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ABSCESS DETECTION ON BOVINE LIVERS WITH A COMMERCIAL SMART IMAGING SYSTEM

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I. INTRODUCTION

Meat processors are responsible for ensuring that animal carcasses are fit for human consumption [1]. Trained meat inspectors play a crucial role in quality control, identifying and condemning unhealthy tissue, with this process occurring at line speed. Whilst optimized for reporting of disease conditions for quality assurance processes, the time and tools currently available to inspectors, or other on-floor staff, restricts the depth of information able to be recorded due to rapid chain speeds. Impacts to the supply chain due to downgraded product can be significant. For example, abscessed condemned at around 3% of beef cattle slaughtered [2]. Line speed automated disease assessment therefore offers a promising layer of objective data for defect capture and producer feedback.Currently, Smart Imaging Systems (SIS) are used in processing plants for foreign object detection, quality assurance and quality control of meat products. One imaging modality, hyperspectral cameras, capture light reflected from the meat product, across multiple wavelengths in near infrared to visible ranges with this data being utilized via Machine learning models to identify multiple visual and biochemical tissue characteristics [3]. Current in-plant hyperspectral imaging systems include the composition analysis of meat cuts and control of foreign materials [4]. Automated assessment for abscesses and other offal health conditions, using imaging systems such as hyperspectral analysis, could therefore expand offal inspection with objective data. To investigate this, the development of hyperspectral disease detection models using commercially available smart imaging system was investigated.

II. MATERIALS AND METHODS

Bovine livers were obtained over 8-month period from a cattle abattoir in Southern New South Wales. The samples were chosen by the trained inspectors at the offal table, after visual assessment but before being marked as condemned. Two types of liver classes were collected: “Condemned” and “Pass” that were identified with or without visible liver abscesses. The samples were scanned under ambient conditions with a Hyperspectral Smart Imaging System (P&P Optica, Waterloo, Canada) and image data collected from both visible surfaces (top and bottom) and from two orientations on the belt. Each scan was masked to identify pixels corresponding to abscessed tissue where abscesses were further classified as (visible active or visible subcapsular). Labelled pixels were then used to train the classification model for detection of liver abscesses. A representation of the development workflow is shown in Figure 1.

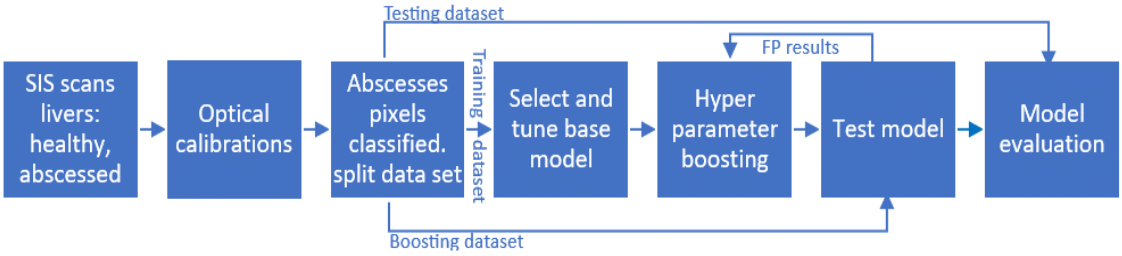


Figure 1 Process for pixel classification model development. Raw data was first optically calibrated to correct for sensor and optical effects. Abscesses were graded and marked as a region of classified pixels. The labelled data was separated into training and testing groups, which were used to develop (build, tune, boost and test) machine learning models that automatically classified abscess tissue.

A support vector machine learning approach (SVM) with feature grouping and boosting was used for model generation. For training, 100 images were selected: 50 livers with no abscess and 50 images with abscesses. An additional 140 images (87 no abscesses and 53 marked abscess) were selected to test the trained model. Model efficacy was determined by evaluating true positive (TP), and false positive results (FP). A true positive identification

was considered as a pixel classed as abscess as identified by the operator (Figure 2 A, B). True positives (TP) were evaluated as a percent of correctly classified abscesses to total abscesses given for classification. False positives (FP) were calculated as the proportion of healthy livers with more than one pixel incorrectly classified as abscessed tissue. False Negative (FN) and True Negative (TN) results were also considered to establish sensitivity and accuracy. Efficacy of the model generated through iterative training, testing and model boosting. Confusion matrices were used to test model assumptions of negative predictive value, precision, sensitivity and accuracy.

III. RESULTS AND DISCUSSION

Abscessed liver tissue was identified using SVM models through iterative training and testing (Figure 2 A) and a leading model identified for analysis of performance (Model 3.1). Models were successful in detecting abscessed tissue where abscesses were active and visible, and with lower efficacy in subcapsular abscesses where a portion of the diseased tissue was below Glisson's capsule (B, C, D). Iterative training with boosting data and additional data filters refined performance giving an accuracy of 88% for liver abscess detection (Figure 3), with a sensitivity of 82%.

IV. CONCLUSION

Proof-of-Concept model development showed that hyperspectral imaging was effective at identification of both visible (acute, pustular) and subcapsular abscesses in beef liver with high precision and sensitivity and good accuracy. Overall, this study found a high efficacy for identification of disease in offal using hyperspectral imaging and SVM modelling at line speed. Additional classification models will be now investigated to improve detection rates of TP and further reduce FP detections for precommercial testing which would increase sensitivity and accuracy of the model. Such an automated assessment of offal disease using hyperspectral imaging offers a new opportunity to enhance postmortem offal line inspections in the meat industry for attenuated data collection and producer feedback.

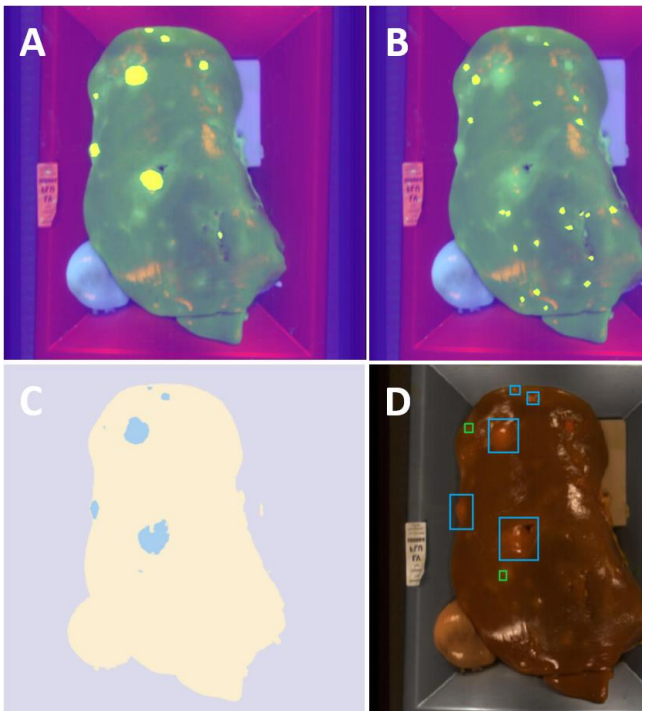


Figure 2. Hyperspectral images of bovine liver with liver abscesses. A, B) Principal Component Analysis was used to visualize features for ROI labelling showing A) Acute, pustular liver abscesses ROI masks (yellow) B) subcapsular abscesses masked (yellow) on the same scan as A). C) True positive identification of abscesses during model training (blue areas). D) Trinorm-filtered images of subcapsular (green boxes) and acute (blue boxes), pustular abscess identification after model processing.

	Liver abscess (n=297)	Healthy Liver (n=173)	
number detections (1) by Model 3.1	TP 242	FP 0	Precision 100%
number of no detections (0) by Model 3.1	FN 54	TN 173	Negative predictive value 76%
	Sensitivity 82%	Specificity 100%	Accuracy 88%

Figure 3. Confusion matrix for leading bovine liver abscess model showing detection rates of True Positive (TP), False Positive (FP), False Negative (FN) and True Negative (TN) detection rates in hyperspectral images of known diseased and known healthy liver tissues. Precision = TP(TP+FP); Negative predictive value: TN/(TN+FN); Sensitivity: TP/(TP+FN); Specificity: TN/(TN+FP) and overall accuracy: (TP+TN)/(TP=TN+FP+FN).

ACKNOWLEDGEMENTS

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