PRECISION LIVESTOCK FARMING IN THE BROILER

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The demand for poultry meat and byproducts has increased significantly in the last two decades (Miller, 2022). Producers are increasing production house size to produce larger quantities of broilers to meet these demands (Miller, 2022). According to the USDA Agriculture Census, the average pounds of live-weight broilers produced in the U.S. has gradually increased from 2004 to 2020 (USDA, 2006; 2011; 2016; 2021). While house size largely determines the number of broilers per flock, on average one house holds approximately 28,000 broilers per production cycle (Li et al, 2022). With several houses per farm, monitoring and managing large numbers of broilers can become time-consuming and laborious.

Table 1. Broiler production by pounds in the United States.

Year	Pounds Produced
2004	45,796,250,000
2005	47,908,100,000
2009	47,752,300,000
2010	49,162,100,000
2014	51,378,700,000
2015	53,364,000,000
2019	58,259,100,000
2020	59,405,600,000

Precision Livestock Farming (PLF) uses technology to monitor livestock and poultry operations by collecting data on the animals and providing relevant information to the producer in real time to help them to make timely and informed management decisions. With real-time warnings and observation, the producer can spend less time trying to locate problems and more time managing them. Precision livestock farming has three functions that assist the producer in making timely management decisions: sensing, decision-making and control (Astill, 2020). Using vision, audio and environmental monitoring systems, sensing is done through various sensors and cameras that collect both environmental and animal-based measurements. This data is then processed by computer algorithms that identify potential changes in production conditions. This data is presented to the producer as relevant information that can be used for management decision-making. At this time, the control piece typically involves the actions taken by producers in response to PLF feedback, but future PLF technologies may be equipped with additional control functionality to complete needed tasks with minimal intervention from the producer. While broiler PLF systems research continues, several technologies currently show potential benefits for the future of the broiler industry.

While PLF with cattle involves the use of wearable sensors and monitoring individual animals, this isn't feasible for commercial poultry because the individual bird value is very low compared to beef or dairy animals (Astill, 2020). In the past decade, researchers have focused on fixed cameras (Yang et al, 2023), microphones (Fontana et al, 2017) and sensors (Astill et al, 2020) that can monitor whole broiler flocks without contacting the birds (Morrone et al, 2022). However, the goal of PLF is not to remove the producer from the poultry house but to provide information to make the producer's time in the poultry house more efficient and valuable (Morrone et al, 2022). Fixed and rail-mounted equipment allow producers to monitor behavior and wellness, detect diseases and various health concerns, monitor and manage various environmental parameters, monitor and manage feed distribution, and detect and locate mortalities (Vranken, 2017; Muvva et al, 2018; Fernandez et al, 2020; Patel, 2020). These PLF systems can potentially reduce broiler farm labor requirements while increasing bird well-being and production efficiency (Astill et al, 2020). While previous publications have focused on specific PLF technologies research, what it is, and how it can be used

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(Berckmans, 2017; Norton et al, 2019; Patel, 2020), very few publications address the role of PLF in the broiler industry and what applications are available for commercial production. While most PLF broiler research has been in lab settings, only a few studies have reached a commercial farm (Silvera et al, 2017; Liu et al, 2019; Ali et al, 2023). As such, more work is needed that demonstrates PLF technology in the broiler industry.

BEHAVIOR AND WELFARE MONITORING

Vision systems use image analysis from cameras fixed to various locations throughout the house or connected to ceiling-mounted rail systems that move through the house above the birds. Vision systems offer real-time flock monitoring to identify production problems. Images are recorded and processed by algorithms that provide producers with both information and alerts. Computer vision-based PLF systems can identify a variety of variables that indicate the flock's behavior and welfare including broiler activity and flock distribution.

Traditionally, producers have manually inspected flock distribution daily, a time-consuming and labor-intensive practice (Zuidhof, 2020). PLF systems can potentially benefit broiler production by allowing producers to visualize flock distribution before entering the house. Knowledge of abnormal flock distribution can help producers better focus on and assess bird thermal comfort and feeder line problems. Because broiler productivity is based on efficient feed conversion, thermal discomfort and malfunctions in feeder lines can be a disadvantage to overall flock uniformity and productivity.

As shown in Figure 1, the SCOUT robot is available in North America and moves through the house on either a half-house or full-house circuit. As the robot moves along the rail, it collects data from the flock below. This data is then processed by computer algorithms in real time to identify potential changes in production conditions. This information is shared with the producer through SCOUT's cell phone alerts and main website where producers can see the data collected by SCOUT in real time. SCOUT relies on computer vision systems to measure flock distribution, detect mortalities and abnormal droppings, and identify wet spots in the litter that could be due to leaking drinkers.

MORTALITY DETECTION

Dead birds need to be removed from broiler production houses promptly because the carcasses can be focal points of disease transmission throughout the flock. As the broilers mature and become bigger, this is an often time-consuming and labor-intensive process that is prone to human error (Li et al, 2022; Muvva et al, 2018). On average, producers spend 3-4 hours a day locating and removing broiler mortalities in the later stages of production (Muvva et al, 2018). Ideally, computer vision systems would provide producers with the quantity of dead birds in a house and identify where they are located, which would significantly reduce the time needed to locate several mortalities. As shown in Figure 2, PLF mortality detection systems utilize computer vision systems and process the images using algorithms that detect mortalities using bird conformation and thermal imaging (Muvva et al, 2018). Vision systems capture images of birds with abnormal conformation,

Figure 1. *SCOUT robot in a broiler house.*

such as feet in the air or a bird lying on its side. These images are then processed by algorithms that determine the temperature of a potential mortality to confirm if the bird is living. If no heat signature is sensed, the mortality is confirmed, and the producer is notified (Muvva et al, 2018). While PLF vision systems can potentially notify producers in real time, they also store this information and provide various infographics and diagrams showing the history of mortalities throughout the house and through the lifespan of each flock. This can benefit producers in determining what factors contribute to higher mortality rates so better management practices can be taken for future flocks.
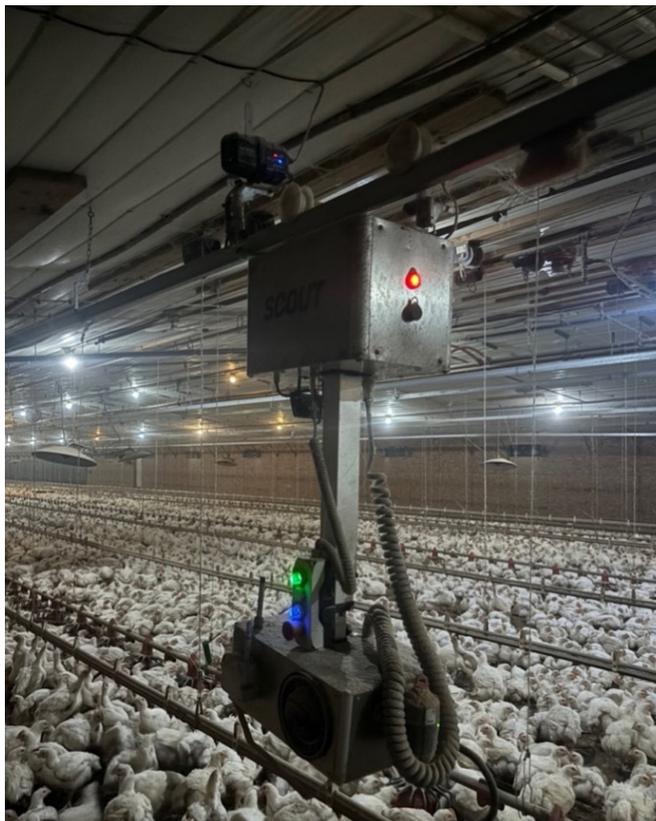
Current technologies, such as SCOUT, can identify broiler mortalities, but producers need to understand that algorithms are still being adapted for better mortality detection accuracy. Several current studies are attempting to create mortality robotic retrieval systems that reduce the labor requirement for locating and removing dead broilers (Li et al, 2022; Muvva et al, 2018). As algorithms are fine-tuned to provide higher spatial accuracy for mortality detection, future PLF systems are poised to save producers time and labor expenses for daily mortality removal.
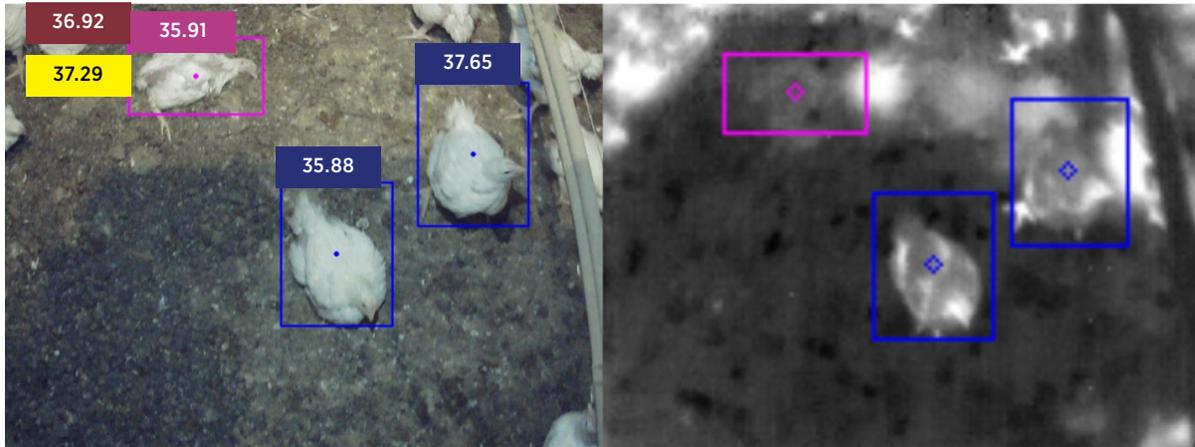
Figure 2. Mortality detection with thermal imaging algorithms.
Cumberland, AGCO. [Photograph of mortality detection software from SCOUT]. Retrieved October 14, 2023 from
https://www.scoutmonitoring.com/robots/image-gallery/33cmjsa/deadbirds.

DISEASE DETECTION

Because broilers are vocal by nature, sound detection can be a beneficial tool for monitoring their health and well-being (Liu, et al, 2020). As broilers mature, the frequency of their vocalizations decreases, yielding a positive correlation between broiler sound and growth rate (Fontana, 2017). Broiler vocalizations can also be used to identify respiratory diseases such as Avian Influenza, Newcastle Disease and Infectious Bronchitis (Banakar, 2016). Because these diseases are highly transmittable and have the potential to wipe out an entire flock, early detection is essential (Banakar, 2016). With the negative stigma established around antibiotic use in livestock production, producers rely on early disease detection to maintain flock health and profitability (Tabler et al, 2019). Respiratory disease strongly impacts broiler vocalizations, making early detection of these diseases possible through continuous sound analysis (Liu, et al, 2020). Sound analysis is done with microphones either fixed throughout the house or on rail-mounted systems and are designed to monitor the entire flock. The recorded sounds are processed by algorithms that filter out nonessential noises, such as pecking, and identify abnormal vocalizations from broilers, like coughing and sneezing.

While no current technology is available to commercial broiler producers utilizing sound analysis, studies have shown a positive correlation between sound and the presence of respiratory disease (Banakar, 2016; Liu et al, 2020). As researchers work to bring audio analytics out of the lab and into commercial production, PLF technology will aid producers in monitoring broiler growth and early detection of respiratory disease.

ENVIRONMENT AND LITTER MANAGEMENT

Environmental control systems are designed to help the farmer monitor environmental parameters and provide warnings when conditions are out of proper range. These systems measure ammonia and carbon dioxide concentrations, temperature and relative humidity, and identify wet spots in litter. Maintaining proper ventilation and litter quality is critical for bird well-being and growth. High heat and humidity levels in broiler houses promote the growth of bacteria and quicker breakdown of urea acid from bird droppings in the litter, resulting in a higher ammonia concentration (Debauche, 2020). Litter moisture higher than 25 percent also can contribute to higher humidity and temperature, hock burns and skin lesions, and poor feather coverage, all of which result in loss of profit (Fernadez, et al, 2016; University of Georgia, 2011).

PLF environmental control systems allow the producer to monitor the controlled environment and adjust ventilation without having to physically visit the house. Because broiler environment has many variables that can affect broiler health, such as ammonia and carbon dioxide concentrations, litter

Figure 3. Environmental data from SCOUT, Cumberland, AGCO. [Photograph of example environmental data from SCOUT]. Retrieved July 17, 2024 from **https://www.scoutmonitoring.com/house/p8k2j3v/graphs**.

Observable	Last Value
Ammonia [ppm]	12.62
Airspeed [mph]	0.05
CO_2 [ppm]	1123.37
Effective temperature [°F]	91.97
Heat stress index	31.83
Humidity [%]	47.21
Humidex	22.64
Light intensity [fc]	2.06
Noise level	48.53
Temperature [°F]	91.61

moisture, temperature, and humidity, having this information in an easy-to-access location can benefit the producer by knowing the exact state of their controlled environment at any time.

The SCOUT robot is a commercially available PLF system that is equipped with various sensors and gauges that measure environmental conditions including ammonia and carbon dioxide concentration, temperature and relative humidity (Figure 3). Data is collected as the system moves through the house and is portrayed to producers in easy-to-read graphs and diagrams that show changes in environmental conditions over time. When ammonia and carbon dioxide concentrations get close to the threshold values, alerts can be sent to producers to remedy the problem promptly. All data collected by SCOUT is stored in a database that producers can access for current or previous conditions. While SCOUT doesn't possess the ability to change ventilation conditions automatically, it offers producers access to broiler house conditions in real-time, so producers only need to visit house controller boxes when ventilation conditions require adjusting. SCOUT also purports to assist producers by identifying wet spots in litter that contribute to poor litter quality. While algorithms are still being enhanced to increase wet spot detection accuracy, this feature has the potential to aid producers in increasing litter quality by fixing leaks in drinker line leaks promptly which will lower production costs. An example of two of SCOUT's many data interfaces is shown in Figure 4 and Figure 5.
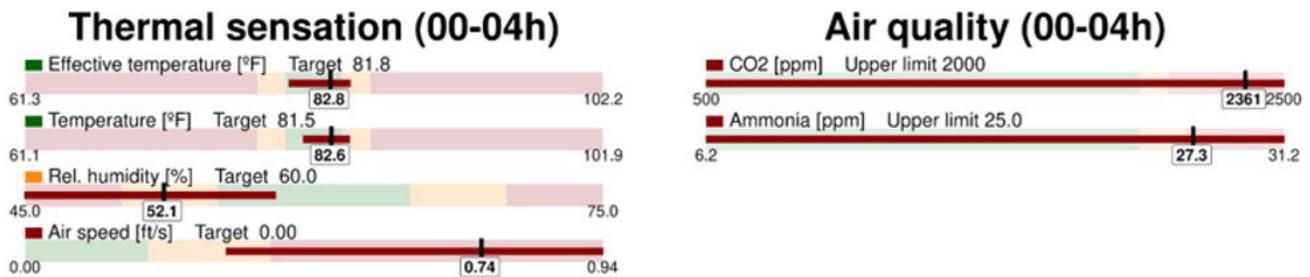

Figure 4. *Environmental data from SCOUT*
Cumberland, AGCO. [Photograph of environmental data from SCOUT]. Retrieved October 13, 2023, from
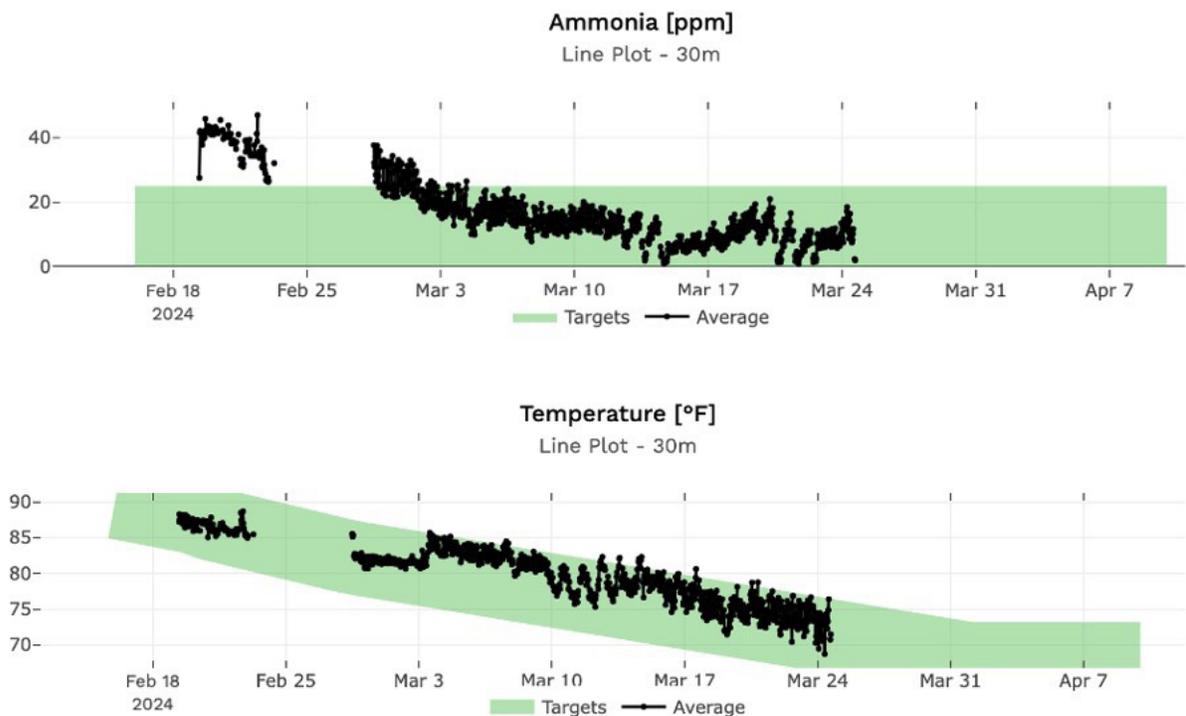**https://scoutmonitoring.com/robots/graphs/33cmjsa**.

Figure 5. *Environmental data from SCOUT*
Cumberland, AGCO. [Photograph of environmental data from SCOUT]. Retrieved July 17, 2024, from
https://www.scoutmonitoring.com/house/p8k2j3v/status.

PRECISION FEEDING AND DRINKING

Precision feeding systems work to provide producers with real-time observation of broiler feed intake and feeding activity. These technologies work to maintain flock uniformity and ensure each broiler is getting the amount of feed they need each day (flock uniformity is achieved when all broilers are within +/- 10 percent of the average weight of individual birds). If a feeder/drinker line malfunction occurs, precision feeding systems alert the producer and provide the location in the house that requires attention. Typically, producers must identify blocks and leaks manually, which is a time-consuming process that is laborious and not timely. Precision feeding offers producers this information without having to enter the house, allowing producers more time to focus on other areas that may need attention to optimize production. Some systems also offer automatic weighing at feed pans so that weight is calculated by all birds that eat and not just the ones that go to the scales. Work is ongoing to develop more efficient technology to meet the specific needs of the broiler industry, but one system has already shown beneficial evidence for the poultry industry (Patel, 2022).
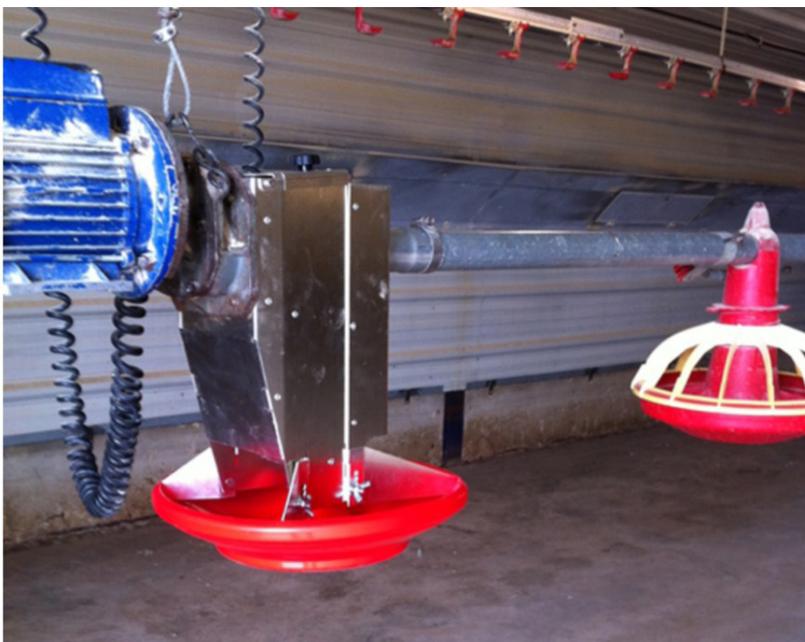
Figure 6. *Kai-Zen robotic feeding system*
IsraelAgri.[Photograph of Kai-Zen feeding 5 robot]. Retrieved May 7, 2024, from
https://israelagri.com/unique-robotic-feeding-system/.

As shown in Figure 6, the Kai-Zen feeding robot originates from Israel and aids farmers in managing feed consumption rates based on physiological development (Patel, 2022). The Kai-Zen robot relies on computer algorithms to calibrate the feeding rate according to genetics, breed, age and demand, which helps optimize the amount of feed utilized during a production cycle. This system has an expected return on investment of less than one year with increased revenues of up to 20 percent (IsraelAgri, 2024).

SUMMARY

With the rise in demand for broiler meat and byproducts, finding efficient ways to maximize productivity while keeping labor costs low is essential in meeting the increasing demand while controlling production costs. Modern-day broiler houses are much larger than in the past, rendering traditional flock monitoring practices for multiple-house farms ineffective. Precision livestock farming offers producers real-time monitoring of the flock and the in-house environment. Current technologies available in the U.S. aid producers in monitoring broiler activity, flock distribution, environment and litter management and automated feed distribution, but few producers currently utilize these systems. While some technologies can detect mortalities within a house, researchers are working to improve algorithms to provide more accurate detection with reduced cost, which may attract more investment. Several studies are working on the use of PLF to aid in early disease detection, but more work needs to be done before these advanced technologies will be available to broiler producers. While the current availability of PLF in the broiler industry is limited, future advancements will create more opportunities for producers to reduce production costs and increase broiler productivity and wellbeing.

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