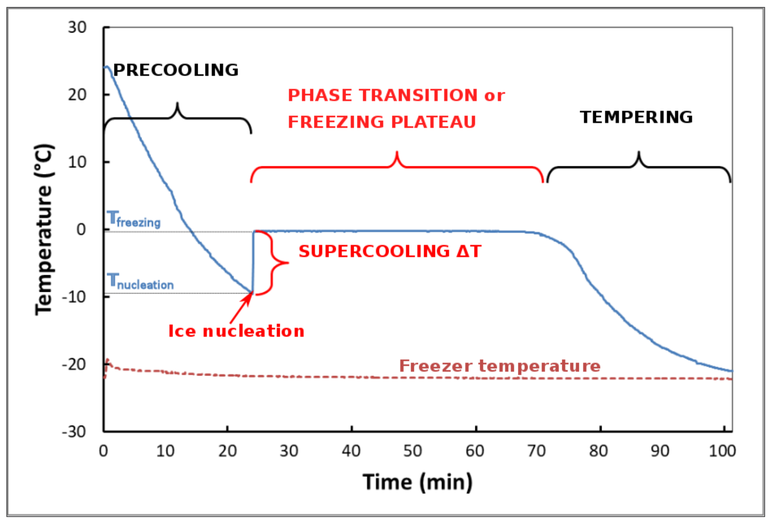

Figure 2. Freezing parameters defined on a typical freezing curve

	0 mT	0.3 mT	0.8 mT	1.5 mT	7.0 mT
Precooling rate (°C/min)	-1.8 ± 0.1	-1.8 ± 0.1	-1.8 ± 0.1	-1.9 ± 0.1	-1.8 ± 0.0
Supercooling degree ΔT (°C)	3.5 ± 1.6	1.2 ± 0.3	5.6 ± 1.9	3.3 ± 2.0	1.7 ± 1.7
Phase change time (min)	51.1 ± 1.3	48.6 ± 2.7	50.0 ± 2.4	48.6 ± 1.9	50.5 ± 1.2
Tempering rate (°C/min)	-0.9 ± 0.1	-0.9 ± 0.1	-0.9 ± 0.0	-1.0 ± 0.0	-1.0 ± 0.0
Total freezing time (min)	92.5 ± 3.0	89.5 ± 2.0	93.1 ± 2.5	87.3 ± 1.5	89.0 ± 0.8

Table 1. Freezing parameters for $FeCl_3$ solutions frozen at different conditions

Freezing kinetics of $FeCl_3$ solutions were not significantly affected by OMFs, whichever the field strength (significance level: 5%)

Lactate dehydrogenase (LDH) cryoprotection

FREEZING PROCEDURE	LDH ACTIVITY (%)
Not frozen	100
0 mT	29.5 ± 1.7
7 mT	28.2 ± 3.3

Table 2. Lactate dehydrogenase activity before (not frozen) and after freezing at different conditions

The application of an OMF of 7 mT at 50 Hz during freezing produced no significant effect (significance level: 5%) in the percentage of LDH enzymatic activity recovered (Table 2).

Hake mince infected with live *Anisakis simplex* larvae

BATCH	9 DAYS POST-MORTEM		12 DAYS POST-MORTEM	
Sample	Fresh	Frozen at 0 mT	Fresh	Frozen at 7 mT
WHC (%)	62.29 ± 2.34	61.03 ± 1.83	68.31 ± 3.76	68.29 ± 1.04

Table 3. Water-holding capacity in minced hake muscle before and after freezing at different conditions

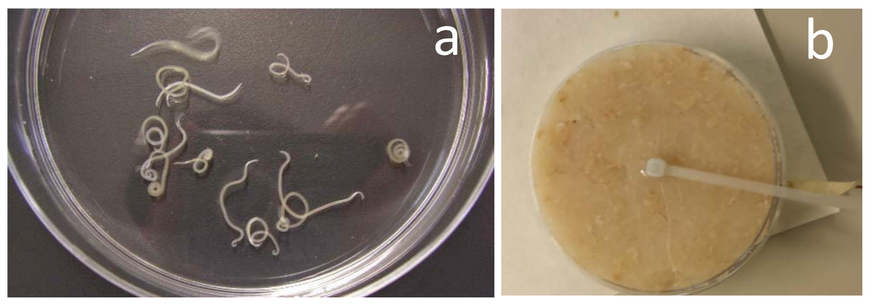

Figure 3. *Anisakis* larvae (a) added experimentally to hake mince (b)

No significant differences (significance level: 5%) in the water-holding capacity of the minced hake muscle were observed before and after freezing either with (7 mT at 50 Hz) or without magnetic field (Table 3). After freezing, all *Anisakis* larvae added to the mince were found non-viable both with and without OMF (Fig. 3).

Conclusions

Our study carried out in 3 systems of different complexity shows no advantages of the application of weak OMFs (≤ 7 mT at 50 Hz) during freezing either in freezing kinetics or in quality preservation. Further studies are needed to evaluate the effectiveness of stronger OMFs in a wide frequency range.

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