Monitoring the effect of the "ultra-high pressure" preservation technology by near infrared reflectance spectroscopy

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Introduction

Ultra-high pressure (UHP) technology for the preservation of foods is under intense research to evaluate its potential as a complementary or alternative process to traditional methods of food preservation. UHP is emerging as one of the most promising new, non thermal technologies in the food processing industry.[1–4] Traditional processing methods require large amounts of energy which may cause unwanted reactions in the food, leading to lack of flavour and loss of vitamins. The application of UHP requires that the food be subjected to pressures in the range of 50–800 MPa. Such high pressure will usually extend the shelf-life of foods by inactivating vegetative microorganisms, enzymes while promoting the germination of bacterial spores into heat-sensitive cell states, while retaining vitamin content and preserving natural flavours.[5,6] This new technology follows the "minimal processing" concept of minimising the quality degradation utilising less energy. At the same time, UHP technology has the unique ability to create diverse textures and gels. We joined the research team at our university involved in the mentioned technology using an ultra-high pressure equipment, recording the near infrared spectra of meat samples exposed to different pressures. The objective of this investigation was to see whether changes in minced meat samples due to UHP could be followed by near infrared spectroscopy.

Materials and methods

Minced beef and pork were prepared from *longissimus dorsi* muscle. Three experiments were designed to study raw beef samples and two experiments were designed to study raw pork. A total of 102 samples of raw beef and 75 samples of pork were analysed. The raw meat was minced and vacuum packed in PE-PA-PE foil. The samples were UHP treated with pressures ranging from 50 to 800 MPa for 20 minutes. All samples had an initial temperature of 8°C. A Food Lab Model SFL850 (Stansted Fluid Power Ltd, UK) was used in batch mode to induce UHP. The equipment had a chamber size of 40 mm diameter × 240 mm length. UHPs were attained within two minutes. Temperature was maintained by circulating water through the cylinder wall of the pressure vessel. Ethyl alcohol, containing 15% castor oil for lubrication and anticorrosion purposes, was used as the pressure-transmitting medium in the UHP vessel. Since the liquid pressure-transmitting medium changed its volume slightly at compression, the UHP vessel did not present operating hazards.

Near infrared spectra of all samples were recorded immediately after the UHP treatment. A "Spectralyzer 1024" (PMC, LaborChemie, Vienna, Austria). was used to measure and store the NIR spectra (range 1000–2500 nm in 2 nm steps). Quality points were calculated using the polar qualifica-

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tion system (PQS)[7,8] data reduction and qualification software along with the "wavelength range optimisation" program. The optimisation goal was to determine the optimum wavelength range that would give the best separation between UHP treatments. The quality of separation was expressed as sensitivity (S), where sensitivity was defined as the distance between the centres of the quality points of two samples divided by the sum of the standard deviations of the quality points of the two samples exposed

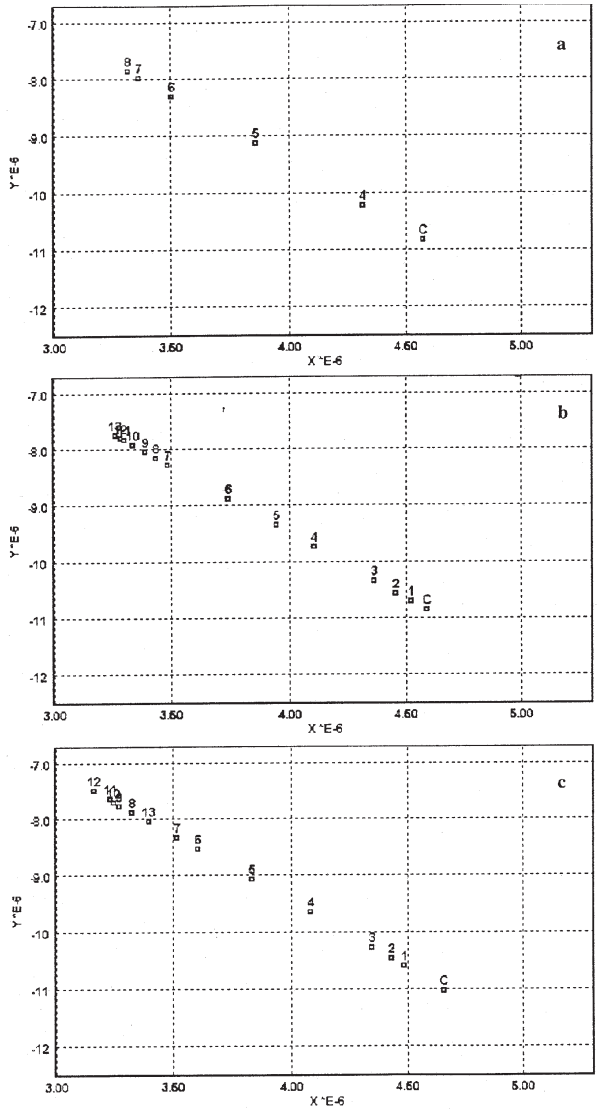

Figure 1. Quality points of the minced beef samples exposed to different high pressures. Quality points were determined from the second derivative spectra in the 1250–1300 nm wavelength range using PQS software [first (a), second (b) and third (c) experiments].

to different pressures. After treatment, the samples were stored at 4 ± 1°C for a week, then they were measured with an "electronic nose" (Daimler–Chrysler Aerospace Model SamDirect, Germany, made chemosensor array in order to see the differences in odour caused by extended shelf-life for the various pressures applied. Evaluation of the electronic nose measurements was performed by using principal component analysis.

Results and discussion

Maximum sensitivity S was achieved using the 1250–1300 nm range. Figure 1 shows the results of the three beef experiments. Figure 2 shows the results of the two pork experiments. Quality points of samples exposed to the same pressure are marked with the same number in the figures. Quality points of the control samples are marked with the letter "c" while quality points of the samples exposed to different pressures are marked with numbers. The numbers and the corresponding pressures were as follows: 1 ÷ 50 MPa, 2 ÷ 100 MPa, 3 ÷ 150 MPa, 4 ÷ 200 MPa, 5 ÷ 250 MPa, 6 ÷ 300 MPa, 7 ÷ 350 MPa, 8 ÷ 400 MPa, 9 ÷ 450 MPa, 10 ÷ 500 MPa, 11 ÷ 600 MPa, 12 ÷ 700 MPa, 13 ÷ 800 Mpa.

Location of the quality points in Figures 1 and 2 clearly show an existing relationship between spectral data and the changes in meat samples caused by the UHP treatment. Shift of the quality points

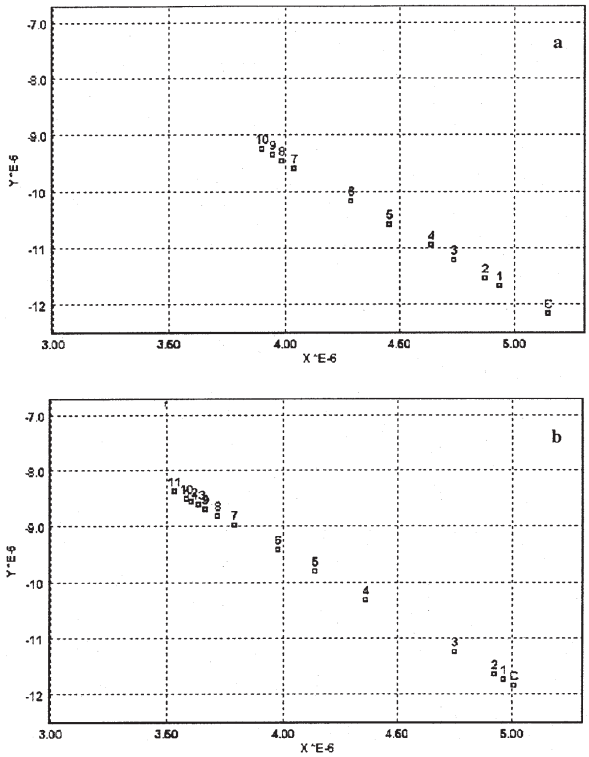

Figure 2. Quality points of the minced pork samples exposed to different high pressures. Quality points were determined from the second derivative spectra in the 1250–1300 nm wavelength range using the PQS software [fourth (a) and fifth (b) experiment].

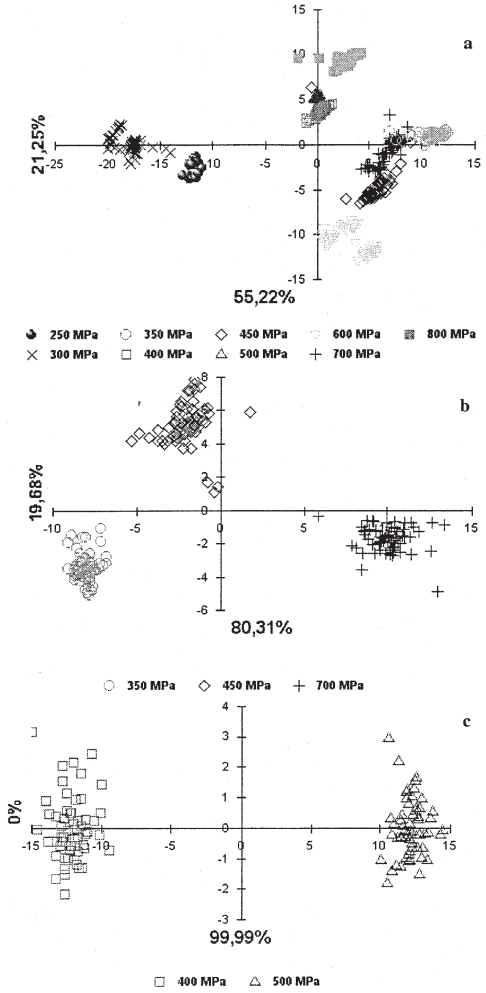

Figure 3. Quality points ("the odour") of nine minced beef samples after a week storage at 4 ± 1°C. The samples were exposed to different high pressures before storage. After storage they were measured repeatedly by an electronic nose. The quality points were determined using principal component analysis, and represented on the projection planes (a, b, c) of the first two principal components of these nine and the a bit overlapping samples.

as a function of the UHP shows that significant changes in meat samples occurred between 200–300 MPa. This change can be assigned to the change in protein structure as an absorption peak of protein can be found around 1276 nm. This wavelength is the middle of the wavelength range found by the wavelength range optimisation program. The sensitivity achieved between the control sample and the sample exposed to 800 MPa was higher than 100. This means that the distance between the two quality points is at least 100 times higher than the sum of the standard deviation of the quality points of these two samples. Repeatability of the measurements was very good, in spite of the fact that it was extremely difficult to produce homogeneous samples.

Immediately after treatment, odour change was not observed among the control sample and the samples exposed to different pressures. Odour measurements, using sensory assessment of the samples after one week storage at 4 ± 1°C, were quite different. Samples exposed to 350 MPa or more tended to maintain their original smell while samples exposed to less than 350 MPa were definitely stinking. Samples exposed to less than 250 MPa were definitely unbearable.

Figure 3(a) shows the quality points of nine beef samples exposed to different high pressures. These samples were stored for one week and measured repeatedly with the electronic nose. The projection plane shown in Figure 3(a) for these nine samples was defined by the first and second principal components for these nine samples. For the three samples exposed to 350, 450 and 700 MPa, a slight overlap exists. However, a new projection plane can be found [see Figure 3(b)] where their separation is perfect. Also note that for the two samples exposed to 400 and 500 MPa—also having overlapping quality points—a new (third) projection plane can be found [see Figure 3(c)] providing excellent separation.

The effect of the pressure on the raw meat is very different depending on the magnitude of UHP. Lower pressures do not inactivate enzymes while the higher pressures definitely inactivate the enzymes. Microorganism behaviour varys depending on the magnitude of UHP. Thus, sample deterioration develops differently during the one week stored at

4 ± 1°C. This seems to explain why the quality points in Figure 3 do not change their position along a strait line or curve as a function of UHP treatment.

Conclusion

Near infrared reflectance spectroscopy is suitable for monitoring changes in meat samples caused by UHP treatments. Both sensory and electronic nose (chemosensor array) evaluations show that the UHP treatment has a significant effect on food quality and on shelf-life of raw meat samples.

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