Digital imaging techniques to assess welfare at a cull sow harvest facility

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Abstract

Objective evaluations conducted at cull sow harvest facilities may serve as an indicator for cull sow health and wellness. These evaluations may include body condition, presence of lesions and abscesses, visceral tissue evaluations, and non-edible trim loss evaluations. Thermal, spatial, and RGB cameras were installed at Midwestern harvest facility to evaluate cull sows immediately prior to their harvest. The recorded images could be used to evaluate welfare indicators in real-time and provide feedback to producers when evaluating sows at harvest. Body condition estimates were obtained using spatial cameras to estimate body weight and indicate condition. These evaluations could assist producers in feed utilization for optimizing cull sow value. Thermal imaging was utilized to evaluate and identify abscesses and sores (hotspots). Utilizing the identified hotspots, their relationship with non-edible trim loss and visceral tissue evaluations was investigated. Skin emissivity, lairage conditions, debris on skin, and other factors are some limitations when utilizing thermal imaging to predict non-edible carcass trim loss. Thermal imaging results revealed that a prevalence for more hotspots in the anterior portion of the carcass resulted in higher non-edible trim amounts. Cumulatively, the application for digital imaging at cull sow harvest facilities may be used to provide information on animal condition that could help producers better understand the sow welfare and condition at harvest. Ongoing work is geared to better assess digital and thermal imaging utilization in evaluating cull sow welfare at the harvest facility and investigate deep learning models on larger data sets having higher spatiotemporal resolution.

Keywords: digital imaging, thermal imaging, body condition score evaluation, trim loss prediction

Introduction

Cull sow health and wellness are often challenging to evaluate in harvest facilities. Existing cull sow marketing networks generally limit the tracking and transparency for cull sow status. Sows are often transported multiple times and can be sold between multiple aggregation facilities (Blair and Lowe, 2019). The inherent variability in transportation distances, aggregation stops, and aggregation management strategies can lead to concerns for cull sow health and welfare (Nielsen et al., 2022; Rioja-Lang et al., 2019; Thodberg et al., 2022). Therefore, it is necessary to implement strategies to evaluate cull sow health and welfare at harvest facilities. These evaluations could serve as a timepoint evaluation for each animal or as an indicator for health and welfare status.

Different strategies have been employed to evaluate farm animals using imaging technology. Previously, imaging technologies have been demonstrated to evaluate dairy cattle body condition, dairy cattle body shape, swine conformation, swine behavior, and other welfare-related measurements (Halachmi et al., 2008; Lao et al., 2016; Stock et al., 2017; Leonard et al., 2018). The ability for thermal imaging to detect or identify trim lost prior to harvest was evaluated by Soerensen and Pedersen (2015). These researchers reported that there was some relationship between surface and body temperatures. It was also reported that the area being measured, ambient environmental temperature, camera accuracy, skin emissivity, as well environmental and animal factors may make conclusions about trim loss challenging to determine.

The main limitations that exist with utilizing thermal and digital imaging to evaluate cull animals at harvest facilities include lairage related concerns and the inability to pinpoint the source of health and welfare concerns. Lairage areas for livestock serve as holding areas prior to harvest. These areas are often semi-exposed to environmental conditions and temperature can influence thermal imaging recordings. Additionally, the animals may be wet or may be covered in debris, which make it difficult to assess the skin temperature and limit the image's effectiveness in accurately portraying the animal (Soerensen and Pedersen, 2015). Additionally, skin emissivity must be considered because the body areas where sores are prevalent may be more emissive leading to increased elevated thermal signatures in that area. Due to current marketing networks, determining the original source of health and welfare concerns may be challenging. Cull sows often travel large distances or have multiple aggregation stops (Blair and Lowe, 2019). This may cause cull sows to change condition prior to arrival at the harvest facility. As such, the change in body condition during transportation or in lairage areas may compromise the accuracy of this information for producers.

Objective evaluations conducted at cull sow harvest facilities may serve as an indicator for cull sow health and wellness. These evaluations include body condition, presence of lesions and abscesses, visceral tissue evaluations, and non-edible trim loss evaluations. Body condition score (BCS) could be evaluated using digital and 3-D imaging. Using these evaluations, reports can be formulated to provide feedback to producers on cull sow BCS. Thermal imaging also can serve to identify sores and hot areas that could be equated with non-edible trim loss. This information could be used to inform producers about the amount and location for non-edible trim loss.

Cumulatively, digital and thermal images could be utilized to indicate health and welfare status for cull sows. Previous research has suggested that digital and thermal imaging can be used to evaluate BCS, confirmation, shoulder sores, body shape, and other production factors. After the cull decision, these measurements could provide producers with valuable feedback on animal condition. Producers could use this information to adjust production practices and maintain a more appropriate condition prior to culling. The overall goal of this research was to illustrate the feasibility for using digital and thermal imaging to evaluate condition at harvest facilities.

Materials and methods

All images were recorded at a Midwestern cull sow harvest facility. Cameras were placed at a specific site – prior to the sows entering the harvest facility. Video recording included capturing a 5-6 second video image as the sow progressed through the restrainer conveyor area. A two-dimensional RGB camera (Hikvision 4 MP DS-2CD2141FD HD WDR IP Network Dome 2.8mm lens, City of Industry, CA) was used for video image capture. Thermal images were captured using a FLIR A65, model number FLIR A65, FOV 90, 30 Hz., version 2016 (FLIR Systems INC., Wilsonville, Oregon, USA) equipped with a focal plane array detector with a resolution of 640 x 512 pixels and a spectral range of 7.5-13 µm. The digital imaging camera was positioned at approximately 2.1 m (7 ft) above the entrance to the restrainer/conveyer, where the sows were immobilized. The thermal camera was mounted in a perpendicular position on the lairage area ceiling rafter (3.0 m) above the entrance to the restrainer/conveyer where the sows were immobilized.

Figure 1: Representative screenshot of video image capture showing the specific site where both video and thermal images were captured.

Body condition evaluation

Materials and methods for body condition evaluation are described in Taylor (2021). Briefly, sow video images (n = 386) were captured and processed. The video images were split into 2 separate scoring rounds (n = 200 and n = 275, respectively) and then pooled into a singular dataset. Only pooled results are presented within. Sow images were scored by experts (Scorers, N = 6). Scorers utilized the traditional BCS scoring scale (BCS 1-5). The modal score for each sow video image was considered the correct score (BCS_{Mode}). Using BCS_{Mode} Mode Agreement ±0 and Mode Agreement ±1 were calculated by taking the BCS_{Mode} for each sow and subtracting the score applied by each scorer. The absolute value of this difference was calculated and used to evaluate Mode Agreement ±0 and Mode Agreement ±1. Therefore, Mode Agreement ±0 represents the percentage of times that each scorer was in complete agreement or had no deviation from BCS_{Mode}. The Mode Agreement ±1 represents the percentage of times that each scorer was within one scoring category of $BCS_{Mode.}$ Later on, the sows assigned a BCS_{Mode} ≤ BCS 3 were further evaluated to examine the scorers' ability to correctly identify sows with a welfare concern due to BCS (BCS ≤ 1) or a potential to become a welfare concern due to BCS (BCS 2 and BCS 3).

Thermal image evaluation

Materials and methods for thermal image evaluation are described in Taylor (2021). Briefly, sows (n = 80) were identified based on their expected trim loss. The categories used for selection were the presence of body sores, poor condition, mastitis, and other welfare related concerns. Selected sows were tracked through the harvest process and a thermal image was recorded for these selected sows. Non-edible trim loss was collected from the identified sow carcasses. Using the sow carcass weight and trim loss, the collected percent trim (PTRIM) was back calculated. After trim loss collection, thermal images were processed and hotspots were identified. Two separate criteria were used. The first identification criteria utilized a fixed identification based on pixel temperature differences that would be associated with carcass bruising. This criterion was referred to as "hotspot surface temperature changes associated bruising" (HSTCB) and defined a hotspot based on a mass of pixels 1.7° C above normal (median) temperature for sow image. The second identification criteria utilized k-means and established a clustering algorithm for each image and was referred to as the "clustering hotspot identification method" (CHIM). Once hotspots were applied to each sow image, the hotspot locations were recorded and analysis was run to determine their location with PTRIM.

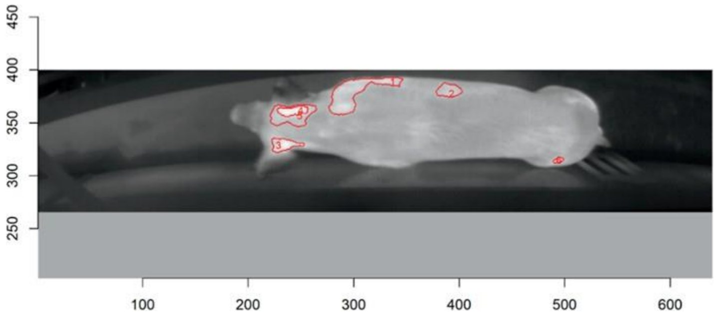

Figure 2: Illustration of a processed sow image with hotspots drawn using the hotspot identification algorithm.

Results and discussion

Body condition evaluations

Scorers were able to accurately identify sow body condition score using digital images. Sow BCS_{Mode} scores were approximately normally distributed with 2%, 18%, 54%, 20%, and 3% of sows being assigned a BCS_{Mode} of 1, 2, 3, 4, and 5, respectively. Table 1 presents the Mode Agreement ±0 and Mode Agreement ±1 for each scorer. All scores were within one scoring category over 90% of the time. In addition, the table shows that scorers were able to identify sows with a BCS3 over a large percentage of the time. This suggests that evaluations made using digital images are fairly accurate and that digital images can serve to identify low BCS sows.

Table 1: Scorer ability to accurately identify sow condition relative to the mode scores applied to each sow image by all scorers (BCS_{Mode}).

	[1]Mode Agreement ±0 (%)	[2]Mode Agreement ±1 (%)	[3]Number of sows with BCS ≤ 3	[4]Correctly scored (%)
Scorer 1	61	93	57	42
Scorer 2	72	99	90	62
Scorer 3	63	95	70	63
Scorer 4	72	98	93	43
Scorer 5	69	98	83	47
Scorer 6	71	100	87	64

[1]Percent of sows that a scorer was in complete agreement with BCS_{Mode}.
[2]Percent of sows that a scorer was within one scoring category of BCS_{Mode}.
[3]Number of welfare concerned sows (BCS ≤ 3) presented to each scorer.
[4]Percent of welfare concerned sows that scorer was in complete with BCS_{Mode}.

These evaluations could assist producers in feed utilization for optimizing cull sow value. Cumulatively, the application for digital imaging at cull sow harvest facilities may be used to provide information on animal condition that could help producers better understand the sow welfare and condition at harvest.

Thermal imaging evaluations

The relationship between trim loss observed and hotspot measurements is shown in Table 2. As shown by the inconsistent nature of these correlations, the hotspot criteria used in this study were ineffective in identifying a consistent relationship with observed trim loss. This is likely attributable to the variability in thermal images caused by lairage factors and skin emissivity in areas were trim loss would likely be observed.

Hotspots were then split by body location. Table 3 shows the results for trim loss means by hotspot location. It was observed that trim loss was significantly lower when more hotspots were present in the carcass's anterior portion.

Table 2: Pearson correlations between hotspot measurements and percent trim loss observed shown for two separate hotspot classification criteria.

	[3]Total hotspots	[4]Hotspot size	[5]Hotspot magnitude	[6]Hotspot intensity
[1]HSTCB	-0.30	-0.03	-0.28	-0.14
[2]CHIM	-0.07	0.09	-0.23	-0.04

[1]Hotspot surface temperature changes associated bruising (HSTCB) fully described in Taylor (2021).
[2]Clustering hotspot identification method (CHIM) described in Taylor (2021).
[3]Hotspots defined using HSTCB or CHIM criteria.
[4]Measured in pixels.
[5]The average temperature increase within a hotspot.
[6]Hotspot Size x Hotspot Magnitude

Table 3: Primary location hotspot relationship with percent trim loss observed.

Location	No Prevalence of Hotspots	Predominantly Anterior Hotspots	Predominantly Posterior Hotspots
[1]%Trim	4%[a] (±0.5%)	2%[b] (±0.3%)	4%[a] (±0.5%)

[1]Amount of non-edible trim observed as a percent of pre-trim carcass weight. Row means without a common superscript differ ($P \leq 0.05$)

Conclusions

This research suggests that sow BCS can be effectively evaluated at a harvest facility. These evaluations could serve as cumulative indicators for the sow's condition. These evaluations could be gathered and formulated so that producers could better understand cull sow condition. Producers could utilize this information to change rations and potentially adjust feeding strategies prior to culling. In addition, this information would increase cull sow welfare by notifying producers about instances when sows were unfit for transport due to BCS at culling (BCS 1). With this information, producers could make more informed cull sow decisions and better manage their breeding herd.

There is scope for further improvements in the technology. The presented hotspot isolation criteria could be improved by having additional information through enhanced imaging and data analysis techniques. Camera angle also may not have allowed for complete capture of hotspots associated with shoulder sores, a common source for carcass trim loss on sows. This is due to thermal image collection taking place in a working lairage area where a side view of sows is not feasible. Additionally, lairage factors may have impacted thermal image collection. Furthermore, this criteria could be corrected by collecting a large sample size. With a larger data set, researchers could utilize computer algorithms and machine learning to better inform hotspot isolation. Information on where hotspots were located on the sow carcass could provide producers with information on non-edible trim loss sources. The ability to detect non-edible trim loss could inform producers on trim loss concerns that are repeatedly observed and may be from sources that stem from farm related issues. With the information provided through trim loss evaluations and thermal imaging hotspots, producers could better understand their sow's trim loss. Information from these evaluations could allow producers to identify cull sow trim loss sources.

Ongoing work is geared to better assess digital and thermal imaging utilization in evaluating cull sow welfare at the harvest facility. Work is being conducted to identify more sows with trim loss and access larger data sets. Current work aims to look at counting sows and identifying sows as they enter the harvest facility. In addition, future work will focus on collecting trim loss from all sows harvested. This information will be used to investigate deep learning models on larger data sets. With these advances and having higher spatiotemporal resolution, both trim loss and body condition can serve to inform better decisions across the swine industry.

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References

Blair B., and Lowe J. (2019) Describing the cull sow market network in the US: a pilot project. *Preventive Veterinary Medicine* 162, 107–109.

Halachmi I., Polak P., Roberts D.J., and Klopcic M. (2008) Cow body shape and automation of condition scoring. *Journal of Dairy Science* 91, 4444–51.

Lao F., Brown-Brandl T., Stinn J.P., Liu K., Teng G., and Xin H. (2016) Automatic recognition of lactating sow behaviors through depth image processing. *Computers and Electronics in Agriculture* 125, 56–62.

Leonard, S.M., Xin, H., Brown-Brandl, T.M., Ramirez B.C. (2019) Development and application of an image acquisition system for characterizing sow behaviors in farrowing stalls. *Computers and Electronics in Agriculture* 163.

Nielsen, S.S., Alvarez, J., Bicout, D.J., Calistri, P., Canali, E., Drewe, J.A., Garin Bastuji, B., Gonzales Rojas, J.L., Schmidt, C.G., Michel, V., Miranda Chueca, M.Á., Padalino, B., Pasquali, P., Roberts, H.C., Spoolder, H., Stahl, K., Velarde, A., Viltrop, A., Winckler, C., … Herskin, M. (2022) Welfare of pigs during transport. *EFSA Journal* 20, 108.

Rioja-Lang, F.C., Brown, J.A., Brockhoff, E.J., and Faucitano, L. (2019) A review of swine transportation research on priority welfare issues: a canadian perspective. *Frontiers in Veterinary Science* 6.

Taylor, W.E. (2021) Utilizing digital imaging to evaluate cull sows at harvest. *Available from Dissertations and Theses @ Iowa State University*. ProQuest Dissertations and Theses Global.

Thodberg, K., Foldager, L., Fogsgaard, K.K., Gaillard, C., and Herskin, M.S. (2022) Temperature conditions during commercial transportation of cull sows to slaughter. *Computers and Electronics in Agriculture* 192, 106626.

Soerensen, D.D., and Pedersen, L.J. (2015) Infrared skin temperature measurements for monitoring health in pigs: a review. *Acta Veterinaria Scandinavica* 57, 1–11.

Stock J.D., Calderon Diaz J.A., Abell C.E., Baas T.J., Rothschild M.F., Stalder K.J. (2017) Development of an Objective Feet and Leg Conformation Evaluation Method Using Digital Imagery in Swine. *Journal of Animal Science and Livestock Production* 1(2), 006.