CHARACTERISATION OF SALT SUBSTITUTION IN PROCESSED BEEF PRODUCTS COMBINING SPECTROSCOPIC, SENSORY AND CHEMICAL ANALYSIS

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Abstract – In this study, the effect of NaCl, KCl and $MgSO_4$ on bovine meat was studied. In our first study, beef meat was brined in marinades containing different salts in the constant content of 5.5 %. By correlating information from FTIR and NIR, it was shown that the NH groups from the protein backbone establish H-bonds with surrounding water molecules when the meat is salted with $MgSO_4$. The same is observed for C=O groups on the α-helices, indicating a partial denaturation of proteins. KCl, on the other hand, induced high amounts of non-hydrogenated C=O groups. These findings were confirmed by WHC measurements, while the sensory analysis showed that $MgSO_4$ was acceptable only when its share was one third or less. These findings were also confirmed in a second study, where the effects of different salt type and concentration on the structure and sensory attributes of Frankfurter sausage were investigated. The study also showed that FTIR imaging could be used to determine the distribution of protein secondary structures throughout the sausage matrix.

Key Words –FTIR, NIR, Protein hydration

I. INTRODUCTION

The food industry is currently putting substantial efforts into the development of strategies to reduce and substitute NaCl, which is the main source of excessive sodium intake in humans. Processed meat products often contain high amounts of NaCl, and the reduction of NaCl in this food category is thus of major importance to the industry. But even though strategies for NaCl reduction and replacements are industrially used, the effect of sodium reduction and its replacement on meat protein structure and water binding properties are not fully understood. In order to complete the picture of protein-water-salt interactions it is highly desirable to be able to follow, simultaneously and *in situ*, all the important interactions in one biological system. Vibrational spectroscopy constitutes a set of powerful tools, e.g. near-Infrared and Infrared spectroscopies, that have been frequently used for studying these interactions in biological systems [1-3]. In our previous studies, we have used these techniques for the characterisation of brined beef meat where NaCl has been replaced by commonly used salt replacers such as $MgSO_4$ and KCl at different concentrations [4-5]. In a recent study, beef meat was marinated with standard marinades, but with different salts in the constant concentration of 5.5 %. The spectroscopic results were linked with WHC and sensory analysis to find the connection between changes in molecular structure of proteins to sensory characteristics and WHC. These findings were also confirmed in a second study, where the effects of different salt type and concentration on the structure and sensory attributes of Frankfurter sausage were investigated. The study also showed that FTIR imaging could be used to determine the distribution of protein secondary structures throughout the sausage matrix.

II. MATERIALS AND METHODS

In the first study, beef muscle aged 2, 7 and 14 days were brined in marinades consisting of water (87%), sodium lactate / diacetate (4 %), dextrose (3 %), sodium ascorbate (0.5 %) and different salts (5.5 %) containing NaCl, KCl, or $MgSO_4$ in pure states or in mixtures. After brining, samples were prepared for FTIR analysis and NIR analysis as described by Perisic *et al* [5]. WHC was measured as cooking loss and a descriptive test was used to describe the sensory attributes. In the second study the similar salts and mixtures were added to a simplified sausage model system [6]. FTIR imaging analysis was performed on cryo-sectioned samples as described by Perisic *et al* [6]. All the results were linked by using the multi-block method Consensus Principal Component analysis (CPCA) [4].

III. RESULTS AND DISCUSSION

The results of the first study showed that Infrared (IR) and Near-infrared (NIR) spectroscopy could be used to reveal changes in meat related to salt substitution. For the former technique, information related to protein structures and hydration properties at the microscopic level is important. The latter technique adds information related to hydration properties on the macroscopic level. The differences among the samples treated with NaCl, KCl and $MgSO_4$ was dominant in all the spectral regions. The effect of the aging time was less pronounced. The effect of the salts on the secondary protein structure was related to differences in chaotropic and cosmotropic effects of the salts and differences in the ionic strengths. The magnesium and sulphate ions are strong cosmotropes and chaotropes, respectively, and are expected to bind more strongly to myofibrillar proteins.

The spectroscopic data and the design information were linked together using Consensus Principal Component Analysis (CPCA). By correlating information from FTIR and NIR data for samples treated with pure salt marinades, it was seen that the NH groups from the protein backbone establish H-bonds with surrounding water molecules when the meat is salted with $MgSO_4$. The same is observed for C=O groups of the α-helices, indicating a partial denaturation of proteins. Contrary to this, KCl induced higher amounts of non-hydrogenated C=O groups. One explanation for this latter effect might be that KCl creates a superfluid HD-water layer around the filaments. These results in general suggest that $MgSO_4$ increases the water binding in meat, whereas KCl has the opposite effect.

Corresponding data of cooking loss measurements for muscles aged for 2, 7 and 14 confirm the conclusions drawn from the spectroscopic results.

The same overall conclusions could be obtained from experiments on Frankfurter sausages. It was revealed that KCl inhibited the partial denaturation of proteins, unlike what was observed for $MgSO_4$ recipes, where an additional increase in protein hydration was detected. These findings were unequivocally supported by WHC measurements, which showed that compared to NaCl recipes, KCl decreased the WHC of sausages, while $MgSO_4$ caused an increase.

On the Frankfurter sausages, also FTIR imaging was used to depict the distribution of secondary structures within a tissue section. This could then be used to reveal denaturation effects and hydration within a tissue section. In Figure 1, an example is provided for a sausage treated with $MgSO_4$.

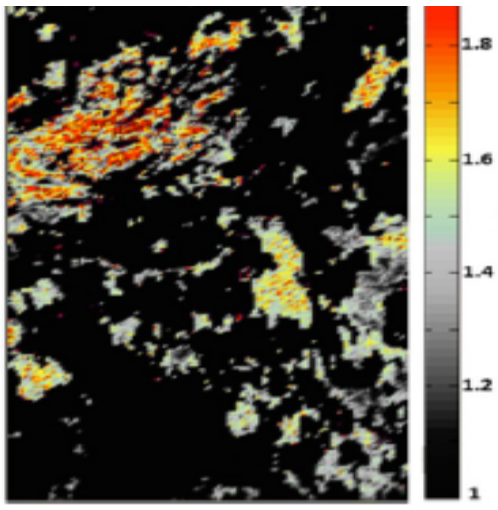

Figure 1. FTIR image depicting the distribution of secondary protein structures in a tissue section of sausage treated with $MgSO_4$.

The sensory study of the marinated beef samples showed that flavor/taste attributes are highly affected by the different salts. The same conclusions were obtained from sensory analysis of Frankfurter sausages made with a commercial type of recipe and 0.9 and 1.8 % of salt. Differences between the effects of salt types on sensory attributes were mostly caused by the differences between NaCl and $MgSO_4$. All $MgSO_4$ samples had bitter taste, and metallic flavor. The sausages made with only NaCl and mixtures of NaCl and KCl were high in salty and unami taste, meat flavor, sour taste, spicy flavor, smoke odour, sweet odour as well as in juiciness and fatness. The effect of the salt type was insignificant on the texture of the sausages, but in this context the salt concentration played a major role.

IV. CONCLUSION

The effects of NaCl, KCl and $MgSO_4$ exhibit distinctly different influence on beef matrices during the marinating process. MgSO4 exerts stronger effects on WHC than NaCl through a caotropic effect, increasing the H-binding between the protein and the surrounding water,whereas, KCl decreased the ability of meat proteins to preserve water. Both KCl and $MgSO_4$ introduced unwanted sensory properties. Similar findings were obtained when these salts were used in Frankfurter recipes. By coupling information from different spectroscopic techniques changes in protein structure and their water interaction within the meat matrix can be better characterized.

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REFERENCES

1. Boecker, U., Ofstad, R., Bertram, H. C., Egelandsdal, B., & Kohler, A. (2006). Salt induced changes in pork myofibrillar tissue investigated by FT-IR microspectroscopy and light microscopy. Journal of Agricultural and Food Chemistry 54: 6733 – 6740.
2. Bertram, H. C., Kohler, A., Boecker, U., Ofstad, R., & Andersen, H. J. (2006). Heat-induced changes in myofibrillar protein structures and myowater of two pork qualities. A combined FT-IR spectroscopy and low-field NMR relaxometry study. Journal of Agricultural and Food Chemistry 54: 1740–1746.
3. Kamerzell, T. J., Esfandiary, R., Joshi, S. B., Middaugh, C. R., & Volkin, D. B. (2011). Protein excipient interactions: Mechanisms and biophysical characterization applied to protein formulation development. Advanced Drug Delivery Reviews 63: 1118–1159.
4. Perisic, N., Afseth, N.K., Ofstad, R. & Kohler, A. (2011). Monitoring Protein structural changes and hydration in Bovine Meat Tissue due to salt substitutes by Fourier Transform Infrared (FTIR) Microspectroscopy. Journal of Agricultural and Food Chemistry 59: 10052 – 10061.
5. Perisic, N., Afseth, N.K., Ofstad, R., Hassani, S. & Kohler, A. (2013). Characterising protein, salt and water interactions with combined vibrational spectroscopic techniques. Food Chemistry 138: 679 – 686.
6. Perisic, N., Afseth, N.K., Ofstad, R., Scheel, J. & Kohler, A. (2013). FTIR imaging for structural analysis of Frankfurter Sausages subjected to salt reduction and salt substitution. Journal of Agricultural and Food Chemistry 61: 3219 – 3228.