Beef fecal detection using a fluorescence multispectral camera system and deep learning object detection algorithm

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I. INTRODUCTION

Existing methods for fecal detection have primarily focused on visible feces. When visible excrement is detected, it is managed by cutting it out with a knife. However, fecal matter has the drawback of being diluted and difficult to detect after washing, as it often becomes less visible. Contamination by microorganisms such as *Salmonella spp.*, *E. coli*, *Campylobacter jejuni*, *Yersinia*, and *Listeria* can persist, highlighting the ongoing need for effective fecal detection (Gorji et al., 2022). Test methods such as ATP testing are used for quality control, but there are limitations in accurately pinpointing invisible contaminants. Specifically, in the context of beef, there is potential for detection using advanced fluorescent multispectral technology. This technology is effective because it allows the location of fecal matter to be visually communicated to the worker. This study aims to detect the fluorescence signals of minute contaminants using a multispectral imaging device that operates at wavelengths of 365 nm and 405 nm. The fecal matter on the beef carcasses exhibited red fluorescence. The research focused on developing an object detection algorithm for real-time detection using red fluorescence fecal images on beef carcasses.

II. MATERIALS AND METHODS

This study aimed to detect fecal matter on the surface of beef carcasses using fluorescence-based rapid detection equipment, specifically the CSI device (SafetySpect Inc, Grand Forks, ND, USA). For this research, LED sources emitting at wavelengths of 365 nm and 405 nm were chosen for their effectiveness in highlighting fecal matter, which appeared red under these conditions. Images were captured at a resolution of 768x1024 pixels. In total, 5807 images were included in the training set, 1243 images for validation set, and 1243 images were used in the test set for model evaluation. Object detection models were trained, including YOLOv8, YOLOv9, and EfficientDet. For hyperparameter tuning, the batch size for all models was set to 32, and each model was trained for 300 epochs. Model accuracy was evaluated using recall (%), precision (%), and F1 score (%). The study also calculated inference time, the time required to process one frame, indicating how quickly the model can be evaluated. Since fecal detection must be conducted in real-time, inference time is crucial for selecting the most suitable model. Thus, inference time was an essential factor in the model assessment. The study used Python version 3.8.9 and PyTorch version 1.12.1 for all analyses.

III. RESULTS AND DISCUSSION

Table 1 presents the results of various object detection models for identifying fecal matter on beef carcasses. In this study, the images were resized to fit the model requirements. Four models—YOLO v8-x, YOLO v8-n YOLO v9-e, and EfficientDet—were trained, and their results were compared. In terms of precision, YOLO v8-x demonstrated the highest performance. Conversely, EfficientDet exhibited the lowest precision. Regarding recall, EfficientDet achieved the highest recall rate, with YOLO v8-n also showing a high performance with a recall of 0.887. When evaluating the models based on the F1 score, YOLO v9-e attained the highest F1 score of 0.909. YOLO v8-n also produced a comparable result with an F1 score of 0.908. However, in comparing inference times, EfficientDet was the slowest at 0.407 seconds, indicating that the model's complexity hinders rapid evaluation. YOLO v8-n had the fastest inference time among the models tested. Although its F1 score was not the highest, it is considered the most suitable model for system implementation due to its quick inference time.

Table 1. Object detection model performance for detecting fecal on beef carcasses.

System type	Models	Precision	Recall	F1-score	Inference time
Object detection model performance	YOLO v8-x	0.952	0.862	0.905	0.024 sec
	YOLO v8-n	0.930	0.887	0.908	0.011 sec
	YOLO v9-e	0.938	0.882	0.909	0.044 sec
	EfficientDet	0.852	0.950	0.898	0.407 sec

Figure 1. Detection of fecal matter on beef carcasses and beef meat using deep learning models.

IV. CONCLUSION

This study was conducted to develop a model capable of rapidly detecting fecal matter on beef carcasses by utilizing deep learning-based object detection models. Notably, the highest performance was attained by YOLO v9-e, achieving an F1 score of 0.909. In selecting an efficient fecal detection model, YOLO v9-e demonstrated exceptional performance in terms of F1-score. At the same time, YOLO v8-n emerged as the most effective model, exhibiting both an appropriate F1-score and rapid inference time. Consequently, for systems necessitating real-time evaluation, YOLO v8-n is identified as the most suitable option. Nonetheless, further data accumulation may enhance the accuracy of these outcomes. This investigation affirms the viability of utilizing fluorescence images for fecal detection.

REFERENCES

1. Gorji, H.T.; Shahabi, S.M.; Sharma, A.; Tande, L.Q.; Husarik, K.; Qin, J.; Chan, D.E.; Baek, I.; Kim, M.S.; MacKinnon, N.; Morrow, J.; Sokolov, S.; Akhbardeh, A.; Vasefi, F.; Tavakolian, K. (2022) Combining deep learning and fluorescence imaging to automatically identify fecal contamination on meat carcasses. Scientific reports 12(1):2392.