Decontamination on pork carcasses: qualification of thermic treatment by thermal imaging

Le Roux, A.; Lhommeau, T.; Péran, T.; Monziol, M.; Minvielle, B.

Abstract

Singeing improves the visual quality of rind in pig slaughterhouses. In addition, the thermic inactivation allows the bacterial contamination of carcass surfaces to be reduced. However, the thermal image of pig carcasses shows temperature differences along the carcasses.

The objective of this study was to develop a method to analyze a thermal image. After defining an imaging protocol adapted to pig slaughterhouses, image analysis was carried out with the free software: ImageJ©. Three methods were developed in order to preserve the spatial arrangement and time information for each measurement: (1) Method by line profile, (2) Method by mouse over, (3) Method by mouse over and line profile. Moreover, the method had to be simple and accurate. After a statistical comparison (mean, variance, distribution) between the three methods on 20 carcasses, the method by line profile was validated to analyze the characteristics of heat treatment in four pig slaughterhouses during process.

This validated method of image acquisition and analysis was a tool used to measure the temperature variability on carcasses. The reference temperature was the temperature of carcasses after 90 minutes of continuous process. This method confirmed temperature differences on carcass surfaces (the top part of the carcass is warmer than the bottom part within a range of 2-7°C) and within a production day; the lowest temperatures were observed when the process started or re-started (after breaks), on average 4°C. These temperature variations along the working day were observed in every slaughterhouse studied. Bacterial contamination was evaluated on carcasses prior and following singeing for two heating settings. Results were similar to the literature (reduction of 3 Log10 CFU/cm² of the Aerobic colony counts).

With this pragmatic method, companies could have access to a measurement tool not only for characterizing, checking, optimizing and qualifying the efficiency of singeing, but also for investigating all thermic treatments on meat in slaughterhouses.

Introduction

The control of hygiene in slaughterhouses is essential for assuring the safety of carcasses and cuts. The level of carcass contamination at the end of the slaughter line depends in particular on a process control like singeing. On the slaughter line, singeing assures the visual quality of rind by the destruction of residual hairs after scalding but singeing also has a bactericidal effect by thermal inactivation (Rahkio et al., 1992; Pearce et al., 2004). Dehairing is well known to increase cross-contamination (Bolton et al., 2002; Gill and Bryant, 1992; Pearce et al., 2004; Rahkio et al., 1992), so using a second singeing system after dehairing (Minvielle et al., 2005) reduces the level of carcass contamination. However, singeing is very gas-consuming representing 30% of pig slaughterhouse gas consumption (Chevillon, 2008). Furthermore, two recent studies have confirmed the importance of singeing for the control of Salmonella presence (Delhalle et al., 2008; Richards et al., 2009). In the latter study a thermal camera was used to show that the temperatures along the carcass were not uniform and detected ‘cold’ spots without thermic decontamination. The effectiveness of heat treatments in slaughterhouses and cutting rooms as corrective measures for bacterial reduction has been shown (Le Roux et al., 2008a, 2008b). Nevertheless for these two studies, it was not possible to
measure the temperature of treated surfaces, due to the lack of appropriate equipment.

The aim of this study was to evaluate the possibilities of a thermal camera for qualifying, validating and possibly optimizing the singeing. The thermal camera seemed to be the best suited method for accurate temperature measurements over large areas.

Material and Methods

The thermal imaging camera used was a FLIR TOOL E60® which allows the temperature of a large surface to be measured precisely (± 2°C) in an innovative and non-invasive way. Firstly, the study consisted of developing a repeatable method for image acquisition in pig slaughterhouses. Thermal images were taken after removal from the singer (between 5 and 8 seconds) with the distance and camera angle controlled. In addition for each image, relative humidity and ambient temperatures (TESTO 400©) were recorded and the distance between the camera and the carcass were measured by ultrasonic range finder. Emissivity was taken as 0.98. Lastly, the time between the last flame on the carcass and the imaging was noted. For evaluating the temperature during process at each period, thermal images of twenty carcasses were taken. The periods were: start activity, restart after a break and every fifteen minutes during activity. This image acquisition protocol was carried out twice in four French pig slaughterhouses.

Secondly, image analysis was carried out with the free software, ImageJ©. Three methods were developed in order to preserve the spatial arrangement and time information of each measurement: (1) Method by line profile, (2) Method by mouse over, (3) Method by mouse over and line profile. The method had to be simple and accurate.

Finally, this validated method was used for comparing two heating settings in a slaughterhouse alongside a bacterial contamination evaluation on carcasses prior to and following singeing. The thermal camera was positioned upon removal of the carcasses from singer 2 and the thermal snapshot was captured with a visual cue, 8 seconds after. Two heating settings were tested: (A) Singer 1 and 2 triggered by the arrival of the carcass; (B) Singer 1 on arrival and Singer 2 continuously in operation. In parallel, bacterial contamination was evaluated on 30 carcasses prior to and following singeing.

Carcasses were sampled by swab (100 cm²) (Figure 1) prior to and following singeing. To enumerate Aerobic colony counts (ACC), diluted stomachates were inoculated on PCA for 48h at 30°C (NF ISO 4833-1) and for Enterobacteriaceae (ENT) on VRBG for 24h at 30°C (NF V08-054). The OXOID alternative method (UNI 03/06-12/07) was used for Salmonella detection (SAL).

Results

Following imaging, a selection of usable thermal images were required for all the periods studied. This selection consisted of the removal of inaccurate images (carcass orientation problem or incorrect thermal image acquisition timing). Image analysis begins with an image reformatting step in order to obtain temperature measurement images. After a statistical comparison (mean, variance, distribution) of each

Table 2

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Prior</th>
<th>After</th>
<th>Reduction</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>6.23</td>
<td>3.21</td>
<td>3.02</td>
</tr>
<tr>
<td>B</td>
<td>6.4</td>
<td>3.17</td>
<td>3.23</td>
</tr>
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The effectiveness of decontamination is the difference between pre- and post-treatment.

The reductions of ACC by the treatments were not significantly different using Students’ paired t-test (SAS 9.2).

Table 1

<table>
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<tr>
<th>Treatment</th>
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<tr>
<td>A</td>
<td>51.70 (2.2)</td>
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measure the temperature of treated surfaces, due to the lack of appropriate equipment.

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Thus, a temperature gradient was observed from the top to the bottom of each carcass. This gradient is due to the position of the gas burner, the carcasses conformation and the heat convection effect. On re-start (after breaks), an average 15-minute delay was observed in the four slaughterhouses in order to attain the reference temperature (90 min without break). This method confirmed some variability on carcass surfaces (the top part being warmer than the bottom part within a range of 2-7°C) and within a production day; the lowest temperatures were observed when the process started or re-started (after breaks), differences recorded were around 4°C. This variability was also observed between slaughterhouses.

The effectiveness of decontamination is the difference between pre- and post-treatment.

The reductions of ACC by the treatments were not significantly different using Students’ unpaired t-test (SAS 9.2).
When comparing the contamination in classes of ENT before and after treatment, the level after treatment was significantly lower than before for the two treatments A and B by chi-square test (SAS 9.2). For *Salmonella* detection, positive samples prior to A and B treatments were at 13% [4-30] and 0% [0-12] respectively. After treatments A and B, *Salmonella* was not detected.

### Table 3

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* All of the *Enterobacteriaceae* counts were below the sensitivity limit (1 CFU/cm²).

**Discussions**

The aim of the project was to develop a method for image acquisition in pig slaughterhouses and an image analyzing method for characterizing singeing. The method by line profile was simple and accurate. The temperature differences observed over time (increase/decrease) were related to several factors: variability of the system functioning, a few minutes production shutdown, conformation of carcasses, gas quality, etc.

Concerning the effectiveness of bactericidal action of singeing, the results were similar to the literature (Pearce et al., 2004; Le Roux, 2008b; Minvielle, 2005). By using a thermal camera, industry can manage heat delivery on the carcasses for new singeing settings and if some important temperature differences are observed, the bactericidal action can be measured by carcass swabbing.

**Conclusion**

In this study, a method of image acquisition and analysis was developed. So, companies can now access a measurement tool for characterizing, optimizing, qualifying or checking the efficiency of singeing. This tool can be used to characterize any thermic treatments in the meat industry: thermic treatment, refrigeration, freezing, thawing. Companies could define the most appropriate treatment regarding energy reduction, quality and food safety requirements.

**Acknowledgements**

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