Blood detection in the spinal column of whole cooked chicken using an optical fibre based sensor system

C. Sheridan\textsuperscript{a}, M. O'Farrell\textsuperscript{a}, W.B. Lyons\textsuperscript{a}, E. Lewis\textsuperscript{a}, C. Flanagan\textsuperscript{a}, N. Jackman\textsuperscript{b}

\textsuperscript{a}Electronic and Computer Engineering Dept., University of Limerick, Limerick, Ireland.

cormac.sheridan@ul.ie

Abstract. An optical fibre based sensor has been developed to aid the quality assurance of food cooked in industrial ovens by monitoring the product in situ as it cooks. The sensor measures the product colour as it cooks by examining the reflected visible light from the surface as well as the core of the product. This paper examines the use of the sensor for the detection of blood in the spinal area of cooked whole chickens. The results presented here show that the sensor can be successfully used for this purpose.

1. Introduction

Previous work done by the authors\cite{1}\cite{2} has involved monitoring cooked food with regards the aesthetics of the products. An optical fibre based sensor is used for this application as it allowed the unobtrusive measurement of surface and internal colour. The products tested for internal colour were 90\% V.L. (very lean) minced beef and chicken fillets, both of which were small and uniform. These tests were carried out in association with Food Design Applications Ltd. This paper concentrates on a more difficult product, i.e. whole roast chickens. This product is complex in shape and has various muscle colours, i.e. breast, thigh and wing meat. Also due to its size, combined with the configuration of the oven, it is possible, with incorrect setting of the oven, to cook the top half of the chicken quicker than the lower half. This is due to the Plenum Tubes (Figure 1), which cook from above and below and can be adjusted in height to give different cooking speeds.

Combining previous work carried out on chicken breast meat, i.e. chicken fillets, it was decided to examine another indication of doneness, the setting of blood along the spine, Figure 2. This measurement is used as a key safety indicator in the food processing industry. After cooking, if the blood is set, it will have a distinctly brown colour and this shows that the chicken product has been safely cooked.

This strengthened the sensor data as information was taken from the top and bottom of the product, thus ensuring a more complete representation exists of the colour and doneness of the whole chicken product. These internal measurements of the spinal column will be combined with previous external measurements of the skin colour and temperature measurements\cite{3}.

2. System Set-up

Optical fibres are used to guide light from a light source to the food product. A single fibre is used to guide the reflected light to a spectrometer. The spectrometer digitises the signal, which is then stored on a p.c. Principal Component Analysis (PCA) is carried out on the dataset from the spectrometer and feed-forward neural networks are used to classify the Principal Components (P.C.s). Neural networks...
have been successfully applied to the problem of colour classification previously [4][5]. More detail on the system setup used for this paper can be found in [1] and [2]. Two different probes were used to gather the data for the results given here, one normally used for external reading and a second, smaller probe, used for internal readings, that causes less damage to the product.

An advantage of taking the spinal reading is that while it is a reading taken within the cavity of the chicken, it is possible to access it vertically through the neck with having to inject through the chicken. This meant that the reading could be taken with either the internal or external probe. While both probes were used in the detection and collection of sensor data it was decided that the external probe would be used for the online measurements as it covered a slightly larger surface area.

3. Results

The feed-forward neural network used back-propagation as the learning function. The learning rate (\(\eta\)) used was 0.8, the momentum term (\(\mu\)) was 0.3 and the maximum error (\(\delta\)) was 0.1. The network consisted of three inputs nodes, two hidden nodes and two output nodes, one each for “blood” and “brown”, brown being an approximation of the colour the blood changes to when it sets. The network was trained on samples from taken from raw chicken and chicken cooked to 72ºC and 82ºC. These temperatures were chosen as 72ºC is the pasteurization temperature and a temperature of 82ºC in the cooked food should ensure that the blood has set, and is a rich brown colour, as can be seen in Fig 2(b). The network was tested using a dataset that consisted of 160 raw samples and 320 cooked samples. The cooked test readings were again taken from whole chicken products whose temperatures were 72ºC and 82ºC, for the reasons already outlined. The dataset was made from samples that were gathered using both the internal and external probe.

3.1. Analysis of Results

The output activation of the nodes in the network is shown in Fig 3. As can be seen from this figure, the network correctly classifies the first 160 samples as containing blood. The next 160 samples are from the 72ºC cooked whole chicken product while the final 160 samples are from 82ºC cooked whole chicken product. There are two areas of inconsistency present in the output for these samples, highlighted in the circled regions. The spectra for these samples (“Test Group A” and “Test Group B” respectively) are shown in Fig. 4. Test Group A represents spectra that were gathered from 72ºC chicken (Fig. 5). In this case, it is probable that the chicken hadn’t been at a high temperature long enough for all the blood to have set and turned brown. This highlights how the sensor can show instances where, even though the chicken will have reached the pasteurisation temperature, blood will still be present. Test Group B represents a ‘confused’ output from the classifier for 82ºC chicken samples. In this case, it is likely that the probe hit a blood vessel, which will retain a red colour throughout the process. Were this to happen during use, an average of the activations would be taken, in combination with the temperature reading, and a decision could be made as to the doneness of the product without the need to split it open and destroy the product as a result.

4. Conclusion

From the tests conducted, it is clear that a reliable and accurate sensor has been developed for the application of detection of blood in the spinal column of cooked whole chicken product. The sensor successfully applies a combination of techniques to the problem, including Principal Component Analysis and feed-forward Neural Networks. The results presented show how the addition of a colour sensor, in combination with a temperature sensor, can enhance the safe cooking of the products.

References
[1] Sheridan C, O’Farrell M, Lyons WB, Lewis E, Flanagan C, Jackman N, “Using Artificial
Neural Networks Combined with PCA In An Optical Fibre System That Monitors Food Colour In A Full-Scale Production Environment”, Proc. 14th Artificial Neural Networks in Engineering (ANNIE), 14, pp. 879-884, 2004

[2] O’Farrell M, Lewis E, Flanagan C, Lyons WB, Jackman N, “Controlling a Large-Scale Industrial Oven by Monitoring the Food Quality, both Internally and Externally, using an Optical Fibre Based System”, Proc. of IEEE, 1, pp. 368 – 371, 2003

[3] M O’Farrell, E. Lewis, C. Flanagan, W.Z. Zhao, T. Sun, K.T.V. Grattan, W.B. Lyons N. Jackman “An All Optical Method for Assessing Food Quality During Cooking In Large Scale Industrial Ovens Based on Intelligent Monitoring of Colour and Temperature” Proc. International Symposium on Advances and Trends in Fiber Optics and Applications, Chongqing, China, pp315-319, 11-15 October 2004

[4] McConnell RK Jr., Blau HH Jr. “Colour classification of non-uniform baked and roasted foods.” Proc. Food Processing Automation IV, pp.40 –46, 1995

[5] Shiranita K., Hayashi K., Otsubo A., Miyajima T., Takiyama R., “Determination of Meat Quality by image processing and Neural Network Techniques” The ninth International Conference on Fuzzy System, pp 989 –992, vol.2, 2000

5. Figures

![Diagram showing the placement of the Plenum Tubes with respect to food on the conveyor belt](image)

Figure1. Diagram showing the placement of the Plenum Tubes with respect to food on the conveyor belt
Figure 2(a) and (b): Examples of the spinal column of chicken before cooking (a) and after cooking (b).

Figure 3: Output activation for each of the test samples of the nodes from the Neural Network.
Figure 4: Blood and brown spectra used to train the Neural Network plotted with the spectra from Test Group A and B.

Figure 5: A picture of one of the chickens cooked to 72°C. Note the redness of the meat, as contrasted with Fig. 2(b)