# REFLECTION MODE MICROWAVE SPECTROSCOPY FOR ON-LINE MEASUREMENT OF FAT IN TRIMMINGS.

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## Background

Microwaves, as opposed to e.g. near infrared spectroscopy, have the ability to penetrate through large volumes of meat. In theory microwave spectroscopy should therefore be well suited for bulk on-line measurements for standardization of fresh meat in the processing industry. In order to test this hypothesis an industrial scale experiment was carried out at a slaughterhouse in Trondheim, Norway. The experiment had been organized by the Norwegian meat company Norsk Kjøtt and MatForsk in Oslo. Apart from microwaves the experiment also included the testing of several commercially available near infrared and x-ray based measuring systems. This paper describes the experimental set up and results obtained with the microwave measurements. Although the results from the microwave experiment were not nearly as good as the results obtained with the near-infrared (Toegersen et. al. 2003) and x-ray instruments the results prove that microwave spectroscopy potentially can be used for on-line fat standardisation.

## Theory

Microwave (MW) spectroscopy has traditionally been used for measuring physical characteristics of molecules with low molecular weights in the gas phase. These type of measurements often referred to as rotational spectroscopy were in the early to mid 20$^{th}$ century used to determine the moment of inertia of the molecules. This information could then give accurate estimates on the length of the covalent bonds in the molecules. MW are characterised by wavelengths in the millimetre and the centimetre range (in vacuum) corresponding to frequencies of around 1 GHz. Just as with infrared spectroscopy molecules with large dipole moments (e.g. water) are the strongest absorbers.

MW spectra of materials in the solid phase are very difficult to interpret as the rotation of individual molecules is greatly affected by intermolecular forces. The presence of salt will complicate matters further and the MW spectrum of frozen water/meat is almost non-existent. However, microwaves have one major advantage over e.g. mid-infrared (MIR) and near-infrared spectroscopy (NIR),- they propagate many centimetres (comparable to x-rays) in aqueous media such as meat whereas NIR and MIR only penetrate the order of 1 mm/1 micron respectively. This gives MW spectroscopy the major advantage of a much better sampling volume than the traditional methods and the technique should in theory be well suited for measurements on very non-homogenous materials such as meat.

## Methods

For generating the microwaves a "vector network analyser" from Rohde and Schwarz, Germany was used. The system was set to scan the frequency range from 4 GHz to 8 GHz at 401 linearly spaced single frequencies. For delivering the MW signal to the meat sample on a moving conveyor a horn antenna was used. This antenna can send polarized microwaves both horizontally and vertically and the reflected signal can also be received in both these directions. This gives rise to 4 transmitter/receiver combinations and the received signals are composed of both amplitude and phase shift relative to the transmitted signal.

The actual set up of the instrumentation at the slaughterhouse in Norway is shown in Figure 1. Here we see the horn antenna situated approximately 40 cm above the conveyor with the meat. The batch sizes ranged from 120 kg to 180 kg (pork and beef). Each batch of meat subjected to the MW measurements was after the measurement mixed well in a mixer and the entire mixer content was ground down to 3 mm particle size. A sub-sample of 100 kg was taken for chemical analysis (acid hydrolysis and Soxhlet extraction) thus minimizing sampling errors. The fat content of the batches ranged from approximately 8 to 30 %.

The empty conveyor was scanned a number of times while the conveyor was running. These scans were then used as reference measurements that were subsequently subtracted from the actual measurements of the meat on the conveyor. Between 25 and 30 scans (4 - 8 GHz) were acquired from each batch while passing under the MW horn antenna.

## Data analysis

The spectra acquired from the batches were first background corrected by subtracting the spectra of the empty conveyor. After this a Fourier transform was applied, converting the measurements from frequency domain to time domain. An example of this is shown in Figure 2 for one of the 4 possible polarization combinations. Here we can see reflections from the surface of the meat, the area between the meat surface and the conveyor. Further from the conveyor we also see signals that are due to multiple reflections.

The average time domain spectra from the 63 batches were analysed using multivariate calibration techniques (partial least squares and neural networks) in order to relate the spectra to the fat content of each batch. The result of this calibration is shown in Figure 3 containing a plot of predicted (cross validation) versus actual fat content of 63 batches.

## Discussion

At a first glance the results in Figure 3 are not impressive. However, the experiment demonstrates that microwave spectroscopy can be used for measuring fat contents of meat on a conveyor. In order to improve these results it will be necessary to place the instrument and conveyor with the meat being measured inside a tunnel acting as a wave guide. This will eliminate external interferences and freak reflections from the surroundings as demonstrated in small scale experiments (Damez, 2002).

## References

G. Toegersen, J. F. Arnesen, B. N. Nilsen and K. I. Hildrum. On-line prediction of chemical composition of semi-frozen ground beef by non-invasive NIR spectroscopy, Meat Science, Volume 63, Issue 4, April 2003, Pages 515-523

Damez J-L., Clerjon S., Dielectric spectroscopy as a tool for food process control, Proceedings of the 48th ICoMST, 2002, Rome.

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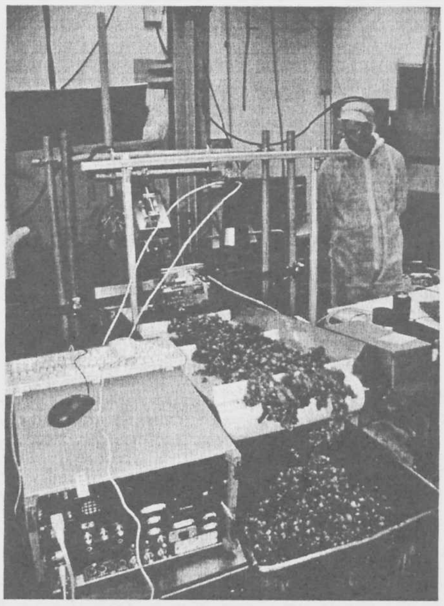

Figure 1: The MW horn antenna is situated approximately 40 cm above the meat on the conveyor.

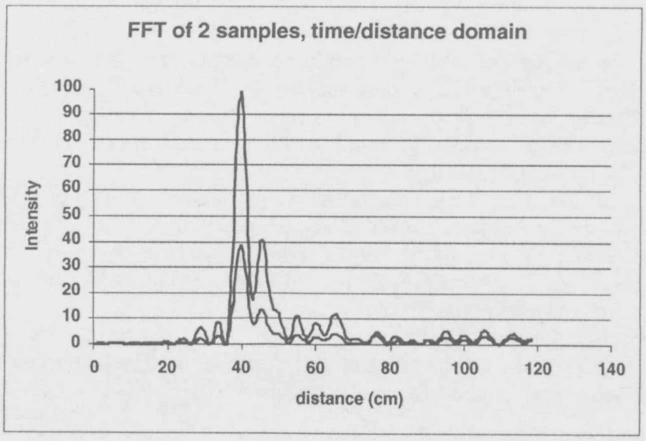


Figure 2: The Fourier transform of the of the original frequency domain spectra.

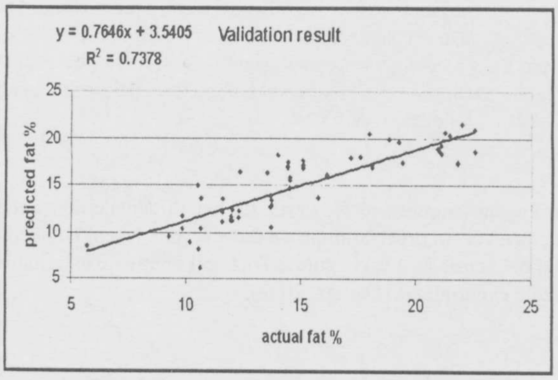


Figure 3: Fat content as predicted from the MW spectra versus the actual fat content of the entire batch. (N=63)