Quantitative analysis of meat spoilage using vis/near infrared spectral imaging

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Introduction

More than 50 methods have been used for the detection of microbiologically spoiled or contaminated meat (e.g. organoleptic, microbiological, and physico-chemical) and most of these are well documented. Due to their limitations (e.g. time-consuming, labour-intensive, retrospective information, and requirement for highly trained sensory panels), they are generally unattractive for routine analysis. VIS/NIR (visual/near infrared) spectral imaging is introduced as a versatile method for quantitative assessment of meat spoilage. It deals effectively with the heterogeneity of meat samples, and captures relevant spectroscopic properties of the chemistries involved.

Materials and methods

In this study, the shelf life of minced beef was studied after storage aerobically under normal atmospheric conditions (×45 replicates), under modified atmosphere packaging (MAP) 40% CO2; 30% O2; 30% N2 (×45 replicates), and storage at 5°C. At the same time microbiological (total viable count (TVC), *Pseudomonas* spp, *Brochothrix thermosphacta*, lactic acid bacteria (LAB), Enterobacteriaceae, yeast and moulds) analysis was performed to provide data for model validation. The data set and FT-IR analyses are described in Ammor *et al.*[1] The actual measured quantities of *Br. Thermosphacta* and LAB showed an increase as a function of storage time, but not a big difference between aerobic and MAP conditions. The other four measured quantities: TVC, *Pseudomonas* spp., Enterobacteriaceae, and yeast and moulds, are all shown in Figure 1.

A VideometerLab spectral imaging instrument[2,3] was used to acquire colour and texture measurements, which can provide information on biochemical changes occurring at the meat surface. The instrument measures a reflectance image at many different wavelengths, e.g. 405 nm, 435 nm, 450 nm, 470 nm, 505 nm, 525 nm, 570 nm, 590 nm, 630 nm, 645 nm, 660 nm, 700 nm, 850 nm, 870 nm, 890 nm, 910 nm, 940 nm and 970 nm. The illumination consists of an integrating sphere geometry with high-power light emitting diodes and a highly flexible illumination control

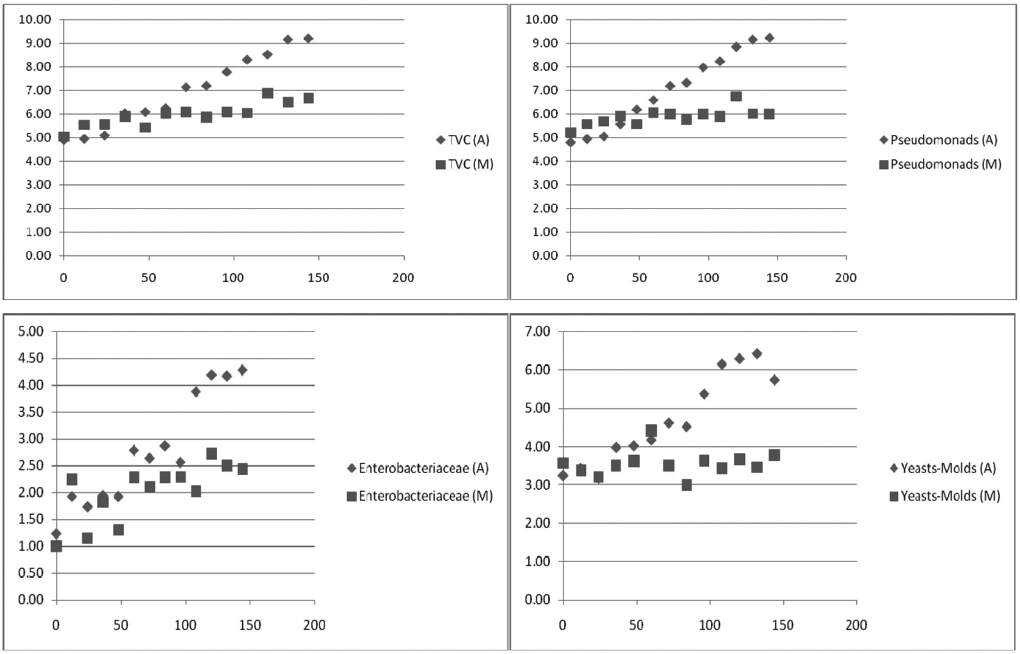

Figure 1. Actual measured microbial quantities as a function of storage time. (A) is under aerobic conditions, and (M) is in MAP packaging. The y-axes refers to enumeration of different microbial groups (i.e. the changes of population in terms of time) and the unit is log10 CFU/g of minced beef.

system. This system provides very uniform and diffuse illumination, which focuses on surface-chemical properties of the sample, rather than on physical properties, such as shape, shading, topography, and gloss. The meat samples were simply presented in 90 mm Petri dishes. Example of VIS images representing meat before storage, after MAP storage, and after aerobic storage are shown in Figure 2.

Imaging and analysis of samples could be done with a cycle time of app. 10 seconds per sample, including manual handling.

The spectral imaging data collected from the VideometerLab was subjected to statistical analysis, including principal component analysis (PCA), minimum noise fractions (MNF) and canonical (aka Fischer) discriminant analysis (CDA), to reveal discrimination of the samples concerning their spoilage status, whilst quantitative predictions of the microbial activity was also conducted.

Results and discussion

The results demonstrated the potential use of spectral imaging in evaluating meat spoilage. Colour and surface chemistry changes during meat spoilage may be monitored using the VideometerLab. Heterogeneity of changes becomes apparent and may be measured. A canonical discriminant function (CDF) trained on meat before storage and after 144 hours of aerobic storage, showed that

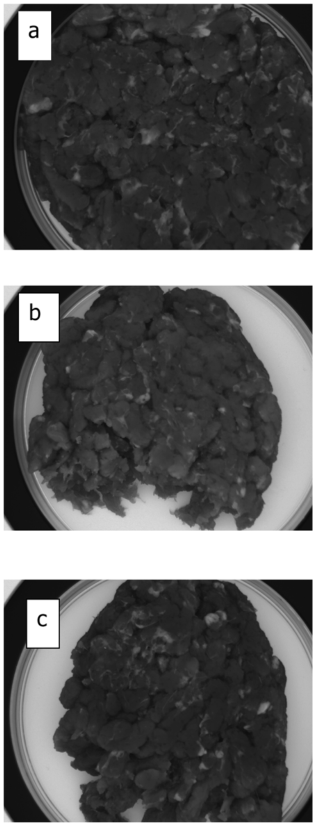

Figure 2. Meat sample before storage (a), after MAP storage (b), and after aerobic storage (c).

(1) Aerobic storage gives a large a bimodal change in colour, (2) MAP storage gives a smaller but significant change in colour, and (3) the changes above can be directly quantified from the histogram of the CDF. Similar transformations may be obtained in an unsupervised and explorative manner using e.g. minimum noise fractions (MNF). Furthermore these transformations can be used to hypothesize about the optical/spectral expression of the different types of microbiology.

The current data set did not allow us to validate such hypotheses, since we did not know which type of microbiology occurs in which image, and where. This is left for future work, which is currently in progress. Figure 3 shows the CDF plotted against storage time.

Due to the heterogeneity of microbial growth and the bimodal nature of the CDF we plot the 90% quantile of the CDF to focus on the part mostly affected by microbiology. It is straightforward to quantify the change in terms of other statistics e.g. mean, standard deviation, and quantiles. From Figure 3 we observed that the most prominent spectral change is (1) sigmoidal in nature, and (2) that the change is most intense from 50 to 100 hours of storage time. This corresponds quite well to the growth pattern of Enterobacteriaceae, and yeasts and moulds. Growth patterns of other microbiology types are overlayed with this prominent pattern, and will best be separated by applying specific and known microbiological cultures to the samples in a new

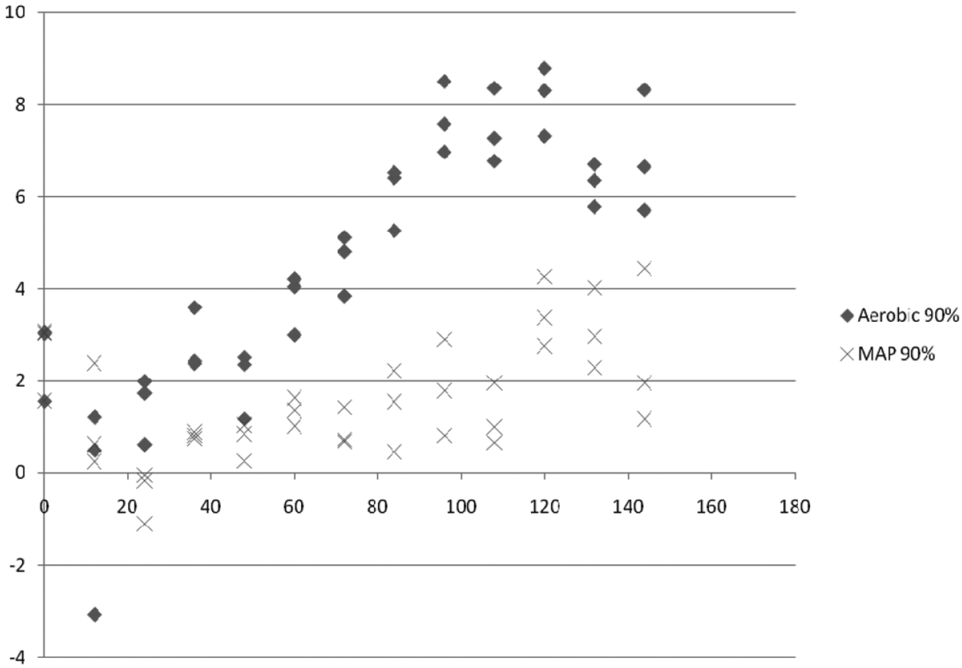

Figure 3. CDF for all meat samples as a function of storage time. 90% quantile of the CDF is used due to the heterogeneous/bimodal nature of the microbial growth.

dataset. The results from looking at explorative projections of the data, predominantly PCAs and MNFs, indicate that the chemical and colour changes occurring in the surface of the sample are heterogeneous, and this applies to both aerobic conditions and MAP packaging. It was therefore concluded that imaging spectroscopy is a very promising technique for fast assessment of microbial meat spoilage, and that this assessment can be performed in the VIS/NIR region of wavelengths between 400 nm and 1000 nm.

Acknowledgement

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