NOVEL NIR INTERACTANCE MEASUREMENTS FOR NON-CONTACT CORE TEMPERATURE OF PROCESSED MEAT PRODUCTS

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Abstract

A novel system for online measurement of core temperature in processed meat products is presented. The system allows near infrared (NIR) light to interact with the product to a depth of up to 2cm using noncontact optics. Two possible meat products were investigated; hot dog and pâté. Both were tested after cooking and chilling. RMSECVs of less than 1.75ºC were obtained for all models and the cooking model for the pâté was tested on 2 different data sets, measured on pâté from a different batch, on a different day and under different conditions to test robustness. The pâté in the test sets was from a different batch and RMSEPS of 1.38ºC and 3.3ºC were obtained for these.

Introduction

Core temperature is a critical control parameter in the monitoring of cooked, ready-to-eat products, in terms of yield loss, food safety and energy efficiency. Typical current practice involves random product sampling followed by thermocouple insertion after cooking and chilling, which incurs large batch losses if an incorrect temperature level is read. Much research in the area of non contact core temperature measurements has been involved developing complex models based on the surface temperature[1] but in the research presented here, by incorporating online NIR interactance measurements, non-contact infrared core temperature measurement has been taken a step further by monitoring light that has travelled further into the product (up to 2cm), thus enabling simpler core temperature models that are not so heavily dependent on surface temperatures and complex modelling of the heat transfer in the product

Materials and Methods

Previous research[2] in the area of fat and pigment measurements in live salmon, resulted in the development of an NIR measurement system that eliminates surface reflection and resolves the interacted light (Figure 1) into VIS and NIR spectra, each with a 20nm resolution (460nm-740nm and 760nm-1040nm). During the core temperature investigation, the NIR region was used, with focus on the second overtone of water at 970nm, which undergoes a shift to higher wavelengths with decreasing temperature (Figure 2). Tests were performed on two Norwegian products; Gilde liver pâté and hot dogs. Initial feasibility investigations were conducted on the hot dogs, while a more extensive study was carried out on the liver pâté.

Twenty eight sausages were cooked to temperatures between 65^{o}C to 83^{o}C, with corresponding NIR measurements taken from each sausage. The sausages were also cooled and temperature and NIR measurements were taken between 1.8 ^{o}C and 9.2 ^{o}C.

Thirty containers of pâté, 4cm high, were brought to an initial equalised temperature of 40^{o}C as done in industry. They were then baked to temperatures between 71^{o}C to 101^{o}C. The temperature half-way down (core) was recorded with a K2 type thermocouple at 2 different positions on the pâté; centre and halfway between the centre and edge as one looks down on the pâté. Rapid (1 second) NIR measurements were then taken at these 2 positions. The trays of pâté were also cooled and temperature and NIR measurements were taken in the range 3.1 ^{o}C to 22.6 ^{o}C

Partial least squares regression (PLSR) was performed on the data, after both the inverse logarithm and standard normal variate (SNV) were applied to the data, to obtain calibration models for heating and cooling. Calibration development was done with the software package, Unscrambler 9.7 (Camo Software AS, Oslo, Norway).

A test set of 30 more containers of pâté, from a different batch, was baked to test the heating model for the pâté. The test set was divided into two groups; 1) samples with an initial temperature of 40^{o}C that were cooked at a faster rate creating a darker crust with different scattering properties and 2) samples that were cooked the same way as the calibration set but with 3 different initial core temperatures, 3^{o}C, 13^{o}C and 40^{o}C, to achieve an exaggerated temperature variation in the product. Though this temperature variation would not be found in a realistic processing plant, it gives a good indication of the robustness of the model and how deep in to the product was actually measured

Results

PLS models were generated for heated and chilled hot dogs in the feasibility test, and for heated and chilled pâté in the study. Cross validation was applied to evaluate each model's predictive ability. The prediction error, which was estimated by the root mean square error of the cross validation (RMSECV), was 1.57ºC for the heated hot dogs, 1.39ºC for the chilled hot dogs, 1.74ºC for the heated pâté and 0.99ºC for the chilled pâté (Table 1). To validate the performance of the heated pâté model, it was used to classify the two test sets. The root mean square of the prediction (RMSEP) was 1.38°C and 3.3°C for test set 1 and 2, respectively (Figure 3). An RMSEP of 1.38°C for test set 1 is encouraging. The higher error for test set 2 is expected, as the light travels from the surface to 2cm down, and the variation in the temperature profile of this test set was exaggerated to produce enough variation in the product to test the model’s robustness. To understand the reduction in performance it is necessary to take into account the relative temperature profiles of the two test sets, which would be very different from each other as they were cooked at different speeds and had different starting temperatures. An advantage of this outcome is that since the light contains information, not only from the core, but from the surface down to the core, the system could potentially monitor the cooking development of the pâtés. Future work will involve expanding the model to provide information regarding the temperature profiling, e.g. surface temperature, core temperature and the temperature between the core and surface, to allow more detailed profiling of the cooking process.

Conclusion

Encouraging results have been obtained in predicting core temperatures of sausages and pâté, both cooked and chilled, with an RMSECV of less than 1.75 °C obtained for all models. The results also show the potential of the system to predict temperature profiles in first 2cm of the product, which would be beneficial in monitoring the cooking profile within the oven.

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References

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Figures and Tables

Figure 1: Interactance in hot dogs and pâté

Figure 2: Sample SNV corrected spectra from pâté at various temperatures

Figure 3: Prediction of test sets 1 and 2, which contain samples with a) darker crust and b) exaggerated temperature variation within the pâté.

Table 1. Calibration results for hot dog and pâté models