D2.1: Test report. Description and functionality of a prototype system to measure and document tail length and tail lesions at the slaughterhouse

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Pig Watch

Background Tail biting can be a problem in modern pig production. Tail docking is an effective preventive measure, but the procedure is painful and does not relieve the underlying cause for tail biting. According to EU legislation, tail docking is not allowed on a routinely basis.

During recent years, tail docking has attracted increasing political attention from the EU, and it has been emphasized to member states that to comply with the EU legislation, farmers must document the need for tail docking before the procedure can be performed legally.

In addition to this, tail biting in welfare labelled pigs, where tail docking is not allowed in any circumstances, can be a serious problem, which is often hard to solve, due to the multifactorial nature of tail biting.

A comprehensive, objective overview of tail biting in pig production might aid the clarification of causal factors in different production systems. And automated tail measurement and lesion detection can provide documentation for the need to perform tail docking, identify if tail docking is done according to national regulations, and pinpoint herds that need special advice.

Aim The aim of the test report is to describe the design and functionality of the TailCam equipment functional model.

Conclusion The TailCam equipment was robust and functional at the slaughter line during a period of 9 months from November 2017 to July 2018. In February 2019, the equipment was started up again. The quality of the images and the lighting was good and visually unaltered during the test period and at re-start. The performance of the system was very promising for in-line surveillance of tail length and lesions at herd level or for other subpopulations. The prototype is already operational, capturing in-line real time images, with an off-line analysis.

Further automation, additional validation and adaption of algorithms and product maturation for the market will be carried out in another project. The TailCam is a one-off equipment, which was only tested and adapted to one slaughter line.

Introduction

The development of TailCam was a part of the Danish activities in the EU-project PigWatch.

Homepage for PigWatch: https://pigwatch.net

The overall aim of the project: "*The project aims to sensitize stock persons to early signs which predict injurious behaviours and to develop automatic measurement techniques that could help farmers to manage their herd.*"

The TailCam equipment

Description of the equipment

The system consists of a digital computer-controlled camera, a controlled illumination system and a gambrel trigger unit. All images are captured using a blue background to obtain an even background. A customized system of guiding bars that rotates and stabilises the carcasses into a 90° angle to the camera was mounted. The 90° angle rotation of the carcasses was implemented to obtain the best possible image of the tail. The equipment is fitted with an IP 66 classified closure.

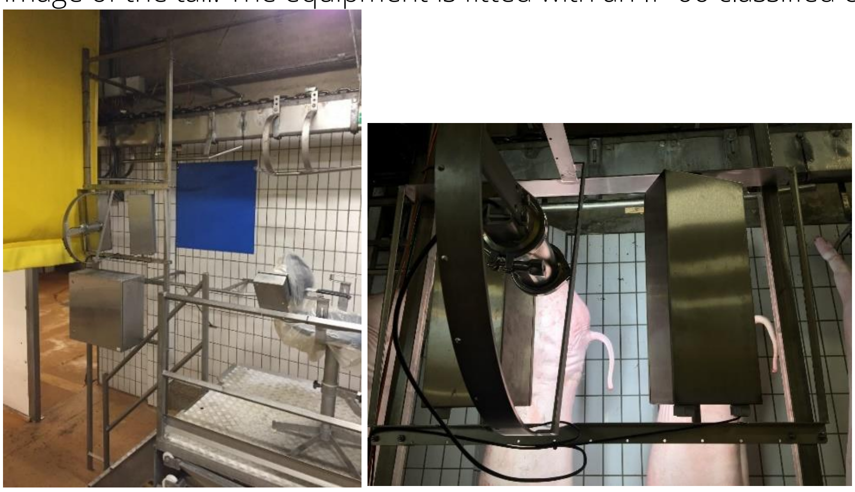

Figure 1. Photo of the TailCam equipment at the slaughter line.

Shields and a soft-dimming system were established to secure the working environment (Fig. 1).

Every gambrel that passes the TailCam contains a carcass to be analysed. The slaughterhouse PLC system sends the gambrel ID's containing carcasses to the TailCam. The TailCam queue these ID's. The gambrel trigger unit initializes the TailCam to acquire an image, and the TailCam fetches the next gambrel ID from the PLC queue and pairs the image and the gambrel ID.

The image analysis for determining the tail length and tail lesions is made offline. Determining the affiliation of each pig ID to the correct herd is done offline as well at this stage.

Integration with slaughter database information

The TailCam was not automatically integrated into the slaughter database, as the TailCam was only developed for investigation use. The integration to the slaughter database should be easy, as the interface is already established. The final integration shall be coordinated with the slaughterhouse that needs to make data fields available for storing the tail information.

Automation

To make the TailCam a fully automated system, the algorithm for determining tail length and tail lesions should be integrated into the system, and calculating tail data should be done in real-time. Determining the affiliation of each pig ID to the correct herd should be integrated and managed as part of the TailCam.

Detection of tail lesions

Algorithm lesions

The first attempt was made by a colour-based segmentation model. But a Convolutional Neural Network based on a pre-trained model provided more accurate results and was easier to develop.

Classification of tail lesions

Tails were divided into three categories, concerning tail lesions:

- No lesion: No wounds on the tail, minor superficial scratches are acceptable. No signs of tail biting behaviour on the tail (Fig. 2).
- Small lesions: Small and acute (a single bite) or healed or almost healed small wounds with no sign of infection, necrosis or spreading (Fig. 3).
- Lesions: Typical tail biting lesions. They are often chronic, may be infected or previously infected, may also show signs of present or previous necrosis (Fig. 4).

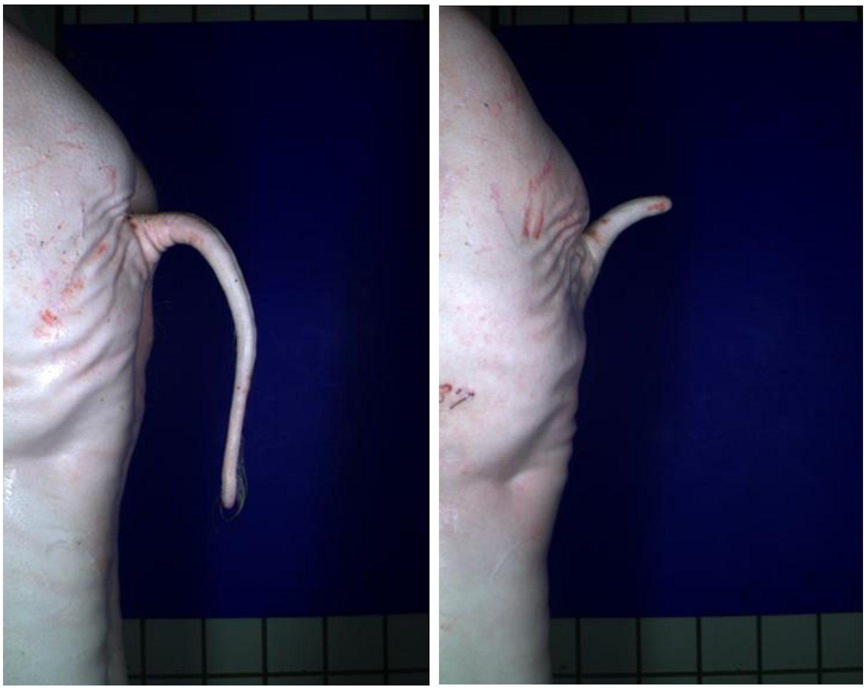

Figure 2. The typical image quality and "No lesion" tails. One long undocked tail (left), and one docked tail (right). No tail lesions were observed on these tails. Superficial scratches do not count as tail lesions, as they are not necessarily linked to tail biting behaviour.

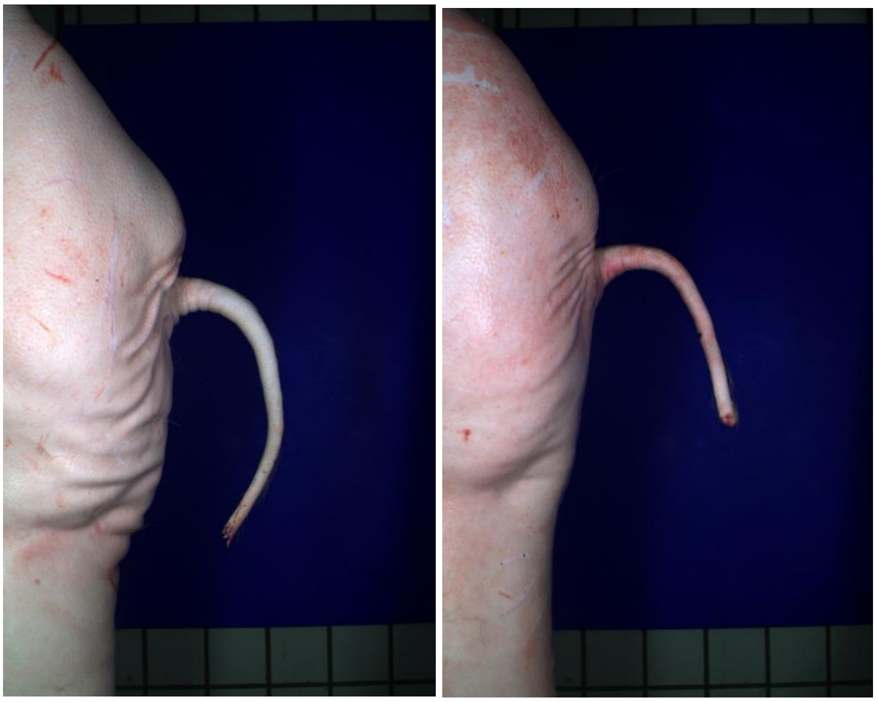

Figure 3. Examples of "Small lesion" tails. "Small lesion" tails can be rather diverse, as they cover both lesions that are healed or almost healed and acute smaller lesions. Superficial scratches do not count as tail lesions, as they are not necessarily linked to tail biting behaviour.

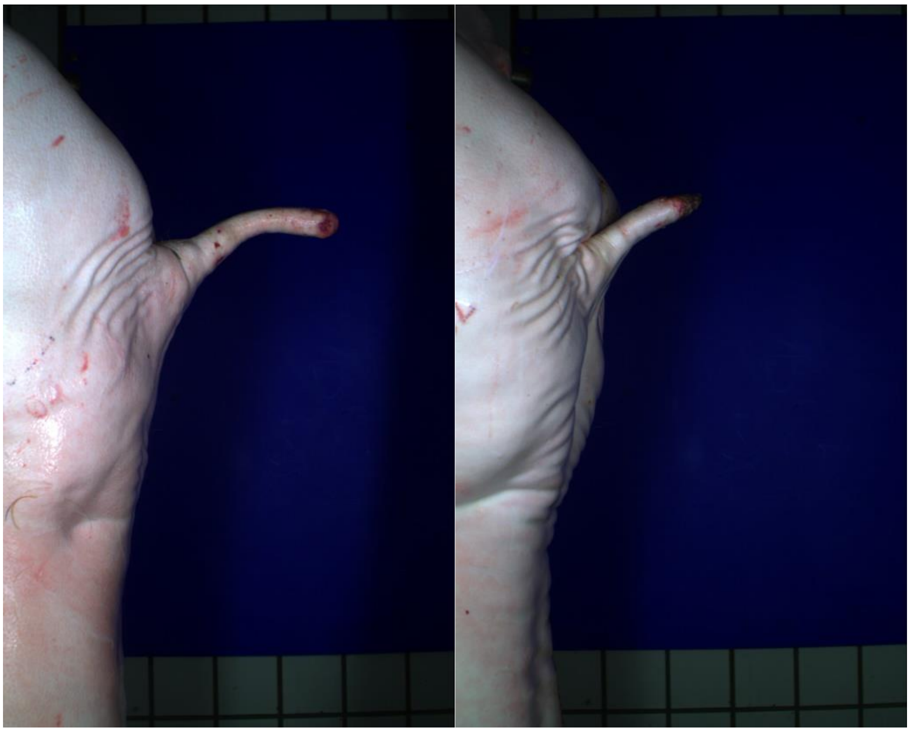

Figure 4. Examples of “Lesion” tails. The “Lesion” category cover tails that without reasonable doubt have been subjected to repeated tail biting. The “Lesion” tail is not by definition a candidate for condemnation by the meat inspection, but such tails should be included in the “Lesion” category.

Visual quality of the images

In an early stage of the TailCam development, the assessment of lesions was made directly on the tails and compared with detection of lesions from the images (Table 1).

Table 1. Comparison of assessment of tail lesions from images and direct assessment on the slaughter line at the slaughterhouse.

	Slaughterhouse assessment			
Image	No lesion	Small lesion	Lesion	Total
No lesion	**160**	19	0	179
Small lesion	4	**19**	6	29
Lesion	0	1	**9**	10
Total	164	39	15	218

A total of 218 tails were observed on the slaughter line and compared to the lesions seen in the images. In 188 cases there was agreement between assessment of image and observation at the slaughterhouse, and in 30 cases there was a deviation of one category (between "No lesion" and "Small lesion" or between "Small lesion" and "Lesion") between slaughterhouse and image assessment. No cases of "No lesion" and "Lesion" of the same tail occurred. The repeatability of slaughter line observation versus image assessment was 86%. Both slaughterhouse observations and evaluation of images was done once by one person. These preliminary results indicated that it is fully acceptable to use TailCam images as reference material for the development of an algorithm for the detection of tail lesions.

A similar evaluation of the present equipment will be made in a new project and compared to an image versus image (intra-observer) repeatability and examination of an inter-observer agreement. An example of the image quality can be seen in Fig. 2, 3 and 4.

Measurement of tail length

Algorithm length

The algorithm for measurement of tail length was developed by first segmenting out the pig carcass from the background by thresholding on the blue level in each pixel. The tip of the tail was then found by fitting a spline to the border of the carcass and finding the point with maximal positive curvature. The central region of the tail could then be approximated by skeletonizing the mask and selecting the branch beginning at the tail tip. Finally, the length was estimated as the distance between the tail tip and the point where the tail reached a certain thickness perpendicular to a spline fitted to the central region of the tail.

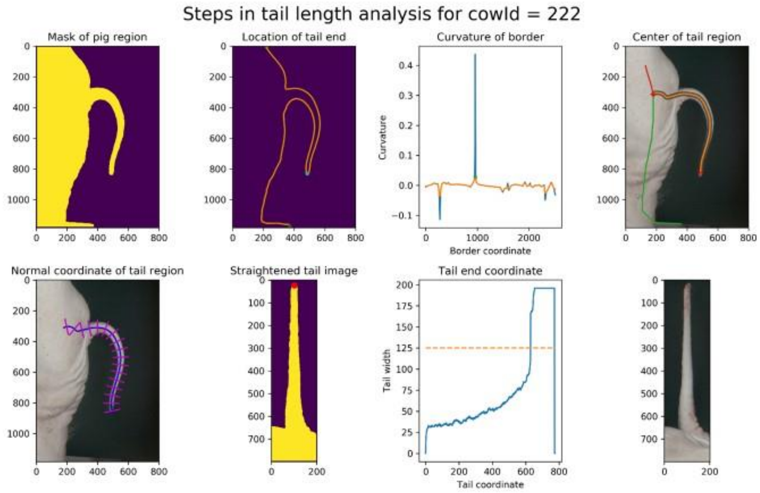

Figure 5. Process flow for the calculation of tail length by TailCam.

First the carcass and the tip of the tail were identified, and then a virtual line in the middle of the tail was established from the tip to the axis of the hindquarter of the carcass. The next step was the introduction of 90° crosslines at regular intervals that were used to create a virtual straightening of the tail (Fig. 5).

Performance of tail length calculation

Overall, the correlation between the measured tail length and the calculated tail length was good (Fig. 6).

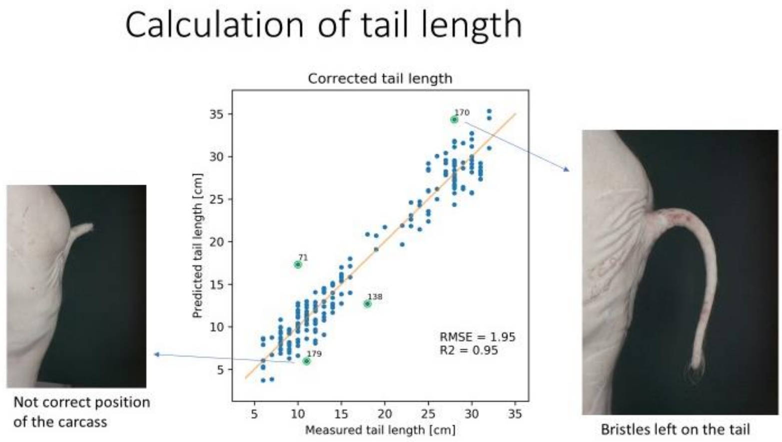

Figure 6. Plot of the measured tail length (X-axis) and the calculated tail length (Y-axis). The tails represented by blue dots with green edges showed a relatively poor correlation between the measured and the calculated tail length. The images on the left and right demonstrate some of the potential causes of poor calculation of tail length.

The calculated values were generally accurate, because the calculated lengths were centred around the measured length. Furthermore, most calculated values deviated less than 3 cm from the measured length (Fig. 6). It is very likely that the precision can be improved by improving the removal of bristles from the tails or sort out tails with excess bristles via the algorithm and omit them from the tail length calculation (Fig. 6, right).

Improving the positioning and stabilization of the carcasses to the camera might also secure a correct angle and improve the precision of the tail length calculation (Fig. 6, left).

An evaluation of the precision and accuracy of tail length measurement with the current design of TailCam will be performed in a subsequent project.

Performance of the TailCam prediction of tail lesions

Performance tail lesion detection

A total of 870 images were classified visually (True label) and by TailCam (Predicted label) into three groups: "Lesion", "Small lesion", or "No lesion" (Table 2).

Table 2. Comparison of visual categorization of tails on images (True label) and categorization done by the TailCam algorithm for detection of tail lesions.

True label	Predicted label			
	Lesion	Small lesion	No lesion	Total
Lesion	**44**	27	0	71
Small lesion	6	**146**	42	194
No lesion	0	26	**579**	605
Total	50	199	621	870

No serious tail bites ("Lesion") were classified as "No lesion" or vice versa.

However, some tails assessed as "Small lesions" were misclassified as "Lesion" or "No lesion" (Table 2). The sensitivity of "Lesion" was 61% (44), meaning that 39% (27) of true "Lesion" tails were classified as "Small lesion" by TailCam.

The sensitivity of "Small lesion" was 75% (146), meaning that 3% (6) were misclassified as "Lesion", and 22% (42) as "No lesion".

The specificity of the algorithm was 96% (579). This means that 4% (26) of the tails completely free from visual signs of tail bites were misclassified as "Small lesion". This may seem like a small proportion, but in herds/subpopulations where tail bites are rarely seen, the proportion of 4% of the tails misclassified as "Small lesions", may disturb the image.

It is expected that the performance of the algorithm can be improved by a few relatively easy steps. First, it must be established how well the reference material is classified. In this project, only one observer was used, and most images were only classified once. This means that a potential "drifting" in the visual classification may have gone undetected. The correct approach will be to reclassify the reference material, and include at least two, preferably a total of three or more observers that classify the reference images twice and re-evaluate the images where disagreement was seen.

Certain manifestations of "Lesion", "Small lesion" or "No lesion" may be particularly hard for the TailCam to classify correctly. Once identified, such examples should be sought out, classified and added to the reference material for further training of the model.

Conclusion

Overall, the results for the detection of tail bite lesions are promising. For research purposes and for the general surveillance of the level of tail lesions in the population or individual herds, and for the pinpointing of herds with specific tail biting problems, the performance may already be operational, if results are carefully revised before reporting. The improvements and automation mentioned above will have to be made before the TailCam can be made commercially available.