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CYST DETECTION ON BOVINE KIDNEYS WITH A COMMERCIAL SMART IMAGING SYSTEM

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I. INTRODUCTION

Meat processing plants are using computer imaging for quality assurance of meat products and foreign material detection at line speed [1]. Multiple imaging systems, including x-ray, visual and hyperspectral systems can be used to interrogate different aspects of product quality or composition. As an example, hyperspectral cameras can identify numerous visual and chemical tissue characteristics to a pixel resolution down to 2mm [2]. However, imaging systems are not widely used in antemortem inspection [3]. The digitization of carcass and offal health may enable higher confidence through traceable and objective defect assessments [4].
Kidney cysts are the second most common disease disposition leading to bovine kidney tissue condemnation in abattoir. Kidney cysts occur at rates up to 5% of carcasses [5]. Cysts are fluid filled voids that result in tissue condemnation. To attenuate defect detection, we investigated the use of a commercially available hyperspectral imaging system, with machine learning based model, to detect cysts efficiently in bovine kidney tissue.

II. MATERIALS AND METHODS

Data was collected from a cattle abattoir in Southern New South Wales to determine the prevalence of kidney cysts as a total proportion of all inspections between 2018-2024. Bovine kidneys were then collected and classed by the abattoir meat inspector as either “Condemned” or “Pass” being with or without cysts respectively. Samples were scanned the same day under ambient conditions using a commercial hyperspectral imaging system at line speed (P&P Optica, Waterloo, Canada). Scans included between 1-4 kidneys with the same class assignment. After scanning, each image was manually masked to identify normal kidney tissue and cyst tissue. The classified image data was then randomly partitioned into training and test datasets for model development.
A support vector machine (SVM) as a machine learning approach, with feature grouping and boosting, was used to build models for identification of kidney cyst material. Models were trained on masked images including Pass kidney tissue (n=107) and those Condemned with fluid-filled or white cysts (n=148). Test images included Pass kidneys of which 45 had no cysts (Pass tissue) and Condemned kidneys of which 61 had fluid-filled or white cysts visible on the surface of the tissue.
Models’ efficacy was measured by evaluating the ratio of true positives (TP – kidney cyst present and identified) to and false positives (FP – no cyst present but model identified as cyst tissue). Iterative training of models was used to increase TP rates and reduce FP rates.

III. RESULTS AND DISCUSSION

From 2019-2024 kidney cysts made up was 11% of all kidney defects in the southern NSW abattoir, leading to the downgrading of 4628 kidney pairs (0.3% of all kidneys an average, Figure 1). To determine if hyperspectral image capture could attenuate the identification of cyst material in bovine kidneys, 191 kidneys were scanned and recorded along with hyperspectral metadata. Figure 2 shows an example of four kidneys, identified by the inspector as containing cyst material, its visual representations and areas of manual masked cyst tissue. Kidney cysts were visually and spectrally different to the kidney tissue and background. Cysts in the scanned sample set varied significantly in size (2mm – 200mm) and presentation. A training set of masked cysts scans and healthy kidneys scans were used to generate kidney cysts detection model.

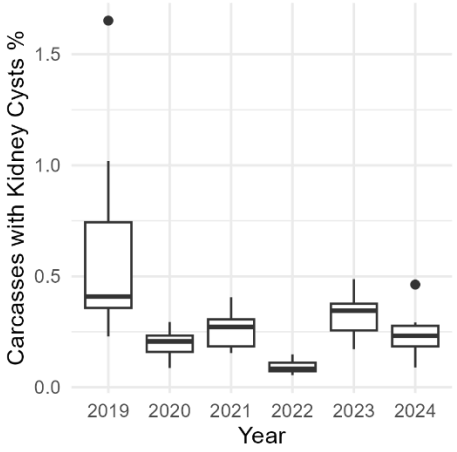


Figure 1 Prevalence of kidney condemnation and downgrading meat inspection assignemnts as toal % of 1,828,639 carcasses processed from from a southern NSW abattoir between 2019-2024 .

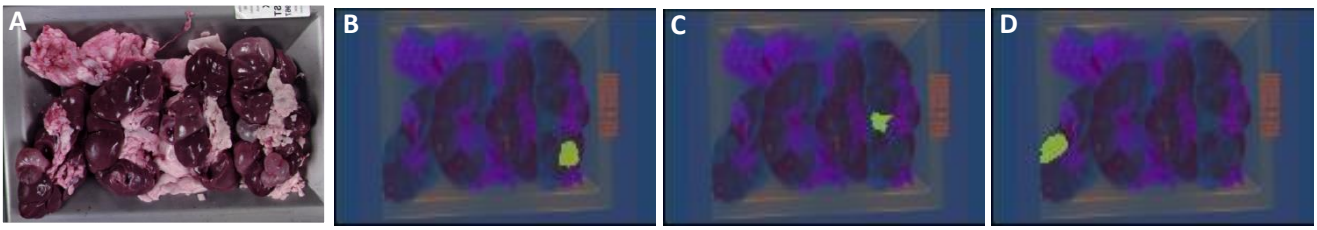


Figure 2. Image capture of encysted bovine kidneys using a commercial hyperspectral imaging system. A) RBG scan of kidney set (n=4) identified with cysts present. B-D) Hyperspectral scan of kidneys shown A). Principle component analysis was used to differentiate kidney tissue from cyst tissue, cysts were manually outlined for model training or testing (kidney tissue – purple; cyst tissue – green).

Figure 3 shows Kidney cyst model outputs. Figure 3 (A, B) shows corresponding kidneys areas with cysts detected as true positives. Figure 3 (C) is an example of where healthy kidneys pixels were detected as false positives.

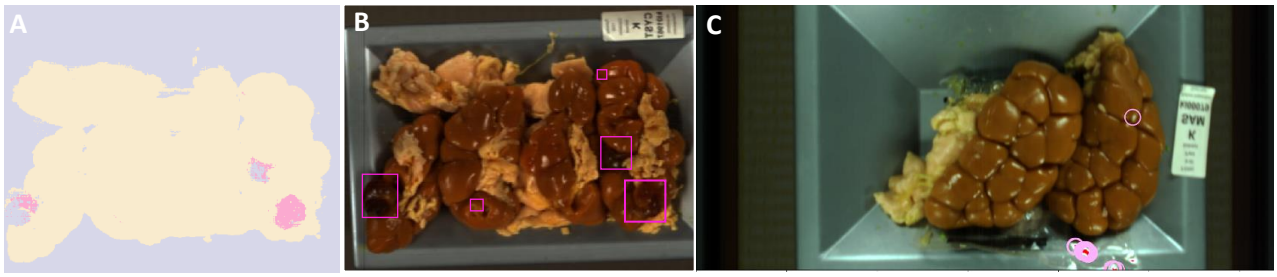


Figure 3. Examples of true positive (TP) and false postitive (FP) evalutation on bovine cysted kidneys (A,B) and bovine healthy kidneys (C). scans from a commercial hyperspectral imaging system with the kidney cyst image classication model applied. A) model classification output coloured background as grey, kidney tissue as yellow, and cyst tissue as pink. B) Tri-norm coloured version with identified cyst regions marked in A) by pink square. All cysts visually identified were independently identified as pink by the model. C) Healthy kidneys were similarly classified by the model to contain 142607 pixels as background, 45517 pixels as kidney and 36 pixels as cyst (pink circles). Healthy kidney scans with one or more pixels incorrectly classified as cysts were counted as a FP. Encysted Kidney scans with positive detection of cyst classes counted as TP.

Our preliminary results prove that the developed Kidney cysts detection models successfully classified background, kidney or cyst materials. The best performing model tested with a true positive rate of 95% (20/21 cysted kidneys) and a false positive rate of 35% (66/191 pass kidneys). False positives were due to incorrect classification of non kidney tissue areas or extremes of light reflectance (Figure 3 C). Future model development will address FP rate by applying secondary models to isolate kidney tissue from fat and background to reduce the tissue presented to the cyst model for identification.

IV. CONCLUSION

The preliminary results demonstrate that a hyperspectral smart imaging system is capable of detecting kidney tissue and differentiating it from kidney white cyst tissue. Classification models for other kidney cyst types and other common offal health conditions will be further investigated in the next stage.

ACKNOWLEDGEMENTS

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