RELATION BETWEEN THE EQUALIZATION TEMPERATURE AND THE THERMOGRAPHIC PROFILE OF THE HAM CUT SURFACE

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I. INTRODUCTION

Final equalisation during transport of meat products is of great value to the slaughter industry as it increases the capacity of the cooling facilities and allows a more flexible production. Today, slaughterhouses in Denmark use blast chilling tunnels (air temperature between -22°C and -18°C) followed by an in-factory equalisation period until the core temperature is below 7°C [1]. A shorter factory equalisation period (EP) combined with a final equalisation during transport would greatly benefit the industry. However, a shorter factory equalisation period requires documentation of sufficient cooling of the products ensuring that the right core temperature will be reached after equalisation during transport [2, 3]. Typically, this quality control has been made with insertions probes [4] and surface measurements. The existing methods are invasive and require manual labour as well. This study aims to investigate the relation between thermography of the ham cut surface and the adiabatic equalisation temperature of ham cuttings as a potential method for automatically documenting sufficient cooling of not fully equalised products.

II. MATERIALS AND METHODS

A study based on seven groups of pig carcasses (83.2-88.9 kg hot carcass weight, lean meat percentage 57.9-66.1%) given different EP after slaughter and blast chilling. The first group was equalised for 6 hours, and with a 1-hour reduction in EP between the groups, the last group had an EP of 0 hours. Each group contained three half right side carcasses. The leg was cut from the carcasses, and a thermographic image of the cut surface was obtained within 30 seconds. The core temperature was measured in the centre of the ham with a Testo 175-T2 temperature logger. Separate adiabatic equalisation was made in flamingo boxes for 15.5 hours. An Optris PI 400 thermal camera equipped with a f=8mm lens placed 45 cm from the cut surfaces was used for the thermographic measurements. A fixed thermal emissivity of 0.95 was used to calculate the temperature [5].

Figure 1. Camera setup used to obtain thermographic images (A), placement in flamingo boxes for adiabatic equalisation (B) and manually annotated pixel region used to calculate T_{surf} (C).

A simple estimator for the thermal state of each sample was constructed by manually annotating the pixel region approximately corresponding to *M. gluteus profundus*, *M. gluteus medius* and *M. gluteus accessorius* on each thermographic image and calculating the mean temperature within this region (T_{surf}). The adiabatic equalisation temperature (T_{eq}) was estimated for each sample from the temperature logger after 15 hours of adiabatic equalisation. The median and standard deviation of T_{surf} and T_{eq} were calculated for each group to reduce noise.

III. RESULTS AND DISCUSSION

Constructing a good estimator for the total thermal energy of the ham region requires the right balancing between the low and hight temperature pixel regions to obtain the best representation of the average of the thermal distribution in the remaining leg region (see Figure 2 left). In this study, T_{surf} was based on an average of the pixel region of *M. gluteus* empirically selected because of the good thermal connection with the remainder of the ham and the simplicity. However, more advanced modelling including other predictors, such as mass, dimensions, and thermal distribution, could possibly create better estimators. A good correlation with a linear coefficient of determination (R^2) of 0.92 between the estimator T_{surf} and T_{eq} was observed, and the corresponding root mean square error (RMSE) of the linear model was 0.59°C (see Figure 2 right). Both results indicate that the thermographic profiles contain information about the total thermal energy. However, the high variations observed in both T_{surf} and T_{eq} also indicate markedly uncertainty regarding the results. Estimation of the total thermal energy in a body with both complex geometry and thermal distribution is a hard sampling task. Existing methods based on either surface measurements or insertion probes offer low spatial resolution. The relation observed in this study exemplifies how thermographic profiles of cut surfaces offer a richer sampling procedure with access to more spatial variations.

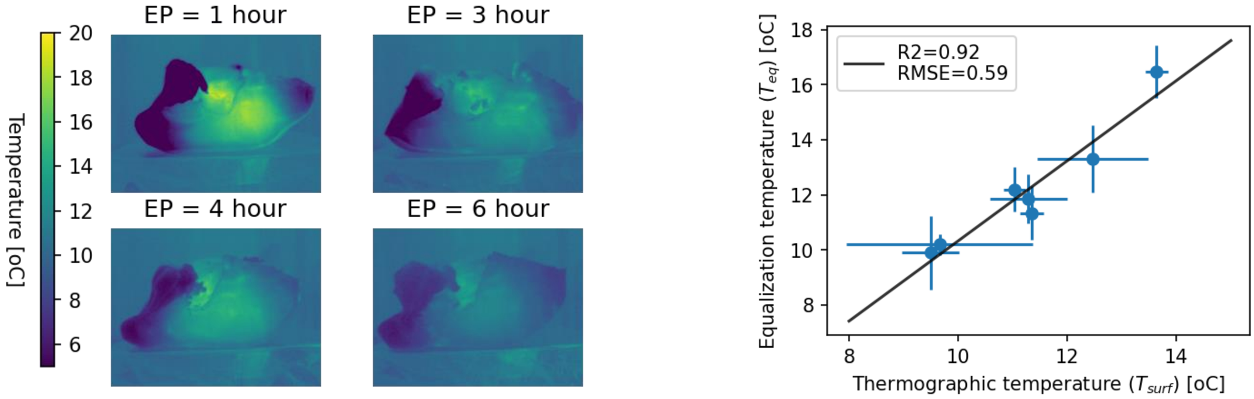

Figure 2. Thermographic profiles of selected EP groups (left). The relation between T_{surf} and T_{eq} where the point is the group median, and the bar is plus and minus one standard group deviation (right).

IV. CONCLUSION

This study observed a relation between the adiabatic equalisation temperature and the thermographic profile of the cut surface on ham products. This relation could have the potential to be used for automatic, inline, and contact free documentation of sufficient cooling for not fully equalised products.

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