DETERMINATION OF THE WATER DIFFUSIVITY COEFFICIENT IN PORK MEAT.

M.A. Ruiz-Cabrera [1], P. Gou [2], J. Comaposada [2], J.D. Daudin [1], L. Foucat[1], J.P. Renou[1]

[1]Unités Génies des Procédés et STIM. Station de Recherches sur la Viande. INRA-Centre Clermont/Theix. 63122 SAINT GENES CHAMPANELLE.
[2] Institut de Recerca i Tecnologia Agroalimentàries. Unitat de Tecnologia de Processos. Centre de Tecnologia de la Carn. Granja Camps i Armet. E-17121 Monells. Girona. Spain.

INTRODUCTION

In the drying process of cured ham the drying rate and the water content distribution are parameters of fundamental importance. Although the mechanism of mass transfer in foods is complex, diffusion models based on the second Fick law are generally considered. For example, Mulet et al. (1992) and Gou et al. (1996) used this approach to model the dehydration process in different meat products. Many studies deal with the assessment of the effective water diffusivity (D_e) but different results have been published. D_e is often deduced from drying kinetic by assuming a constant value with a simple analytical solution of the second Fick law. More sophisticated methods can provide a relationship between D_e and the moisture content (X, kg water/kg dry matter). The objective of this study was to compare in the case of pork lean meat the value of D_e assessed with either a drying kinetic method or a method based on NMR images of moisture profiles (Ruiz-Cabrera et al. , 1997) during drying.

MATERIAL AND METHODS

Two hams of Duroc (D) breed and two hams of Large White x Landrace (L) crossbreed were selected according to the pH (<5.8) and electrical conductivity (< 3 µs) measured 24 h post-mortem in the *Semimembranosus* muscle from which the samples were taken. One ham of each genetic group was studied with each method. Moisture content (A.O.A.C., 1980) and fat content (Arneth, 1972) of each sample were determined.

Drying kinetic method:
Two samples of each ham (D1, D2, L1 and L2) were shaped as a parallelepiped of 30x40x50 mm (±5mm). To ensure that the direction of the water movement in the tissue was approximately parallel to the direction of muscle fibres, the samples were covered with polyethylene polyamide film on the appropriate faces (Gou et al., 1996).
The raw meat samples were dried for 23-35 days in an experimental drier-box, where the drying air was conducted through a filter with silica salt to maintain relative humidity at 80%. Air speed was very low. The drier-box was in a chilling room at 13ºC.
The drying rate was periodically determined by weighing the samples (every 2 or 3 days). D_e was estimated as in Gou et al. (1996), using a moisture content in equilibrium with air of 0.283 (Comaposada et al., 1998). The D_e estimates depend on the sample length, which decreased during drying Therefore, the length of the sample was also periodically measured in triplicate with a SOMET calliper. Finally, D_e was determined using a range of lengths from the initial length to the final one.

NMR method:
The experimental procedures were carried out using the apparatus and methods which have been described in detail by Ruiz-Cabrera et al. (1997, 1998). Each sample (D3, L3 and L4) was shaped as a parallelepiped of 30x15x10 mm and placed in a cell which was maintained at 16 ºC by circulating water and dried in constant conditions (1 m/s, 24°C and 45% RH) on one face to promote water movement parallel to fibres. The moisture profiles were extracted from the 2D NMR images. Then, the moisture profiles were first plotted against the dry matter length (ξ), which remains constant during drying, instead of the spatial abscise. The master curve was integrated numerically to calculate the effective diffusivity (D_e) as a function of water content (X) with the following equation :

$$D_e(X) = -\frac{1}{2}\left(\frac{\partial \eta}{\partial X}\right)\int_{X_o}^{X} \eta \partial X \quad \text{where } \eta = \xi/\sqrt{t}$$

The different steps applied to obtain a master curve from which a D_e versus X relationship can be derived, have been described in Ruiz-Cabrera et al. (1997).

RESULTS AND DISCUSSION

Drying kinetic method:
The water content (kg/kg dm) of samples ranged between 3.04 and 3.46 before drying and between 1.27 and 1.84 at the end of drying. The average fat content (g/100 g dm) of Duroc and LWxLR samples was 11.56 and 2.28 respectively. The estimated D_e values using different length, from the initial length to the final one, are shown in Figure 1. Shrinkage in the longitudinal direction must be mainly due to the shortening of myofibres. Duroc samples showed lower shrinkage than LWxLR samples, this could be due to the major intramuscular fat

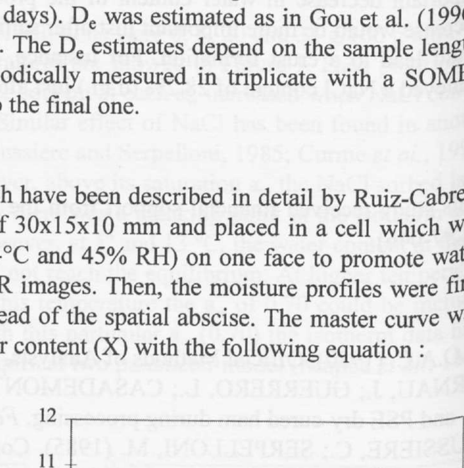

Figure 1. D_e Values versus sample length, from the initial length to the final one.

content of the Duroc breed which would maintain better the initial structure of meat during drying. Using the average of initial and final length, the highest D_e was obtained in the L2 sample. However, the effect of genetic origin was not significant (P>0.05).

NMR Method :

Fat content (g / 100 g dm) of D3, L3 and L4 were 0.98, 0.44 and 6.12 respectively. Figure 2 shows the master curve of the sample D3. After 3 hours of drying the moisture profiles in the master curve follow the same pattern. Thus, the last moisture profiles between 3 and 5 h were used for the calculation of D_e. Figure 3 shows the dependence of D_e on water content (X) and on fat content of the sample. Moisture diffusivity is highly influenced by the water content: it increased from 5.10^{-11} m²/s for a X of 1.3 kg/kg dm to 10^{-9} m²/s for a X of 2.8 kg/kg dm. This value is about the same as diffusivity in pure water. Fat content also had a slight effect on De values: as fat content increased the De values decreased.

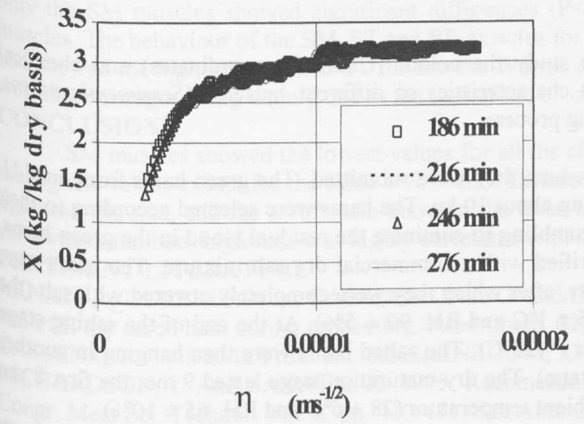

Figure 2. Master curve X versus η for the experiment D3.

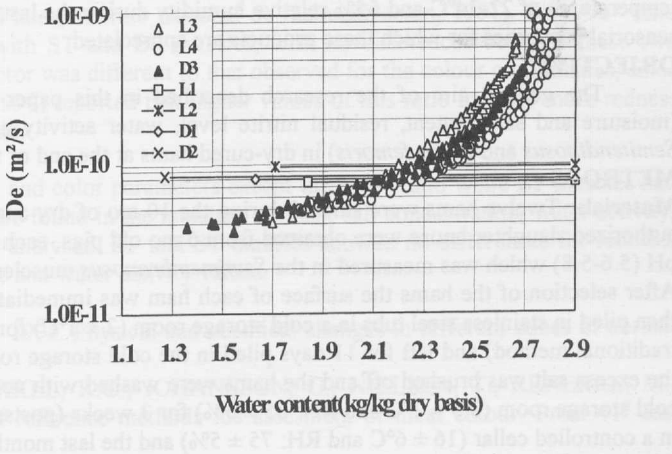

Figure 3. Diffusion coefficients (D_e) determined wiht drying kinetic and NMR methods versus water content (X).

Comparison between methods:

The two methods gave D_e values of the same order of magnitude and showed only slight differences between samples. The drying kinetic method gave average D_e values fitted with a Fickian diffusion model, which assumed no spatial variation of D_e with X within meat. If D_e varied strongly with X, as shown by the NMR method, the internal water transfer, and consequently the measured drying rate, was mostly controlled by the water diffusivity of a thin layer of product located below the surface. The moisture content at this layer was approximately constant and lower than the average content. Therefore, the D_e values obtained with the drying kinetic method would correspond to this local moisture content, which may be, according to the NMR method, around 1.9-2.3 kg/kg dm.

ACKNOWLEDGEMENTS

This study received financial support from the Instituto Nacional de Investigaciones Agrarias and from the INRA 'Réseau Dynamique de l'eau.'

REFERENCES

A.O.A.C. (1980). Official Methods of Analysis. 13th ed Association of Official Analytical Chemists, Washington, DC.

ARNETH, W. (1972). Uber die Refraktometrische Schellfettbestimmung nach Rudisher in Fleisch und Fleischwaren Fleischwirtschaft, 52: 1455-1458.

COMAPOSADA, J. ; GOU, P. ; ARNAU, J. (1998). Isotherms in pork meat at different temperature and salt content. 44th International Congress of Meat Science and Technology, Barcelona, Spain.

GOU, P.; MULET, A. ; COMAPOSADA, J. ; BENEDITO, J. ; ARNAU, J. (1996). Water diffusinon in dry cured ham. Proceedings of the 10th International Drying Symposium, Vol. B: 778-784, Kraków, Poland.

MULET, A., ; BERNA, A. ; ROSSELLO, C. ; CANELLAS, J. ; LOPEZ, N. (1992). Influence of fat content on the drying of meat products. Proceedings of the 8th International Drying Symposium, Vol. B: 844-853, Montreal, Quebec, Canada

RUIZ-CABRERA , M.A. ; DAUDIN, J.D. ; FOUCAT , L. ; RENOU, J.P.(1997). Une nouvelle méthode d'estimation de la Diffusivité de l'eau dans les matériaux biologiques. Test sur la gélatine. In Récent Progrès en Génies des Procédés, 11, 53, pp 1-6. Lavoisier, Paris.

RUIZ-CABRERA , M.A. ; DAUDIN, J.D. ; FOUCAT , L. ; RENOU, J.P. (1998). Assessment of Water Diffusivity in Foods from Moisture Profiles Measured Using Magnetic Resonance Imaging. International Symposium on Water Management in the Design and Distribution of Quality Foods (ISOPOW 7). Helsinki, Finland.