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Documentation of 50% water conservation in a single process at a beef abattoir

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ABSTRACT

Beef slaughter is water intensive due to stringent food safety requirements. We conducted a study at a commercial beef processor to demonstrate water conservation by modifying the mechanical head wash. We documented the initial nozzle configuration (112 nozzles), water pressure (275 kPa), and flowrate (152 L/head washed), then developed a 3-D CAD model to identify regions of water use redundancy. The mechanical head wash was modified by reducing nozzle count (72), decreasing pressure (138 kPa) and flowrate (78.4 L/head). To objectively document visual cleansing, heads were photographed at three locations post decapitation: 1) prior to manual wash, 2) prior to entering, and 3) upon exit of the mechanical head wash. Changes in red saturation between stations 1 and 3 provided an objective measure of relative cleanliness. Prior to altering operating parameters, the post-wash red saturation was 5%; after modification this increased slightly to 7.5%. Water use was reduced by 48.4% without altering head cleanliness acceptance.

1. Introduction

In 2015, 28.8 million cattle were harvested in the United States (USDA ERS, 2016). Each animal slaughtered in the U.S. must be inspected in accordance with United States Department of Agriculture – Food Safety Inspection Service (USDA FSIS) post-harvest food safety regulations. The objective of this research was to validate modification of an existing commercial mechanical head wash to reduce water consumption in a beef processing facility. Each animal harvested undergoes postmortem inspection with emphasis on the head. Prior to inspection, the head must be washed free of blood and digesta so that lesions or other indicators of disease can be readily identified and to cleanse edible items (head meat, tongue) of contaminants. Assessment of head cleanliness is determined by trained USDA FSIS inspectors. Due to variability and subjectivity amongst inspectors and the cost of failed inspection, the head wash process is susceptible to the use of excess water. True conservation of water will reduce both water consumption and waste water treatment cost. Furthermore, water conservation techniques for a head wash could be adapted to other washing systems (i.e. pre-evisceration, final carcass wash). Previous research in a controlled laboratory setting demonstrated substantial water savings could be achieved during the head wash process (DeOtte, Spivey, Galloway, & Lawrence, 2010; Galloway, Lawrence, & DeOtte, 2013). The objective of this research was to demonstrate the transferability of water conservation to a commercial abattoir.

2. Materials and methods

Determining the effectiveness of the mechanical head wash is difficult due to the subjectivity of inspection and difficulty in quantifying cleansing effectiveness with many dynamically coupled variables. In order to provide objective measures of relative cleanliness, heads were photographed and the images analyzed to quantify percentage of red pixels in a defined area. A CAD model of the nozzle and spray configuration in the mechanical wash assisted identification of water use redundancy. Image analysis provided a tool to evaluate the reasonableness of the modifications.

2.1. Image capture

To photograph heads, digital cameras (Model D3100, Nikon Corp, Japan) were mounted at three locations, 1) after decapitation once head was placed upon the conveyor, 2) after the manual wash process - prior to mechanical wash and 3) after mechanical wash. The physical placement of cameras in reference to the production line placement is illustrated in Fig. 1. The camera shutter was activated by a photo detector (MIOPS, 2015) that triggered when a passing head blocked the laser beam (Accession No. 9410958-01, OPCOM O.E. Inc., Xiamen,

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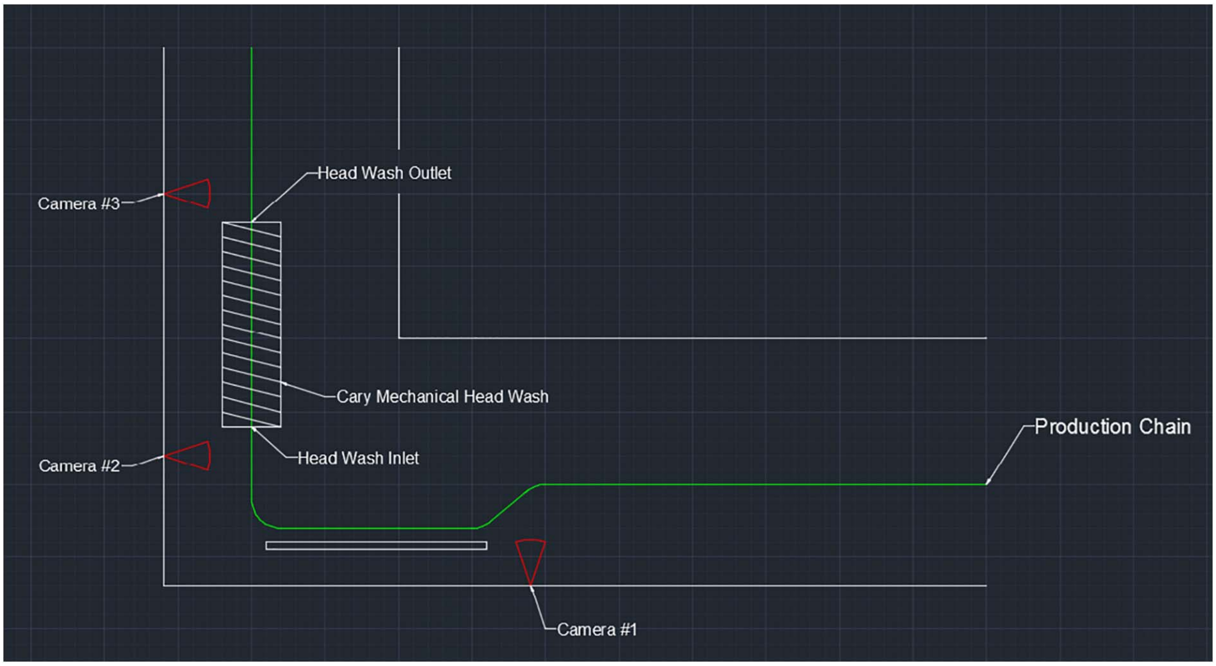

Fig. 1. Schematic of layout for head conveyor and wash. Heads were removed from the carcass after the point indicated as "Production Chain" and photographed at each of three camera locations. Camera #1 captured the unwashed head. Following that, the gullet and head were manually washed. Camera #2 captured the head prior to mechanical wash, and camera #3 took the final photograph as the head exited the wash cabinet.

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2.2. Image analysis

Assess© computer software was used to interpret color pixelation of digital images (Assess, 2015). This software was written to evaluate plant leaf health and integrity in crop applications using algorithms that compare vegetation discoloration for measurements of disease. Although *Assess*© was optimized for plant disease measurement, the program is flexible enough to be used as a laboratory tool for other colorimetric analysis such as determining red saturation. The number of red colored pixels references the total count within a set threshold or intensity in an image. For a head from a slaughtered animal the entire area of the head was selected. Within this area, a red pixel threshold of 75–235 pixels was compared to the remaining pixels in the selected area, and from this a percentage was calculated. Using red saturation as a surrogate for the blood covering the head *Assess*© was used to quantify cleanliness both before and after mechanical washing.

2.3. Modeling to improve wash cabinet efficiency

The mechanical head wash system (W. R. Cary Engineering, Inc., Springfield, Missouri; Fig. 2) is a long shower (similar to a car wash) through which heads pass horizontally. It is equipped with fan nozzles (25° spray) on 16 arbors that articulated through an angle of 55°. The mechanical wash was divided into 4 sections, each with a maximum capacity of 48 nozzles (each side with 8 arbors containing 3 nozzles). As illustrated in Fig. 2, the spray interferes with visibility thus making it difficult to visually determine the actual coverage from individual nozzles. A CAD model (*Autodesk Inventor Professional*©; Fig. 3) offered the opportunity to overcome this difficulty. The model of spray coverage was developed by measuring nozzle orientations with the spray pattern for each nozzle delineated. The model permitted determination of surface coverage for each nozzle, repetitive coverage, and alternate spray locations that would maximize water contact. Water spray area was represented as a static solid to illustrate total coverage by a single nozzle. With the ability to pinpoint the contact of water spray in mid oscillation, the effectiveness and total area covered by each arbor of nozzles was determined. Nozzles that excessively duplicated coverage (n = 40) were capped. Water flow was recorded using an electric turbine meter (Model GSCPS-200, Great Plains Industries, Inc., (GPI), Wichita, Kansas).

Fig. 2. Image of the entrance into the Cary Mechanical Head Wash.