CHAPTER 12

# CONCLUSION

This study has integrated rapid *multivariate data acquisition* from modern sensors and analysis methods in meat quality applications. Using the data supplied by modern computerised *spectroscopic techniques*, an exploratory screening for advances in the meat quality measurements has been investigated. An important tool in this screening has been the advanced data analysis tools provided by *chemometrics* and *image analysis*.

Meat quality issues are represented by three main headings, *compositional quality*, *functional quality*, and *eating quality*. The compositional quality characteristics include the carcass lean, which for pork carcasses have been used for payment grading for decades. Beef grading utilises the shape, fatness and colour of the carcass measured either instrumental or by manual inspection. For both species more qualitative information of the carcasses and the meat are requested by the industry and the consumers. Qualitative composition information investigated in this study includes loin muscle area, intramuscular fat, back bacon composition, and water content. Functional meat quality is related to the dynamic changes in the meat related to the storage and genetic differences and to the muscle to meat conversion. The functional quality characteristics involved in this study are water holding capacity and contraction of the myofibrillar space. Eating quality attended here is tenderness and warmed-over flavour sensory properties of reheated food.

The *Autofom ultrasound scanner* for pork abattoirs was superior to manually operated grading equipment in performance and functionality. The performance of the Danish Classification system by NIR-probes gave equally good lean predictions. However, the applicability of the Autofom is much broader due to the non-invasiveness, speed of the measurement and the feature of the total scanning of the carcass enabling the characterisation of individual muscle groups. Currently, the Autofom is used for the longitudinal estimation of lean of the total carcass and the primal cuts. The potential of the system is, however, far from fully utilised. This study has shown good results in evaluating the *loin muscle area* from the transversal images by applying advanced image analysis techniques based upon *active contour segmentation*. Due to resolution problems in especially the mid-line region of the ultrasound images, special attention to this problem was given by adding information of the common loin structure with a

score-image from a principal component analysis to the segmentation method. Evaluation of *intramuscular fat* was demonstrated on a sample set with increased resolution, obtained by reducing the line speed of the Autofom. Due to the diverging resolution in the different directions, a special textural method, *two-dimensional angular moment technique*, was developed capable of analysing regions of different size, dimensionality and resolution. This approach provided good prediction on the improved resolution images, but failed on the normal resolution images. The *back bacon quality* has briefly been dealt with in a small scale. There was a clear indication that the ultrasound data provided significant data from the bacon region on the sides of the carcass. Textural information from the two-dimensional angular moment transformation supplied some information of the manually evaluated bacon slices, but more information about the meat structure should be pursued in future work, where also more data is necessary. In general, the potential use of the Autofom principle for provision of qualitative information is outlined in this study.

*Visual reflectance spectroscopy (400-800 nm)* was successful in the applications regarding the *water holding capacity*, the warmed-over flavour *sensory* and the *days of storage* of the cooked meat. The visual spectra were measured with an industrial system from NIR Systems with on-line potential by using a fibre guided measurement extension. The results generally indicated an advantage of including the entire spectral information from the measurement, instead of limiting the information to a colour measurement which basically integrates spectral information from three spectral regions only. Thus, a future advancement of a colour system should include information from e.g. myoglobin, oxymyoglobin, and NADH. Eventually, the visual system could be developed using the multivariate filter-based Fat-Quality-Meter (SFK Technology). Thereby the visual information could be combined with a near infrared information, which has not provided much information in this study, though, in previous work, however, near infrared has shown potential to supplement the visual data with e.g. protein information.

The *fluorescence* measurements had positive indications related to oxidation on especially the warmed-over flavour sensory properties and the evaluation of the effect of storage for cooked meat. The instrumentation utilised did not, however, justify reasonable conditions for comparing with the remaining spectroscopic techniques due to the small measured area (1×9 mm) with this dedicated laboratory equipment. More studies should be performed with a system more adequate for meat measurements

The problem with the sample representation brings the attention to a central point in measurement of meats, namely the *non-homogeneity* of the sample. From this study it has been obvious from especially the composition measurements, that the fluorescence instrumentation and the fibre optical insertion probe measurements suffers critically by the poor representation of the meat. This again emphasises one major advantage of the Autofom; the large representation of the carcass despite of the

rapid measurement. One approach to solving this problem for spectroscopic measurements have been outlined in the discussion of the imaging spectrograph, where the specificity of the spectral measurements delicately is combined with the representational advantages of imaging techniques. The technique was compared successfully in fluorescence measurement of wheat flour to laboratory instrumentation where the sampling effect representation was not critical. Imaging spectroscopy was also successfully applied in non-homogeneity measurements of meat. Despite its success, the method is not readily applicable in on-line situations due to the design, but could be used as an intermediate set-up for optimising more realistic applications before designing a prototype.

*$^{1}$H Low field nuclear magnetic resonance* (LF-NMR) is advantageous with regard to sample representation, because the relaxation signal is integrated over the entire sample and not just the surface. The multivariate study of the LF-NMR data showed good results in predicting water holding capacity in fresh porcine meat, eating quality of the cooked and reheated meat, as well as stress group of the different porcine meat quality extremes. The multivariate treatment of the exponential data tends to be superior to the exponential fit parameters, which however, present some unique interpretation facilities. In meats evaluated in this study, a two-component exponentially fitted model was appropriate in all experiments. Especially the $T_{21}$ parameter has provided very qualitative information in the results obtained here. Due to the relationship to the *post-mortem swelling* and contraction in the myofibrillar space and the difference measured for two different porcine muscles with different structural proportions in the *myofibrillar spacing*, $T_{21}$ can be directly related to the spacing in the myofibrillar system. These observations can lead to a better understanding of the water holding properties and the tenderisation process in all meat types in future work.

The multivariate processes evaluated for use in meat quality applications in this study have showed promising indications of *future on-line innovations* as illustrated by the following schematic overview valid for the equipment ised. However, the perspectives involve much more than these initial screening tools utilised here. The Autofom requires improved resolution and the spectroscopy techniques need to overcome the problems with sample representation to fulfil the demands for the accuracy of on-line. Furthermore, it is essential that this hardware development is combined with a costly and time consuming effort to build a library with representative spectroscopic data as well as advanced and thorough reference information to facilitate a global calibration of the quality analyses. This requires a vertical collaboration between many sciences and involves instrumental developers, the meat industry, and research affiliates and such an endeavour cannot be overcome without this integrated harmony.

| | Measurement Characteristics | | Meat Composition | | | | | | Functional and Eating Quality | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | On-line potential | Sample representation | Total Lean | Primals cuts lean | Loin muscle Area | Back bacon | Intramuscular fat | Water | Water holding cap. | Extreme MQ | Sensory (WOF) | Chemical (WOF) |
| Autofom | ■ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ |
| Insertion Probe | ■ | □ | ▒ | ▒ | ▒ | ▒ | □ | □ | □ | □ | ▒ | ▒ |
| NIR | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | □ | ▒ | □ |
| Visual | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | □ | ▒ | ■ | ■ | ■ |
| Fluorescence | ▒ | □ | ▒ | ▒ | ▒ | ▒ | □ | □ | ▒ | □ | ▒ | ▒ |
| Raman | ▒ | □ | ▒ | ▒ | ▒ | ▒ | □ | □ | ▒ | □ | □ | □ |
| NMR | □ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ■ | ■ | ▒ | □ |

■ Very successful / high accuracy / large representation
▒ Successful / acceptable accuracy / acceptable representation
□ Unsuccessful / poor accuracy / low representation
▒ Not tested