

ANNEX III

COMMUNICATION PRESENTED

AT THE *ICEF97* CONGRESS

Engineering and Food, Brighton, UK.

APPLICATION OF IMAGE ANALYSIS TO THE STUDY OF WATER LOSSES FROM POTATO SLICES DURING FRYING

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1. SYNOPSIS

Transport phenomena during frying include fat uptake and water loss. Water is lost from the potato in the form of vapour bubbles which are formed at the potato-oil interface, and are clearly visible in video films. This study focuses on the application of image analysis techniques for describing this water loss process. Experiments at two different temperatures (140 and 180 °C) were performed with slices of different thicknesses (1.0 to 5.0 mm) and with french fries (8.5mmx8.5mmx50mm). Individual samples were fried in a glass thermostatic bath and the experiments were video-taped. The images were acquired by a computer and analysed with image-processing software. The observations agreed well with results obtained by measuring gravimetrically the water content of fried samples, showing that this technique can be used to study the water loss process during frying.

2. INTRODUCTION

Frying is a complex process, involving a number of phenomena, whose description still lacks both qualitative and quantitative interpretation. Two important mass transport processes occur: water loss and fat uptake. These two transports are often studied by following the concentration of fat or water during frying, requiring the analysis of a large number of samples removed after different frying times (1,2,3,4). Attempts to analyse these processes continuously by Magnetic Resonance Imaging techniques are reported in literature, although the results are still tentative (5).

Water is lost from the potato in the form of vapour bubbles which are formed at the potato-oil interface, and are clearly visible in video films. Analysis of bubble formation and release should therefore provide valuable information on the water loss process. The evaluation of the total area of bubbles in a given frame is not a real measure of the water loss, but may be expected to be proportional to the rate of water loss. The objective of this work was to assess the usefulness of image analysis to study water losses during frying and to compare the results obtained in this way with those obtained by conventional methods.

3. MATERIALS & METHODS

3.1. The frying experiments

Frying was performed in a glass bath with 16 l capacity. The temperature was controlled by a thermostatic head (Braun) and the oil was agitated to avoid temperature gradients. Slices were cut from the flesh of potato tubers (cv. Van Gogh) with a Milano rotary slicer. Different thicknesses (between 1.0 and 5.0 mm) and diameters of 46 or 42 mm were tested. In addition some experiments were made with french fries (8.5mmx8.5mmx50mm). Each potato slice was suspended on stainless wire and immersed in the frying bath. Slices thicker than or equal to 3.0mm were hung horizontally while thinner slices were hung vertically, to avoid the deformation of the potato slices due to the pressure that otherwise would be build-up by the

bubbles released in the lower side of the potato. Frying was conducted at 180°C, a common frying temperature, and at 140°C, to assess temperature effects.

3.2. Capturing the images and image analysis

The potato slices immersed in the oil bath were illuminated by a halogen lamp on each side. Black paper was placed behind and under the glass bath to improve image contrast. Frying was videotaped with a VHS camera (Philips VKR6850). The camera was placed in front of the glass bath close to the wall. The images were taken at 25 frames per second and each shot lasted for 1 to 20 min depending on the slice and on the frying temperature. This means that from 1500 to 30 000 pictures could be analysed. The maximum number of images used for each experiment was, however, 200, as a higher number of images was found not to change significantly the estimation of water loss. The images were acquired into a computer (486DX4/66MHz) using a Data Translation frame grabber DT55. Image analysis was performed using the software Global Lab 2.0 (Data Translation).

3.3. Measurement of water loss the conventional method

For each experiment 16 frying times were considered. Three replicates were performed. The water content was measured gravimetrically by the AOAC-984.25 method.

4. RESULTS & DISCUSSION

4.1. The experimental method

The colour picture captured by the video camera was played back on a video recorder and paused at selected intervals. The frame grabber converted the colour signal to grey values ranging from 0 to 255. The differences between the pixels obtained with this conversion were not clear enough to differentiate the areas where water bubbles were present. Another filter was then applied - ILUT (Input Look-Up Table) (6). The ILUT applied depended on the illumination. Different slices with the same illumination were treated with the same ILUT. Figure 1 shows a typical image.

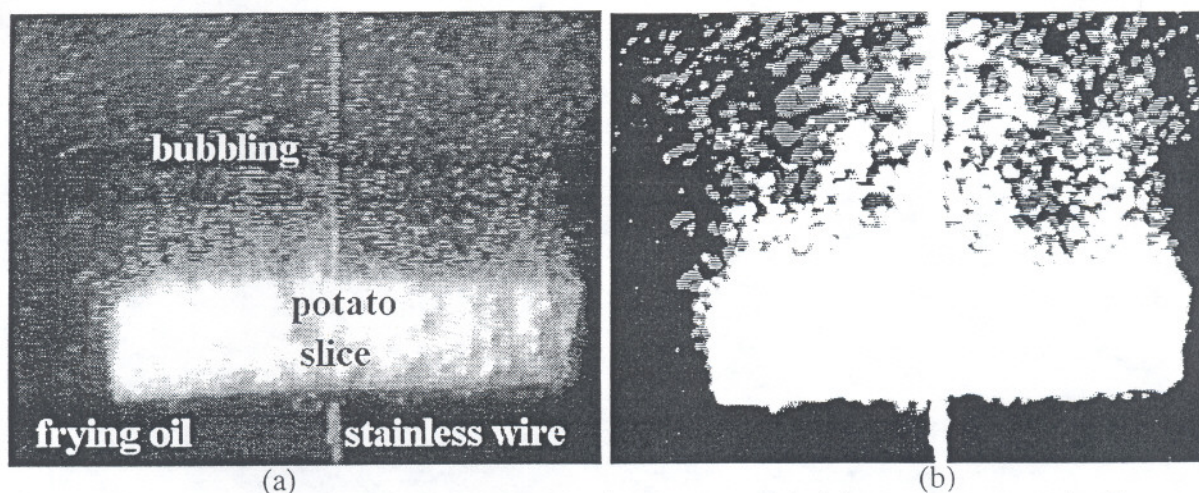


Figure 1 - Image captured on the computer monitor screen with (a) normal grey scale filter and (b) after application of an ILUT filter ($T = 140\text{ }^{\circ}\text{C}$; french fries; time = 226 s)

For each experiment a portion of the image was followed during frying. Image analysis was used to calculate the area occupied both by the potato slice and by the water vapour bubbles. All the values obtained were subtracted from the value obtained at the initial time, so that the slice size was not included in the bubbling area. The Input Look-Up Table was selected not only in order to promote a higher definition of the image, but also to reflect the amount of water lost in the bubbles hidden in the back planes by those formed closer to the wall. An adequate ILUT will lead to a very weak light colour for an isolated bubble, while when more bubbles are

flowing in the back a lighter colour will appear. In this way although the values are obtained using a 2-dimensional image, information on the 3-dimensional reality is somehow included because the colour intensity is proportional to the depth of bubbles in each location. After ILUT remapping, thresholding was applied. The maximum and minimum thresholds were chosen empirically.

4.2. Evolution of frying

It was observed that immediately upon immersion the potato slices releases some tiny bubbles (diameter $\approx 0.1\text{mm}$). The bubbling increases at the slice edges and gradually travels towards the centre. Bubbling continues to increase, due both to a greater rate of bubble formation and to new bubble formation sites, leading to a violent bubbling, after which a reverse pattern is observed. Figure 2 shows a typical plot of the evolution of the area occupied by bubbles with frying time, where the existence of a maximum water loss rate is clearly visible. Similar results were obtained in all the experiments performed. Greater water loss rates were observed for 180°C and smaller thicknesses. The frying time at which the maximum water loss rate was detected was also dependent on temperature and slice thickness: 20 to 53 seconds at 140°C and 8 to 15 seconds at 180°C , increasing with thickness.

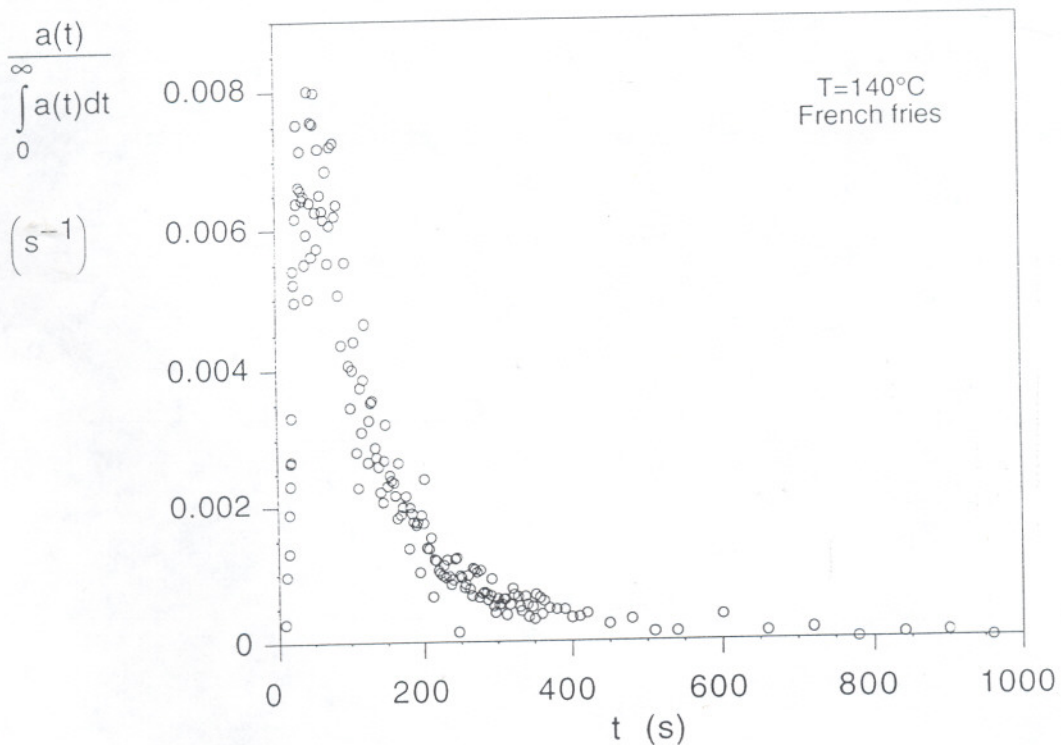


Figure 2 - A typical result of water loss rate during frying
($a(t)$ - bubbling area at time t)

After this point it is noticeable that water loss tends to be concentrated in a reduced number of sites, though larger bubbles are then generated. This may be due to the formation of cracks in the potato crust during the process.

Conventional gravimetric method yielded water loss curves similar to those on Figure 2. The times at which the maximum water loss rate was detected in both methods were compared (Fig. 3). For times shorter than 40 s a reasonable fit was obtained ($r = 0.82$) while for greater time periods, i.e., for 140°C and/or thicker samples the values obtained by image analysis are greater than those obtained by the gravimetric method. This means that extreme differences were only found at smaller water loss rates.

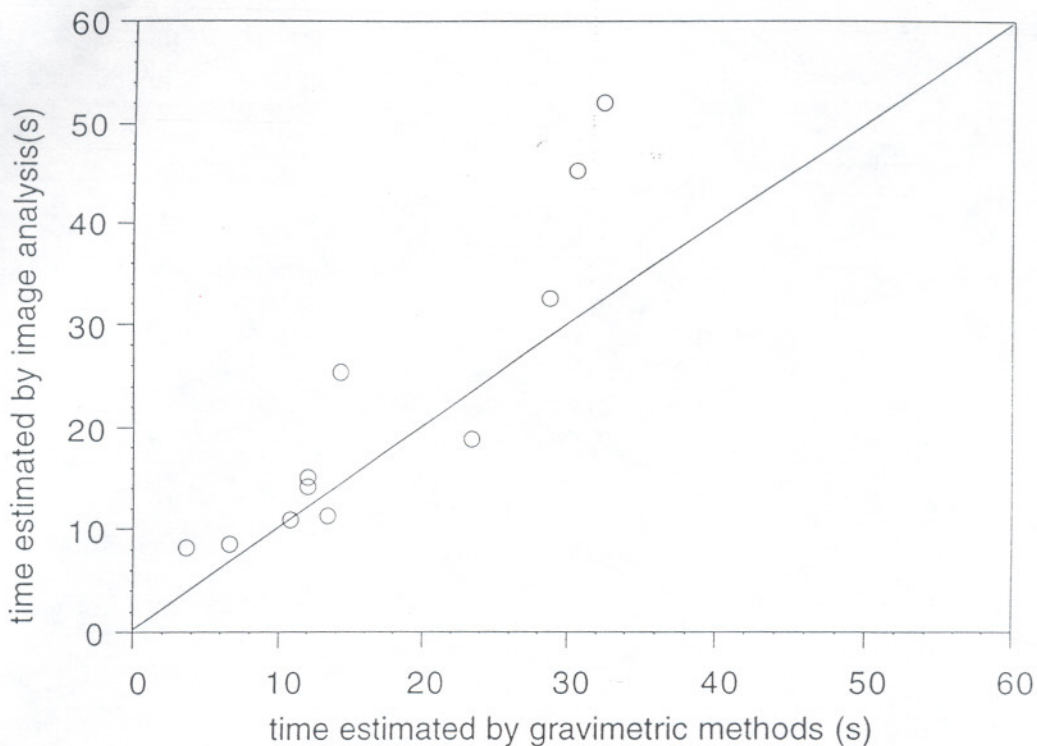


Figure 3 - Comparison of the time at which maximum water loss rate was detected by image analysis and by gravimetry.

5. CONCLUSIONS

Image analysis helps identify the patterns of water loss and yields results comparable to gravimetry. More work is needed to explore further the potential of this novel tool.

6. REFERENCES

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ACKNOWLEDGEMENTS

The first author acknowledges the Praxis XXI programme for financial support. The authors are grateful to Leonard Illincanu for persistence in his continuing efforts to put the image-capturing device to work.

6. OTHER ACTIVITIES

Posters presented

Costa, R.M., Oliveira, F.A.R., Gekas, V. *Application of image analysis to study water losses from potato slices during frying*. Presented at the 7th International Congress on Engineering and Food, April 13th-17th, 1997, Brighton, England.

Costa, R.M., Oliveira, F.A.R., Henriques, A.A., Mateus, M.C., Quadrado, R.E., Oliveira, T.G. *Análise da perda de água durante a fritura de diferentes alimentos por aplicação de técnicas de análise de imagem*. Presented at the "3º Encontro de Química de Alimentos", March 23th-26th, Universidade do Algarve, Faro, Portugal.

Costa, R.M., Oliveira, F.A.R., Gekas, V. *Application of image analysis to study water losses from potato slices during frying*. Apresentado no Second Main Meeting on Process Optimization and Minimal Processing of Foods, Copernicus Programme CIPA-CT-94-0195, December 13th-14th, 1996, Warsaw Agricultural University, Warsaw, Poland.

Articles in Proceedings

→ Costa, R.M., Oliveira, F.A.R., Gekas, V. *Application of image analysis to study water losses from potato slices during frying*. Presented at the 7th International Congress on Engineering and Food, April 13th-17th, 1997, Brighton, England.

Costa, R.M., Oliveira, F.A.R., Henriques, A.A., Mateus, M.C., Quadrado, R.E., Oliveira, T.G. *Análise da perda de água durante a fritura de diferentes alimentos por aplicação de técnicas de análise de imagem*. Presented at the "3º Encontro de Química de Alimentos", March 23th-26th, Universidade do Algarve, Faro, Portugal.