THE FEASIBILITY OF MICROWAVE SPECTROSCOPY FOR EVALUATION OF FREEZING METHOD IN MEAT

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Abstract – Freezing is an essential part of the value-chain in the meat industry, and therefore optimization is a goal that many researchers have sought to address. However, the techniques available for monitoring or observing the differences between freezing methods is limited and they suffer from being costly, cumbersome and time consuming to employ. Therefore, this paper reports on a novel technique using microwave spectroscopy where differences in microwave spectra between 4.0 – 7.5 GHz have been observed and classified in relation to three different freezing methods. The technique was also able to determine a highly reproducible difference between samples before and after freezing.

Key Words – microwave spectroscopy; freezing method; sensor.

I. INTRODUCTION

Freezing is used widely in the meat industry as a method for the preservation of products, ensuring that as much of the original taste and nutritional value is available to the consumer. The quality of frozen products is highly dependent on the nature of ice crystal formation (e.g. size, shape, etc.) which can be responsible for physical damage, such as disruption of cellular walls, and changes in osmotic pressure due to extracellular concentration of solutes. To improve the situation over conventional freezing, a number of studies have considered methods to improve freezing, including the use of electrostatic or radio frequency fields [1, 2], magnetic fields [3, 4], combinations of pulsed and static electric or magnetic fields [5], high pressure freezing [6-8] and ultrasound [9, 10]. While new methods of freezing have met with varied levels of success, it is noted that the techniques employed for establishing effectiveness are cumbersome. Typically, those methods include monitoring of temperature profile during freezing, assessment of water holding capacity (WHC) or visual inspection using some form of microscopy (e.g. scanning electron microscopy, SEM). These methods are time consuming (for example, WHC measurements take ≥ 24 hours), are invasive, and potentially costly to implement in the case of SEM analysis.

Thus, the authors have been investigating the feasibility of using microwave spectroscopy as a technique for rapid monitoring and assessment of different freezing techniques. The technology has already been demonstrated in other applications, such as rapid prediction of WHC [11] and water activity [12], and may be characterized by its capability to conduct rapid measurements without the need for invasive sampling. Furthermore, the technique is robust for use in harsh environments, such as chilling rooms or freezers, meaning that in-situ measurement is possible. This paper therefore reports preliminary findings of a study which compared three freezing methods on samples of pork loin: a Frigor chest freezer (F) at -36 ºC, a typical household freezer (H) at -18 ºC and liquid nitrogen freezing (N) at -196 ºC.

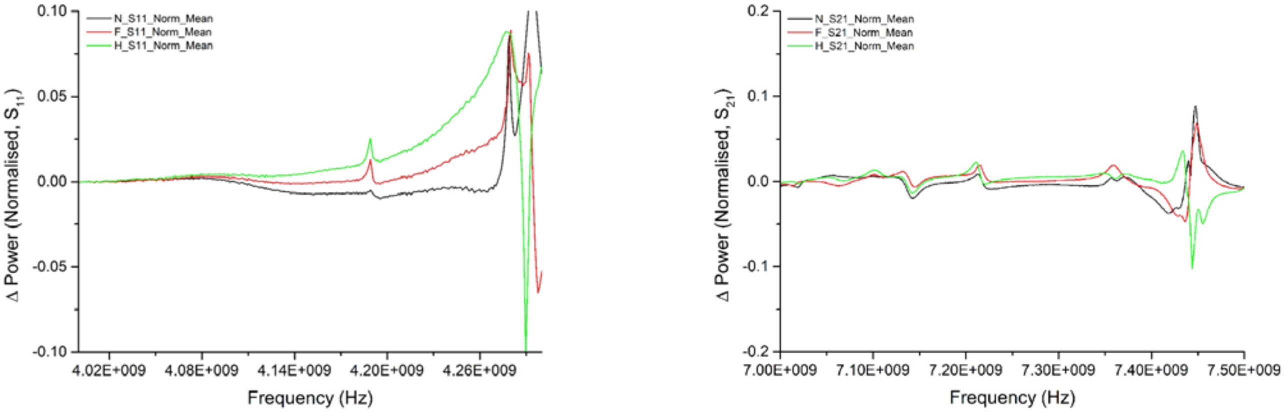
II. MATERIALS AND METHODS

The sensor used for this work is a bespoke rectangular cavity, the configuration of which is described in previous works [11, 12]. The system was configured to capture microwave spectra between 4.0 and 7.5 GHz, at 0 dBm (1 mW) output power and using 4000 discrete swept frequencies. Measurements took place in an industrial cooling room at 4 ºC to minimize the likelihood of confounding temperature effects. Both reflected (S_{11}) and transmitted (S_{21}) spectra were captured. A total of 6 samples taken from pork loins, as per the EZ-Driploss WHC technique, were measured using each freezing method (F, H and N) before and after freezing. In each case, the samples were measured every minute over a 10 minute period. Data was captured using a bespoke LabView application, and the pair-wise mutual information (PMI) data analysis technique was employed to identify areas of significance within the spectral data regarding the freezing method.

III. RESULTS AND DISCUSSION

The PMI analysis method found several regions within the captured spectra where variation in sensor output could be attributed to freezing method. For S_{11}, 4.06 – 4.26 GHz and 5.84 – 6.0 GHz were identified as significant, with the former being the most significant, and illustrated in Figure 1(a). For S_{21}, 7.01 – 7.02 GHz, 7.28 – 7.29 GHz, and 7.42 –

7.43 GHz were similarly identified, with the latter being classified as the most significant; all regions identified are illustrated in Figure 1(b). It was also noted that at 6.23 GHz it is possible to classify, with 100% accuracy, the samples in terms of their before and after freezing state.



(a) *(b)*

Figure 1. Variation in microwave spectrum (a) at 4.06 – 4.26 GHz, S_{11}, and (b) 7.0-7.5 GHz, S_{21}.

IV. CONCLUSION

This paper demonstrates the feasibility of identifying comparative variation in freezing methods using microwave spectroscopy which offers both rapid and non-invasive measurement options. At certain frequencies, the technique shows variation which can be related with freezing methods used, in addition to being able to distinguish between fresh and thawed (before and after freezing) sample states. Further work, using additional freezing methods, will seek to further assess the capabilities of the technique.

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REFERENCES

[1] M. Dalvi-Isfahan, N. Hamdami, and A. Le-Bail, "Effect of freezing under electrostatic field on the quality of lamb meat," *Innovative Food Science & Emerging Technologies,* vol. 37, Part A, pp. 68-73, 2016.

[2] M. Anese, L. Manzocco, A. Panozzo, P. Beraldo, M. Foschia, and M. C. Nicoli, "Effect of radiofrequency assisted freezing on meat microstructure and quality," *Food Research International,* vol. 46, pp. 50-54, 2012.

[3] H. Zhao, H. Hu, S. Liu, and J. Han, "Experimental Study on Freezing of Liquids under Static Magnetic Field," *Chinese Journal of Chemical Engineering*.

[4] L. Otero, M. Pérez-Mateos, A. C. Rodríguez, and P. D. Sanz, "Electromagnetic freezing: Effects of weak oscillating magnetic fields on crab sticks," *Journal of Food Engineering,* vol. 200, pp. 87-94, 2017.

[5] J. H. Mok, W. Choi, S. H. Park, S. H. Lee, and S. Jun, "Emerging pulsed electric field (PEF) and static magnetic field (SMF) combination technology for food freezing," *International Journal of Refrigeration,* vol. 50, pp. 137-145, 2015.

[6] D. Chevalier, A. Le Bail, and M. Ghoul, "Freezing and ice crystals formed in a cylindrical food model: part II. Comparison between freezing at atmospheric pressure and pressure-shift freezing," *Journal of Food Engineering,* vol. 46, pp. 287-293, 2000.

[7] G. Su, H. S. Ramaswamy, S. Zhu, Y. Yu, F. Hu, and M. Xu, "Thermal characterization and ice crystal analysis in pressure shift freezing of different muscle (shrimp and porcine liver) versus conventional freezing method," *Innovative Food Science & Emerging Technologies,* vol. 26, pp. 40-50, 2014.

[8] S. Zhu, H. S. Ramaswamy, and A. Le Bail, "Ice-crystal formation in gelatin gel during pressure shift versus conventional freezing," *Journal of Food Engineering,* vol. 66, pp. 69-76, 2005.

[9] X. Cheng, M. Zhang, B. Xu, B. Adhikari, and J. Sun, "The principles of ultrasound and its application in freezing related processes of food materials: A review," *Ultrasonics Sonochemistry,* vol. 27, pp. 576-585, 2015.

[10] H. Kiani, Z. Zhang, and D.-W. Sun, "Effect of ultrasound irradiation on ice crystal size distribution in frozen agar gel samples," *Innovative Food Science & Emerging Technologies,* vol. 18, pp. 126-131, 2013.

[11] A. Mason, B. Abdullah, M. Muradov, O. Korostynska, A. Al-Shamma’a, S. Bjarnadottir, *et al.*, "Theoretical Basis and Application for Measuring Pork Loin Drip Loss Using Microwave Spectroscopy," *Sensors,* vol. 16, p. 182, 2016.

[12] S. G. Bjarnadottir, K. Lunde, O. Alvseike, A. Mason, and A. I. Al-Shamma'a, "Assessing quality parameters in dry-cured ham using microwave spectroscopy," *Meat Science,* vol. 108, pp. 109-114, 2015.