A report for:

Innovations in poultry production

Increasing the sustainability of commercial poultry

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Executive Summary

The poultry industry has made tremendous strides over the past 30 years in improving the growing conditions in poultry houses. Many of those improvements are unknown to consumers not associated with the rearing of poultry. The challenge is continue to improve conditions and processes to ensure birds are well cared for and demonstrate reduced stress or discomfort to consumers.

Technologies to improve bird welfare include early chick feeding, on-farm hatching, litter moisture management and implement precision livestock farming. Each of these technologies have positive implications for the welfare of the birds, through improvements in gut health, the livestock environment, and in improved data collection for validating and certifying these conditions.

Technologies to improve the environment (air, water, energy) have become more critical in today's industry. Solar brood is a technology that uses the sun to preheat air prior to entering the poultry house, resulting in energy savings. Two technologies explored to reduce air emissions: heat exchangers and the Schulz Emmi emission minimizer. The heat exchanger saves energy and benefits the environment by reducing dust emissions. The Schulz Emmi reduces emissions, which also improves the environment. Two mortality management technologies are discussed: The Ecodrum in-vessel composter and Advanced Composting.

Strategies for sustainability, public perception, the social license to operate must be included in any discussion of technology and sustainability. The public perception changes quickly and the industry needs to lead that conversation. Mandates by the public in production and technology implementation that are not science-based will be detrimental to the viability of poultry production and all of animal husbandry. A technology eggXYT addresses the social license to operate for the layer industry is discussed in this report.

Ultimately, for animal-based agriculture to continue and thrive, producers must become more proactive in addressing the concerns of the public. These technologies and strategies are suggestions to improve the sustainability of commercial poultry production.

Table of Contents

Table of Figures

Foreword

My desire to help others led me to work in agriculture. I did not grow up on a farm, but while in high school, I became friends with a local farming family. Observing the challenges, the risks, the work ethic, and the commitment to grow food to feed others, inspired me to want to do something to help farmers. As I was nearing the completion of my college degree, a local poultry company, Perdue Farms, came to do on-campus interviews. The poultry industry became my career and opportunity to help farmers be more competitive and sustainable.

Over the past 25 years, the poultry industry has given me the chance to learn and grow personally and professionally. I worked for Perdue Farms for eight and half years as a Flock Supervisor and then as an Area Supervisor. I was responsible for training new and existing growers, mentoring associates, and troubleshooting performance issues on farms. I worked for Mountaire Farms for three years, training new producers in all aspects of management in their new poultry houses so that they could be competitive and successful. While working at Mountaire, I decided to build poultry houses. In 2006, I had four 19.8m' x 183m poultry houses built on my farm. Initially I grew large conventional birds, and then in 2015 I made the transition to raising organic poultry for Coleman Natural Foods. The transition to organic poultry improved the financial sustainability of the farm.

The experience of working for poultry companies, as well as growing chickens, has given me a broader perspective and appreciation for the challenges we face. I teach classes on communications to improve the relationship between the grower and the poultry company I consult with MidAtlantic Farm credit, Farm Service Agency, and other lending institutions to assess existing farms to identify what is required to be competitive today and into the future.

I can truly say that every experience in this journey has prepared me for the next step. After becoming the 2017 Nuffield International Farming Scholar, I started working for the University of Delaware as the state's poultry extension agent. As an extension agent, I do outreach and education with local poultry producers, troubleshooting problems on farms, and educating the public and school age children about the importance and value of the poultry industry to our state.

I am thankful to MidAtlantic Farm Credit, Mountaire Farms, and Delaware Department of Agriculture for their investment in the Nuffield International Farming Scholarship. The opportunity to travel has broadened my perspective, given me a much greater appreciation for the resources we have in the United States for farmers, and given me insight in to trends and technologies that will help protect, preserve, and sustain the poultry industry on Delmarva (the state of Delaware, and the eastern shore of Maryland and Virginia. Traveling to the Netherlands, Israel, Germany, Brazil, New Zealand, and various parts of the United States has exposed me to new innovations and technologies that improve bird welfare and sustainability.

Acknowledgments

I am grateful to the following for making this opportunity possible:

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The University of Delaware (Dr. Michelle Rodgers, Dr. Mark Isaacs, and Dean of the College of Agriculture Mark Rieger), for allowing me to have this experience so early in my career at the University.

Nuffield International and Nuffield USA for the opportunity to broaden my horizons, to grow as an individual, to increase my knowledge, experience, and add value to my community at state, country, and international levels.

My children, Claudia, Nicholas, and Austin who told me this was a once in a lifetime opportunity and encouraged me to go for it.

Jennifer Moran, for her encouragement and management of the farm, ensuring that the daily tasks were accomplished.

My mom, Dianna Harris, for her encouragement and support.

Abbreviations

ABF Antibiotic Free

DPI Delmarva Poultry Industry, Delmarva Delaware, Maryland, Virginia (eastern shore)

IPPE International Poultry Processing Expo

NAE No Antibiotics Ever

NRCS Natural Resource Conservation Service

PLF Precision Livestock Farming

U.S. United States

Objectives

This study aims to identify technologies and strategies to improve the sustainability of commercial poultry production. The following is a list of key technologies and strategies:

- Technologies to improve and address animal welfare.

- Technologies to improve or help reduce environmental impact. This includes air, water, and nuisance issues.

- Opportunities to connect with consumers to build understanding and belief in the quality, safety, and well-being of commercially raised poultry and to maintain the social license to operate.

Chapter 1 - Introduction

The Poultry industry on Delmarva consists of three states, Delaware, the eastern shore of Maryland, and the eastern shore of Virginia. The Delmarva Peninsula has the Chesapeake Bay on one side and the Delaware Bay on the other. Because of the close proximity of these bodies of water and the density of poultry production, the poultry industry is under greater scrutiny and legislative pressure than other areas of the United States. The Delmarva poultry industry on the peninsula is critical to the economy of the region. In 2017, 605 million chickens were grown, producing 1.9 billion kilograms of chicken. The Delmarva poultry industry consists of 1,549 poultry growers who received US$256 million in contract payments. In addition, the poultry companies employ over 20,000 people. Typically, the industry enjoys a 2% annual growth; however, in 2017 there was an increase of 13% in housing capacity (statistics from Delmarva Poultry Industry). Most corn and soybeans grown on Delmarva go to the poultry industry. One-third of the U.S population lives with eight hours of Delmarva, so it is a prime location for fresh product to be grown.

Broilers are the primary poultry produced on Delmarva. Broilers are meat chickens raised for human consumption. The target weight and length of time these birds are grown is consumer driven. The egg laying industry is minimal in this area of the United States. The typical size of a farm prior to 2010 was four houses. By 2015, farms were being built with 6, 8, and 12 houses. This has changed the dynamic of the poultry industry on Delmarva. Poultry housing was not perceived as a nuisance, but with the growth in the size of the houses and the number of houses on a farm this has changed. What once was viewed as family farming is now perceived as industrial farming.

Over the past five years, the poultry companies have had such a need for capacity to meet increasing demand for product that they accepted poor performance on farms and continued to place birds on farms that were not cost competitive. In 2018, we had a perfect storm of circumstances. One of the companies that had planned for a major expansion had an issue that prevented them from increasing production. Then with trade issues between China and the U.S., less pork and beef were being exported, resulting in surplus protein being on the U.S. market, causing chicken prices to decline. These factors, combined with poor lending practices that financed excess capacity, has resulted in a decline in poultry farm values.

The intersection of agriculture and the environment is magnified in the Chesapeake region, therefore making it urgent to identify and implement strategies and technologies that increase the social license to operate. In many ways, we are more advanced than other areas of the U.S., but we must always try to seek out new ways to mitigate and reduce the environmental impacts. For the poultry industry to grow and thrive here on Delmarva we must remain competitive and efficient in our production practices, meeting the expectations of consumers and animal welfare standards. It is critical, with the amount of new housing, farmers need to understand the technologies they already have and that they are utilizing them to their full potential.

As a Nuffield International Scholar, my mission is to explore and share technologies and strategies that will strengthen the poultry industry locally and nationally. The more proactive and environmentally conscious producers are, the more likely it is that the poultry industry will be successful and sustainable on Delmarva.

Chapter 2 - Animal Welfare

Animal welfare has come to the forefront of concern for consumers. Consumers are more aware and desire to know how the birds are raised, what are the conditions like, and are the birds treated well? The shift to more antibiotic free production has required growers to be much more proactive in their management. Early gut health is affected by early access to feed after the chicks hatch. This section will discuss early chick feeding and on farm hatching. On-farm hatching could be one of the most innovative concepts to change the poultry industry. Other technologies utilize artificial intelligence to document and inform the grower of the house conditions, litter conditions and bird comfort. All of the technologies and innovations have the potential to improve animal welfare: benefitting the chicks, the grower, and the perceptions of consumers.

Hatchcare

The author visited Probroed & Sloot hatchery in Germany. This hatchery features a system of hatching that provides early chick feeding called HatchCare. The incubation period for a chicken is 21 days. Conventional hatcheries transfer eggs from a setter that keeps eggs of different stages of development for 18 days. During incubation, the eggs transfer to a hatcher where the hatching process takes place. The length of time it takes for the first chick to hatch to the last chick hatching can be 24 to 36 hours; this is called the hatch window. In traditional hatcheries, chicks will not have access to feed and water and then there will be additional time to deliver the birds to the farm where they will have their first opportunity to eat and drink. During the transport of chicks to the farm, access to feed and water (in gel form) is available.

Newly hatched chicks are going through intensive development that requires water to prevent dehydration and feed for maintenance and growth. The yolk sac that is absorbed prior to hatching has antibodies that help the chick have better health. When the yolk sac is rapidly consumed for maintenance and growth, then the gut health and immune system become compromised. In an antibiotic-free production system the development of the gastrointestinal system and immune systems are critical to improved weight gain, feed conversion and overall bird health. The Hatchcare system allows the chicks 40% more space than traditional hatch baskets. Another benefit is the birds hatch in an illuminated environment, so the chicks will be accustomed to the light, thus reducing stress. In a traditional hatchery the chicks are separated from the hatching debris, which requires birds to go through a separator and be sorted and counted into trays. The stress associated with this handling is reduced with HatchCare.

Figure 1 shows the progression of birds hatching in a Hatchcare hatchery. The figure shows an environment that is lighted increasing the activity level, chicks hatching from the egg, the egg stays in the top tray, as the chick exits the shell he falls through to the tray below, leaving the shell debris on the top tray. Once in the bottom tray, the cjicks continue to dry and immediately have access to feed and water.

Figure 1: Picture from HatchCare website

NestBorn®
On-Farm Hatching- Hatching birds on the farm rather than in a traditional commercial hatchery. Technology that transfers eggs, monitors humidity and temperature, and supports hatching of chicks in the poultry house.

The benefits of on-farm hatching: transport of chicks, more natural hatching process, makes it possible to have day old chicks every day of the week, which results in improving weights for processing. Benefits to early feeding: direct access to feed and water, improved immunity development, improved intestinal health. This results in less disease pressure, antibiotics, mortality, stress and more robust chicks. The farms I visited with the ability to do on farm hatching were satisfied with the improvements in hatching, liveability, and animal welfare due to the reduction in stress from transport and delivery.

NestBorn is new technology that transfers eggs to the poultry house at 18 days of incubation. The birds are placed on a fresh bed of litter. The stress of transfer and delay in access to fed and water is eliminated by the concept of on farm hatching. The birds hatch with immediate access to feed and water. The NestBorn® technology monitors temperature, humidity, and chick hatch activity. The NestBorn® application sends an alarm when hatch conditions are not within acceptable parameters. The delivery unit can place 45,000 eggs per hour. One of the main advantages of the NestBorn® system compared to the other on-farm hatching techniques is that the grower does not need to install specific equipment. The monitoring units to measure the conditions are small and portable. These units are placed on the litter bed with the eggs. The units are approximately 16 cubic centimetres at the base. The main unit that communicates with the smaller units is blue tooth-enabled and the size of a small toolbox.

Figure 2: Pictures by Author. Nestborn® bluetooth unit collects data from monitoring stations placed within the egg set. Eggs are placed on pine bedding material three days prior to hatch

Figure 3: Pictures by Author. Monitoring unit measures temperature, humidity and hatch activity. The right-hand picture shows a newly hatched chick

Vancomatic

The Vancomatic system consists of a large rack with a belt on it that drops down to floor level to take the eggs at 18 days of incubation. This system requires installation of equipment in the poultry facility and adds the benefits of early chick feeding and reducing stress on chicks from transport and delivery. The system does have a cost associated with it that is much higher than that of the NestBorn ®system. The author had the opportunity to observe the system installed on a farm in the Netherlands.

The farmer had not had the oportunity to utilize the unit. Figure 4 shows the Vancomatic installed on a poultry farm, the eggs are placed on trays, as the chicks hatch they fall to the cradle below.

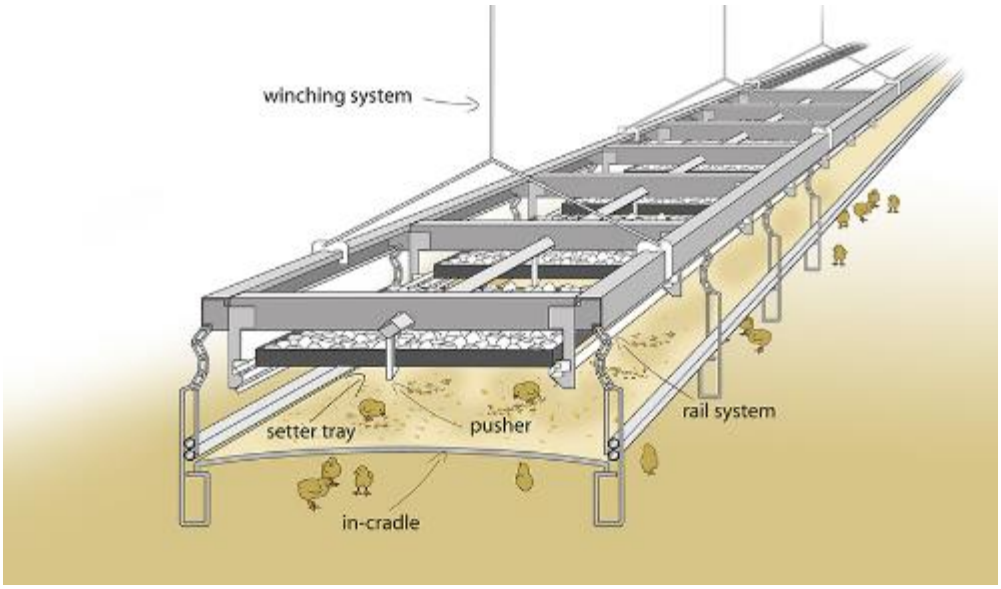

Figure 4: Pictures above and below from Vancomatic website.

Picture by Author. Vancomatic installed on a farm in the Netherlands.

Litter Management

Managing litter conditions in the house minimizes stress and is essential to the health of the birds. Many areas of the United States reuse litter (bedding material mixed with manure) flock after flock. The reuse of litter occurs because of the high cost of bedding material and the limited supply. Reusing the litter requires conditioning to reduce moisture and pathogens. Once litter reaches a point of 30% moisture, it has a tendency to crust over, called caking. This crusting over of the litter prevents the absorption of moisture from the birds defecating. Limiting cake build up with in the poultry house improves animal welfare, improves bird comfort, and reduces the chances of paw burns (ulcerations on the foot of the bird). There are different methods of litter conditioning techniques utilized in the United States. For many years, one of the most utilized methods was "crusting out" the house with a machine that removed litter that had crusted over (litter that has reached 30% moisture). The poultry industry has started windrowing litter into conical piles, one meter high, that heat up to 55^{o}C for three days; the piles are then turned, so that they can go through a second heat for three days. The litter is then spread and levelled in the poultry house. The impact of windrowing reduces the particle size of the litter, allowing moisture to be released and pathogen levels to be reduced. These practices address between flock management but do not address issues that may occur during a flock while birds are present. The ability to condition litter, reducing moisture content can improve bird comfort and reduce stress.

Frantumix

The author learned about the Frantumix, from Italy, while visiting the International Production and Processing Expo in Atlanta, Georgia. Frantumix is a line of litter-conditioning equipment designed to operate in the house with birds present. The Frantumix model 080 and 088 offer a walk behind model. This unit can break up the crusted material reducing the likelihood of paw burns and improving bird comfort. Conditioning litter with birds present does present some concerns, in particular the creation of dust. The Frantumix is designed and built as a closed structure, so that dust is contained and the material is not thrown. The author has not observed this unit being utilized on built up litter. This could potentially cause some ammonia to be released, which would be of concern. Further investigation is needed to determine if this is a viable option. Figure 5 shows the Frantumix being utilized in a poultry house with birds present. This shows the conditioning of the litter (fluffing it up and aerating it while limiting the amount of dust created in the house).

Figure 5: from Frantumix website.

Precision Livestock Farming

Precision livestock farming (PLF) monitors inputs and outputs, creating continuous automated real-time data that can influence health and welfare of livestock and the environment. Tomas Norton with Ku Leuven explained the benefits of "smart farming". Developing technologies to acquire smart data will improve the poultry supply chain. As Block chain technology is integrated into poultry production, PLF technologies will become integral for measuring, managing, and documenting all operations. An example shared by Norton included monitoring and controlling egg incubation (reducing the hatch window) using Tegg (technology that measures eggshell temperature as a non-invasive method of measuring embryonic development within the egg). A few other examples PLF shared by Norton include continuous automated monitoring of feed intake using sound and video, continuous fully automated weighing of broilers, and early warning systems for broiler houses using cameras to monitor bird distribution. The challenge with these technologies is volume of data ("big data") and how do we change that information to "smart data". Monitoring and documenting conditions such as temperature, humidity, bird comfort and distribution are indicators of bird welfare. There are a multitude of innovations and technologies that are available and in development to provide data for this purpose; some of these are described below.

Fancom-eYenamic

Figure 6: from Fancoms website

Fancom-eYenamic unit places cameras throughout the house. The unit uses an algorithm to evaluate bird distribution in the house. The bird distribution indicates if conditions in the house are optimum. The eYenamic has the ability to alarm the producer if the bird distribution is not optimal. The benefits of evaluating bird behaviour, based on bird distribution, include more timely feedback about bird comfort, uniformity of bird distribution, optimizing feeder and drinker space, highlighting feed and water issues and temperature control. Figure six shows how the eYenamic technology using cameras and bird distribution translated into smart data.

The ability to sense a situation in a timelier manner would reduce stress and improve bird comfort. Another example would be if there were an issue with feed availability, the birds would shift away from the area that did not have feed present. This unit would capture a malfunctioning feed line in a timelier manner than our current methods of monitoring feed outages. One other example of how this technology could prove beneficial is in water management. The eYenamic system would help identify a flood situation in a timelier manner than our current methods. Currently, a poultry farmer would receive an overflow alarm if a pipe breaks. Because the parameters a farmer has to set to capture a flood situation are quite broad, it could take extreme flooding to trigger an alarm, whereas with this technology notification would come much more quickly because the birds would immediately react and avoid the area resulting in an alarm. The eYenamic technology has tremendous potential for improving bird welfare, performance, and possibly issue documentation that assures consumers of the environment we are creating for the birds.

Faromatics Chickenboy Robot

Faromatics headquarters is in Spain and is a company focused on developing robotics to improve livestock farming using practical and precision methods. The innovators of this technology shared its potential at the Poultry Technology Summit at Georgia Tech

Figure 7: Picture from ChickenBoy presentation by Heiner Lehr, CEO, Faromatics, Poultry Tech Summit Georgia Tech Summit November 7, 2018

The Chickenboy is an autonomous robot suspended from the ceiling of the poultry house (Figure 7). The unit has the ability to monitor ambient conditions (temperature, humidity, air speed, C02), health and welfare, and equipment failures. The unit uses artificial intelligence to provide information about the following areas: excrement classification (quality of digestion and indication of health issues), recognition of dead and cull birds (maps location of these birds), wet spots in litter, defective drinkers, stream video, thermal imaging, audio, photograph animals and facilities, and alarms the farmer of abnormal conditions. The proposed cost of this unit is approximately US$10,000/house with a US$100/month charge to access the cloud for service and maintenance. One unit that has the capacity to gather information, identify, and provide early detection of issues which could be tremendously beneficial to the sustainability of each farm. Widespread adoption of units like this could animal welfare and productivity of the whole industry. Figure 8 shows a thermogram from the Chickenboy, it shows the temperature of the litter in the poultry house. The areas that are red and yellow are warmer, indicating that there may be issues with air flow or moisture.

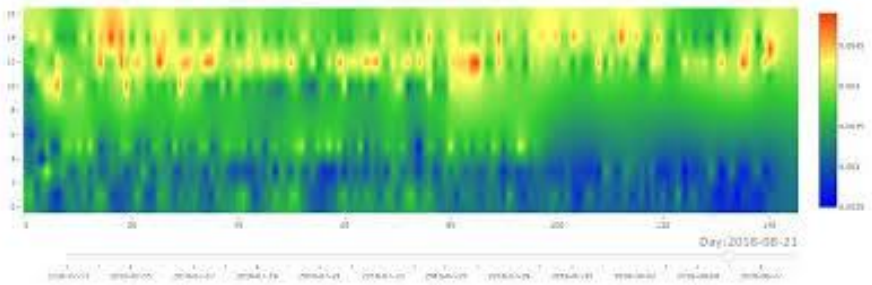

Figure 8: Visual map of temperature documented by ChickenBoy. Picture from ChickenBoy presentation by Heiner Lehr, CEO, Faromatics, Poultry Tech Summit Georgia Tech Summit November 7, 2018

Rotem

Prior to 1990, the temperature in the poultry house was controlled by thermostats. Each piece of equipment was controlled by an individual thermostat. A typical poultry house would have eight heaters and twelve fans for minimum ventilation and cooling. The houses were equipped with curtains that would be manually raised and lowered depending on inside target temperature and outside conditions. The transition for cooling the house through vents that mixed air to tunnel ventilation that creates a wind tunnel effect in the house were done manually. In this example, the grower would have 20 thermostats to adjust daily. As the target temperature changed to optimize bird comfort, the thermostats would need to change. In the mid 1990's, growers started adopted environmental controllers. These controllers automated the ventilation system to have the ability to make transitions in ventilation from vents to tunnel, while also bringing all the thermostats to one location. The controller was programmable and equipped to look at multiple sensors located in different areas of the house to turn on fans and heaters as needed. This evolution in managing the ventilation system with environmental controllers has been one of the most significant adoptions of technology, reducing the workload of the poultry producer, resulting in one individual being able to take care of more birds, while simultaneously improving bird welfare. Rotem environmental controllers are developed, tested, and assembled in Israel. Rotem controllers are the primary controllers used on Delmarva. The improvement in bird welfare is because the controller, if programmed properly, can provide a more consistent environment. The primary developer of new Rotem products discussed some of the forthcoming technologies. Pictured below is how Rotem products have evolved. Developments to improve communication with the ComBox and the Communicator 2.0 unit that is the interface for data, communication, and alarm systems (Figure 9).

The new product will allow for communication directly through the web without a second party application and features improvements in hardware, with more digital inputs for gathering more data. A new product that has been developed is a digital backup to the primary controller box. Currently we use mechanical thermostats as a method of backing up and protecting chickens should there be an issue with the primary controller. The challenge of using mechanical thermostats is that adjusting them as temperatures change can be overlooked. In our discussion about the capabilities of Rotem products, it was brought to my attention that U.S. poultry growers do not utilize the controllers to their full potential. New technologies provide phenomenal tools to growers but if they do not understand them, they may be fearful and not utilize them.

Figure 9: from the Rotem Website shows how the various components interface providing improved communication and connection.

Another innovation in development is utilizing thermal imaging to measure and adjust the environmental controller rather than ambient temperature. One of the projects under development by the Israeli Ministry of Agriculture is gathering the data from thermal imaging and transferring that data to an algorithim that correlates to bird comfort. Our current method of measuring temperature through ambient temperature does not take into account air movement and windchill and the the impact these factors have on bird comfort. Thermal imaging for managing bird comfort could be a major improvement in bird comfort and reduce stress that will optimize bird performance.

Chapter 3: Environmental Innovations

As previously discussed, the Delmarva region comes under a higher level of legislation and scrutiny because of its proximity to the Chesapeake and Delaware Bays. Technologies and strategies to minimize the infiltration of nutrients into waterways must be explored and implemented. Many inventions have been adopted by farmers to minimize this impact. For example, utilizing ammonia control products, constructing manure storage facilities, installing heavy use concrete pads and the entryways of the poultry house, and installing vegetative buffers. The adoption of these best management practices has significantly reduced the impacts of ammonia production, and reduced the infiltration of excess nitrogen and phosphorous into ground and surface water. Animal agriculture must be proactive, approaching the challenges with the mind-set of striving for continuous improvement in mitigating environmental impacts.

Environmental and energy management

Air emissions are the next environmental challenge to the poultry industry. We have utilized vegetative buffers on Delmarva to lessen the impact on neighbours. These vegetative buffers function as a windbreak (reducing energy costs), capturing particulates from the fans, and make the farm more aesthetically pleasing to neighbours. The increase in size of poultry farms and the close proximity to existing residential areas has elevated the concerns about emissions. Vegetative buffers take time to establish and may not completely satisfy the concerns of neighbours. Heat exchangers and particulate filters are ways to reduce emissions of dust, ammonia, and odours. The challenge with these types of systems has been the cost and reduction in airflow capacity.

Heat exchanger by Big Dutchman

While in the Netherlands, I had the opportunity to visit two farms with heat exchangers. The Netherlands has higher standards for emissions from the poultry house. Both farms had the Big Dutchman heat exchanger (Figure 10 and 11). The heat exchanger recovers the heat from exhaust fans. This technology has the potential to save 35% to 60% of the heating cost. The benefits of this technology include reducing emissions of ammonia, dust, and odour. Heat exchanger technology saves heating costs, improves house conditions, and reduces emissions.

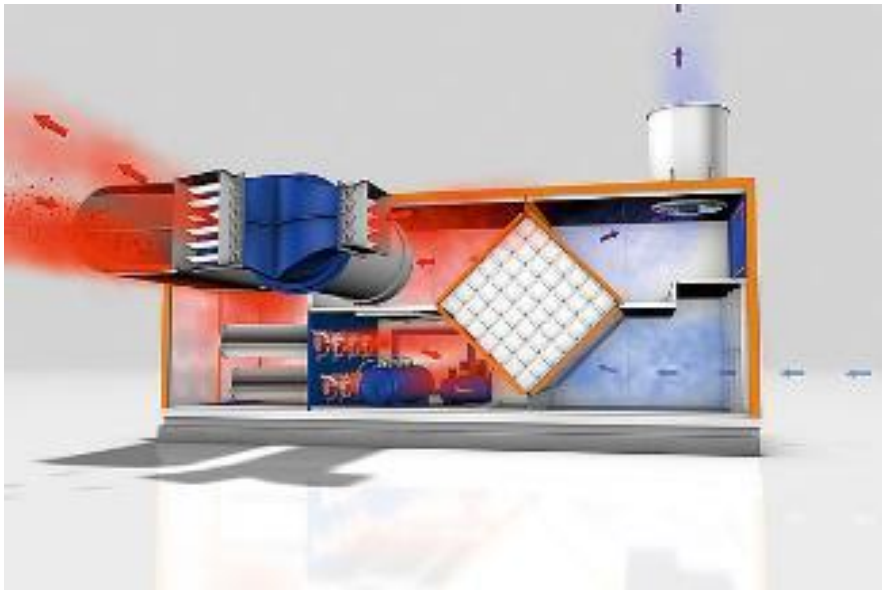

Figure 10: Pictures above and below from the Big Dutchman website.

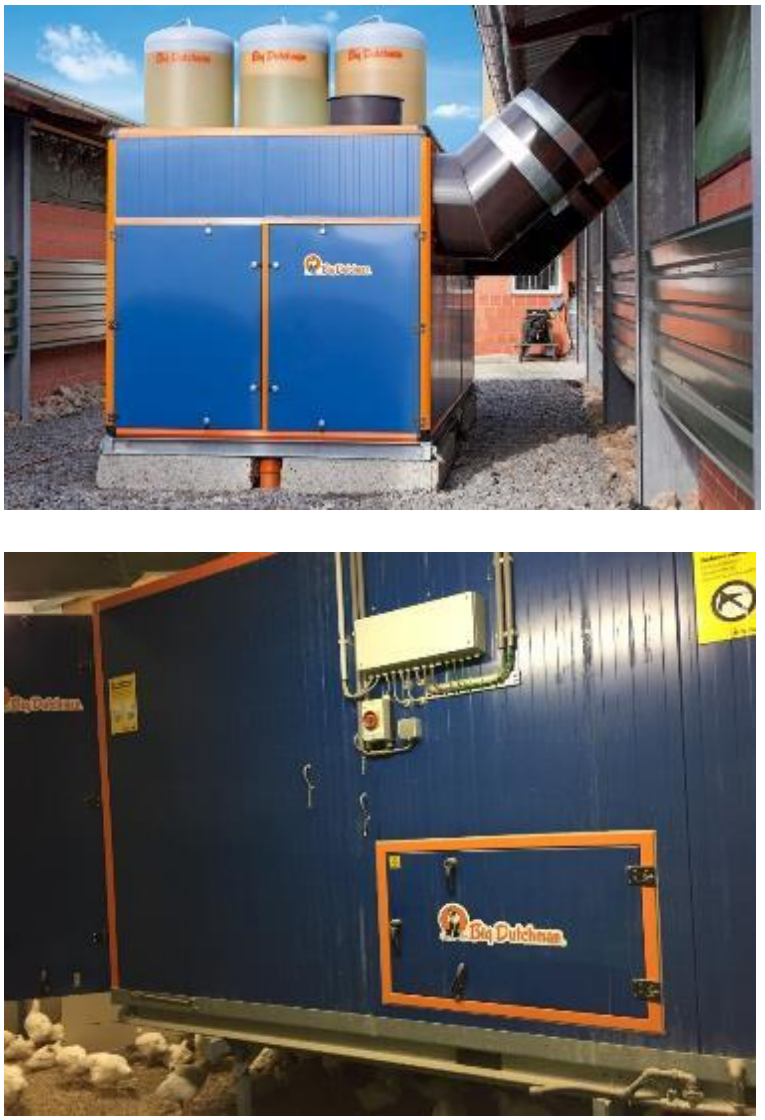

Figure 11: Picture by Author. Heat Exchanger in outdoor access area for chickens.

The exhausted air from the house enters a chamber in the unit that has large filters, the air is filtered and then moves through the exchanger in a cross flow pattern where the warm and cool air pass through but do not come in contact. The aluminium exchanger uses the warmth of the exhausted air to warm the fresh air before it enters the house. The dust and particulates are retained in the filters. The filters are cleaned periodically throughout the flock. An example of an exchanger is the Schultz Emmi.

Schulz Emmi (Emissions Minimiser)

The Schulz Emmi functions as an air scrubber Figure 12: The unit has the ability to reduce emissions of the following materials by the following amounts: ammonia 90%, dust 70%, fine dust 90%, and odour 50%. The unit uses a technique that triple-filters air that is exhausted from the poultry building using conductivity that assists in capturing the dust particles. As the air passes through the chambers: ammonia and dust are sprayed with water, then pass through an acid and droplet illuminator, and then washed again before air exits the building. The diagram below shows the how the unit processes the material from the poultry house. The limiting factors for incorporating the Emmi technology on U.S. farms would be prohibitive due to cost and the problems with the disposal of wastewater material from the unit.

Figure 12: Photos from The Schulz Systemtechnik website

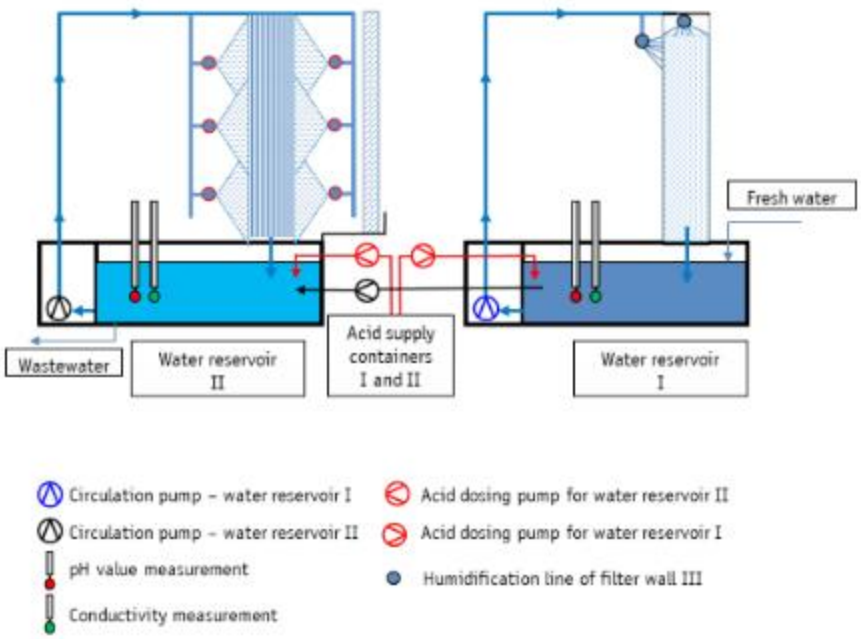

Figure 13: Photos from The Schulz Systemtechnik website

The author learned about this unit at a farmer appreciation day in Germany but did not see it working. Figure 14 shows a structure with material that looks similar to mulch in a wire mesh serves as a particulate filter. Using this type of technology would financially be a more viable option for reducing particulates from poultry houses, even though it is not as effective.

Figure 14: Photo by Author of Display at Farm Appreciation Day, Germany. Particulate filter for dust made of mesh and mulch type of material.

Solar Brood

Solar Brood describes systems generate fuel savings by utilizing the sun to heat air in the poultry house. While visiting the University of Arkansas, I observed a new technology named Solar Brood This technology utilizes the sun to heat air that is sucked into the poultry house. This technology reduces the fuel needed to heat the poultry houses. Transpired solar collectors are recognized as the most efficient methods of collecting solar energy.

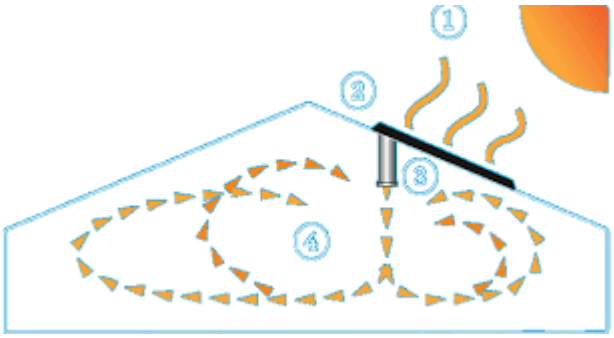

Figure 15: Picture from SolarBrood website

Figure 15 shows how it works: Solar radiation from the sun (1) continuously heats this layer of fresh air on the surface of the transpired non-conductive absorber (2). The negative air pressure in the barn draws the heated fresh air through the collector (3) to heat the barn (4).

This technology would very in cost, depending on the size of the building. The benefits are on not only saving fuel but also the benefits of pulling warmer, drier air into the house. The warmer and drier air helps to ventilate the house and improves litter quality. Improved litter quality helps reduce ammonia levels, improves paw quality, and aids animal welfare.

Solar Brood technology has been adopted in climates with warmer temperatures. Areas with greater day lengths with more sunlight. This technology proves to be more economically viable in those areas.

Mortality management technologies

The typical poultry farm on Delmarva loses approximately 5% of the flock due to birds that may not properly develop, may have reactions to vaccinations, may have respiratory issues (species specific), or other health related issues. Traditionally we have composted mortalities in bin or channel composters. The birds are composted using manure and a carbon source such as straw or pine shavings. Proper management of composting material is critical to its effectiveness and success. Some poultry farms struggle with this process. Poorly managed composting creates issues with biosecurity, flies, and odors. Composted material is utilized as fertilizer to be spread on crops, if the mortality is not properly composted the material is not acceptable for application to the land as fertilizer. A relatively new technology being adopted is freezers for dead birds. The carcasses frozen, and then picked up and be taken to a rendering plant. The mortalities are then recycled into other usable resources. In the Netherlands, farmers that do not have their own land are not allowed to compost; they are required to freeze mortalities and pay to have them rendered. As farms have grown in size, managing mortalities has become more challenging, adopting new technologies like freezers, and in-vessel composting will improve the sustainability of the industry on Delmarva, as described below.

In-vessel Ccomposting ecodrum

Ecodrum is an in-vessel method of composting. The vessel is built out of non-corrosive, UV inhibited, high-density polyethylene. The inside of the drum is food grade plastic. It sits on a steel frame with rollers, rotated by a motor to turn the compost two to six times per day and introduces air in to the system to provide oxygen for the composting process. The number of times the drum rotates and amount of time air is sucked into the drum varies according to the size and amount of birds. Four rotations per day in conjunction with eight minutes an hour of air is what we observed on older/larger birds.

The process requires a carbon source for the composting process, such as pine shavings, saw dust or peanut hulls. The ratio of carbon to mortality based on volume is 2:1; for example, two buckets of pine shavings to one bucket of mortality. The cost of carbon source will vary.

The unit is sized according to the average daily mortality for the flock and then upsized. The cost of the unit varies.

On a farm with 64,000-placement capacity with 5% mortality, 49 days grow out with an average wt. bird of 2.9 kg the average mortality a day would be an average of 222 kg per day. The model that would be chosen for a farm this size would be model 460 with a 285 kg loading capacity per day. The retail cost for this unit would be US$52,900.

The Ecodrum unit should be placed on a concrete pad. The installations we observed had concrete pads that ranged from 4.8 m to 7.3m wide. The unit does require cover and storage area for the carbon source material. A recent quote received for 10 cm of concrete for a 4.8m x 12.2m' building was US $15,000.00 That does not include site work preparation which should be minimal unless material such as clay base needs to be brought in and you may add US$1,000-$1,500. This building would work for the Ecodrum model 260. Current Natural Resources Conservation Service (NRCS), requirements for composters and heavy use pads are 13 cm of concrete. A building to meet the needs

of the above-mentioned scenario would need to have a building 7.3 m' x 18.2 m'. The building without grading would be approximately US$23,000 and 15 cm concrete would add about US$2,500. Installation requirements vary according to local regulations. In some areas to meet permitting requirements, the area where composted material exits the drum must be covered. Figure 16 shows an example of material being covered at the exit end of the drum.

The Ecodrum in-vessel composter unit would be a viable alternative to channel composting or as an alternative option to freezers. The greatest benefit to the in-vessel composting unit is the improvement in the quality of composted mortality exiting the unit and the improvement to biosecurity concerns of predators spreading diseases (e.g. . . Avian Influenza). The composted material from the Ecodrum has minimal nutrients relative to typical poultry compost. The in-vessel style of composter reduces the volume of material by 80% compared to traditional composting.

Figure 16: Picture from Ecodrum website.

Figure 17: Picture by author. Composted material exiting Ecodrum.

Advanced Composting

Advanced composting is a process that puts mortalities in a mixer that blends manure and a carbon source so that there is smaller particle size and more uniform mixture (Figure 18). The mixture is then placed in a channel composter that has pipes that inject air into the pile (Figure 19). The mixing process speeds up the composting process. The operator should be safety conscious due to the moving parts and open top to the mixing unit.

Figure 18: Advanced Composting website.

Figure 19: Composter Channel with air injection.

Figure 20: Pictures from the Advanced Composting website.

These technologies come at a higher cost than traditional composting; however, they do provide a much more bio-secure method of dead bird disposal, a uniform product for land application, and a reduction in nutrients used. One of the major benefits to these technologies is an improvement in the quality of life for neighbours; these practices reduce the major nuisances of odour and flies.

Chapter 4: Sustainability

Public perception: communication and the social license to operate.

One recurring theme throughout my travels on the Global Focus Program and on my individual study program was the need for farmers to share their story. The nature of many farmers is not one that wants to "toot their own horn", or engage with the general public who may not have knowledge of or understand modern farming practices. While in the Netherlands, the author asked one farmer "If you knew what you knew today thirty years ago; what would you do differently?" His response was, "I wish I had told my story as a farmer, there was so much propaganda and the public was brainwashed about farming." Not telling the story and not pushing back on that misinformation has led to additional legislation on bird mangement techniques that were not based on scientific research. It has also resulted in increased costs of production and limited opportunity for growth. Additional needs to meet legislative requirements has led to more poultry being imported from places that do not have the same rerquirements, which allows for that imported product to be produced at a lower cost.

The author attended the Animal Ag. Alliance conference'which is a group that helps bridge the gap between food and fork. Their motto is "*Connect, Engage, Protect*." Kay Johnson Smith, the president of the Alliance, shared some information about the challenges facing animal agriculture. In particular, she stressed the underlying push to elliminate animal agriculture. There are a number of well funded organizations collaborating to undermine the integrity of and villify animal agriculture. It is critically important for farmers to understand this threat to our sustainability. Farmers need to understand that their mode of operation is through pursuing environmental regulations, animal rights, animal welfare requirements, and the push for vegan lifestyles. Social media has been utilized to perpetuate misinformation about modern animal rearing techniques. Mark Gale, from Charleston Orwig, a marketing company, stated that we must build "reputational capital," (armor ourselves against these negatives). There are many practices that have been adopted in poultry production that have dramatically improved animal welfare and the impact to the environment. The consumer is unaware of these improvements. The anti-animal production movement plays to the consumers emotions by describing farmers as uncaring, and having a lack of regard for the environment. Consumers want the story behind their food and farmers must be willing to step up to the table and have the conversation. There is a growing demand for transparency; consumers want authentic communication and direct dialogue from real people. Dallas Hockman, with the National Pork Producers Council suggested we need to say what they are for: animal welfare, environmental stewardship, continous improvement. Build trust in the statement that farmers "want to do the right thing."

The challenge for farmers is to build their comfort level with engaging with consumers. The "armour against the negative" should be fact based to help dispell the misinformation, but it must be delivered in such a way that is not confrontational, nor condescending. It cannot be taken from the stand point that the consumer just does not understand, or if we just educated them they would get it. The approach needs to based on connecting and building an understanding that you value what they value. These values should include taking care of the animals is of the utmost importance and on describing how we provide that environment; that is on building an understanding of the "how" and "why" of what we do and how farmers are limiting and lessening their impact on the environment.

Here are just a few of examples of that misinformation and how farmers can share the real story:

Frank Mitloehner, PhD at the University of California Davis, described how the FAO's report, Live Stock's Long Shadow, shared information about global numbers on the impact of animal agriculture

that do not reflect modern production and regional practices. Different methods are often used to evaluate the impact of animal agriculture versus the transport industries. For animal agriculture, lifecycle assessment was from "cradle to grave" versus transportation only evaluated at the tailpipe emissions, not that of the full cycle of production. The truth is that in the U.S., 3.8% of green house emissions come from pigs, cattle, sheep, and poultry. Poultry produces minimal methane relative to other animal proteins. A poultry farmer engaging in a conversation should be armed with the true facts about the impact that their industry and their operation have on the environment. Some facts a poultry farmer could utilize in this discussion are: poultry have a lesser impact on the environment than other animal proteins, due to how efficiently a chicken takes feed and turns it into body weight. The only animals with a higher feed converion efficiency are fish.

Alison Van Eenennaam , PhD of Animal Science, University of California Davis stated that "fear sells". Efforts to gain short term market share have been detrimental to the poultry industry. For example, labeling poultry as "hormone free," "steriod free," "antibiotic free" lead consumers to believe poultry without that label contain those items. This is untrue, no commercially grown poultry contain those items. Genetic improvements can have the greatest impact on the sustainability, plant and animal breeders have the most compelling story for sustainability." Poultry is a perfect example of what genetics can accomplish. Many consumers believe that the change in the size of birds is due to hormones and steriods. This is untrue and farmers need to explain why birds are grown to larger sizes than they were 25 and 50 years ago. Genetic changes have been the primary reason poultry has evolved as quickly as it has. Poultry have a comparitively shorter generation interval; the shorter period for maturity and gestation has allowed for poultry breeders to rapidly select for traits or qualities such as larger breast, improved feed efficiencies, and increased weight gains. Improvements in nutrition and housing have also contributed to this change in bird growth. Helping farmers build their understanding and putting more "tools" in their communications tool box will help them be more comfortable and effective in sharing their story.

Avocating for the poultry industry and animal agriculture will need to take many forms. To be successful farmers must be willing to engage in all areas: social media, one on one, and for speaking to community groups like school children. The messager will range from sharing how we got into farming, to our families, to what we value, to how many people we feed, to why we do what we do, sharing what has changed, sharing what has improved and sharing the struggles and the successes. Collectively, this will help build that "armor against negative."

During my visit to the Netherlands, I visited Albert Cuyp, a food marketer. One way farmers are building trust with consumers is through traceability on the packaging. There is a QR code on each package that can be scanned; this code has information about how the poultry was produced, information about the farmer and the farm, and what practices for welfare and the environment are being implemented. This is a practice starting to be utilized in the U.S.

EggXYT

Most of this report has addressed the technologies that benefit broiler meat production. However, most of the public perceives all poultry production to be the same for both egg and meat production. One developing technology available in 2021 (Figure 22), that will primarily benefit the egg layer industry but could have some benefits for broiler production is eggXYt. This technology allows for the sex of the fertilized egg to be determined prior to the egg being incubated. The ability to identify the sex of the egg prior to incubation is beneficial because it saves the grower from the cost of incubating male eggs in the layer industry that serve no purpose. Meat breed chickens, both the male and female birds serve a purpose, these birds are bred to be high meat yielding and while there will be a sexual dimorphism between the male and female, both yield a desirable product. Breeds for egg laying are much leaner and not as desirable to be used for meat (Figure21). The males serve no

purpose in the egg laying industry other than in breeder stock. Each year the egg industry euthanizes seven billion male chicks around the world. This would be unacceptable to the average consumer. We do not have the ability to identify if the egg was male or female until the egg hatched, which resulted in approximately 50% of those hatched birds being euthanized and sent to be rendered. This could be perceived as an inhumane practice and could cost the industry its social license to operate. The technology offered by eggXYt uses CRISPR technology to introduce a biomarker identifying the male egg. Prior to incubation, the egg is passed through a light scanner that makes the shell of male eggs glow a different colour from the female. The scanner then sends a signal to the machine that separates those male eggs. The identification of the male eggs prevents them from being incubated and they can now be utilized as eggs for human consumption. The benefits of adopting this technology for the layer industry are that it doubles the hatchery capacity, reducing hatchery costs, removing of the need for manual sexers and creates new revenue by selling the male eggs. For the meat producing industry, it is a cheap and elegant method of sex separation that saves on feed costs and improve feed efficiency. For the consumer, they have the choice to purchase eggs that prevented the culling of male chicks. Preventing the need for euthanizing chicks increases consumer acceptance resulting in the social license to operate.

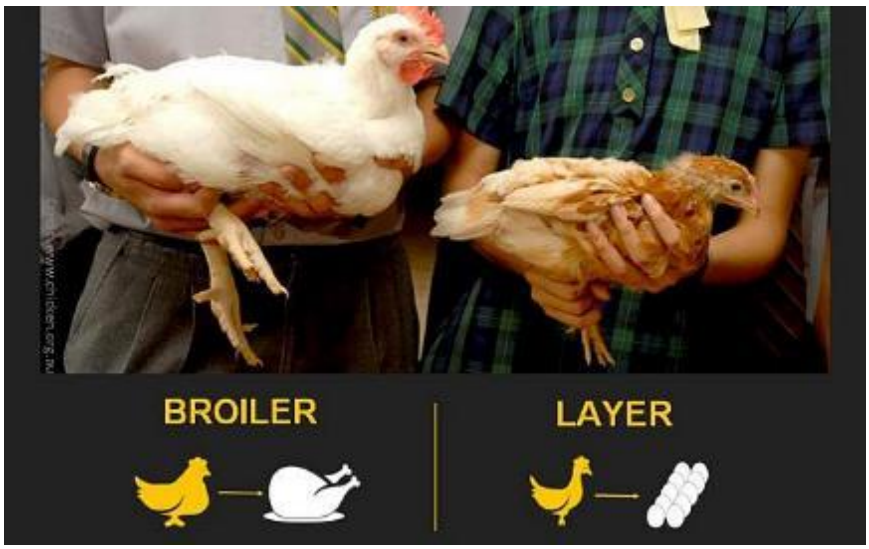

Figure 21: Pictures from presentation by Yehuda Elram, CEO eggXYT, Poultry Tech Summit Georgia Tech, November 6, 2018

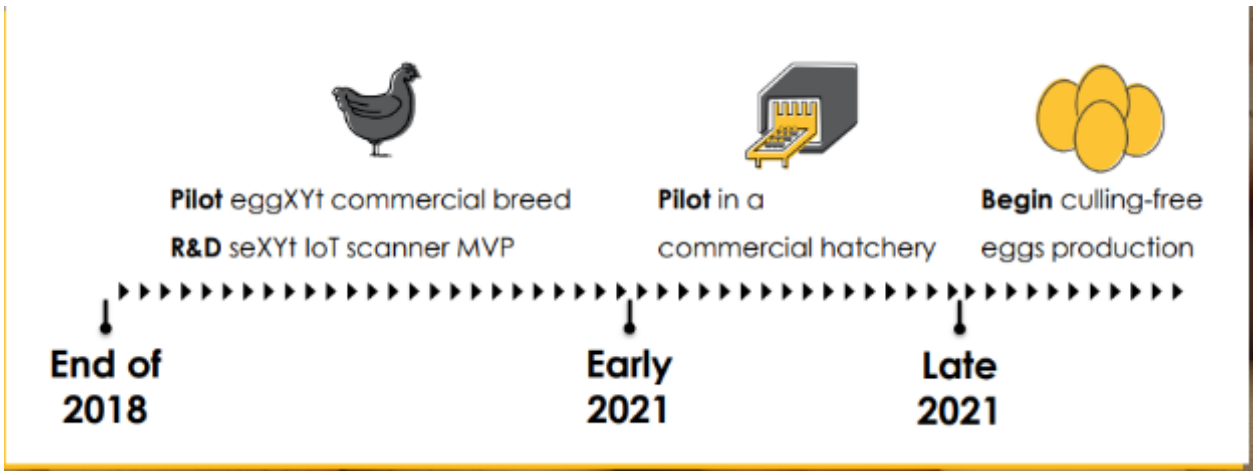

Figure 22: Pictures from presentation by Yehuda Elram, CEO eggXYT, Poultry Tech Summit Georgia Tech, November 6, 2018. Time line for development and availability of technology.

Conclusion

Over the past thirty years, the poultry industry has experienced significant changes in technology. Consumers and "prosumers" have changed the dynamic of how birds are raised. Prior to my Nuffield scholarship, I was unfamiliar with the term "prosumer." A prosumer makes purchases based on what they value and believe about a product resulting. Unfortunately, the industry has not done a good job of sharing all the technologies that have improved bird health and welfare. The social license to operate will require both farmers and integrators to share the success and improvements that have occurred. It will require more transparency and building of trust in the processes. We must share our story. We need to advocate, which for our food and farming industry could be called "agvocate".

Most of the commercial poultry grown in the U.S. is through contracts between growers and a poultry integrator. The poultry farmer must meet the housing requirements of the integrator to receive a contract. Profit margins can be minimal. Unless, or even if the integrator requires a technology, it can be difficult to adopt because there is not enough cash flow to offset the cost of implementing the new technology. In countries like the Netherlands, poultry growers are more independent in decision making, which allows for innovation and technology adoption. The profit margins are greater but so are the risks.

A proactive approach to minimizing environmental impact is critical to the sustainability of animal agriculture. The more poultry farmers can do to prevent issues, the less likely that legislative mandates will be required. If we are good stewards and good neighbours, taking steps to minimize emissions by adopting technologies that minimize odour, dust, and ammonia, there will be a greater chance at success. Forward thinking about impact on surrounding communities should be at the forefront in considering new construction sites. Evaluating existing sites for compliance with best management practices will increase the opportunities for success.

Precision animal agriculture is our future. New technologies that provide smart data to farmers will improve the conditions in the poultry house to optimize bird comfort and performance. Having access to this data empowers the farmer and the integrator to make better and timelier decisions.

The adoption of innovations typically provides multiple benefits. Adoption of a practice to benefit animal welfare may also benefit the environment (e.g. Solar Brood gives improvement to litter quality and reduces energy consumption.) Practices to improve the environment can improve biosecurity for the birds (e.g. In-vessel and Advanced Composting).

Finding a balance to consumer demands, legislative requirements, and profitability is the key to sustainability.

Recommendations

- Seek out proven technologies and adopt them as they become accessible (affordable and available.)
- Integrators (Poultry Companies) should consider On Farm Hatching. It is my opinion that this could have multiple benefits to improve broiler health, reduce stress, and improve animal welfare. It could save transportation costs, hatchery space, and improve the economic viability of the poultry industry.
- Growers of poultry should consider adopting technologies like eYenamic or Chicken Boy to gather and provide data, resulting in more timely management decisions.
- Growers need to take more initiative in learning how to access and utilize the data provided to them by current and future technologies to improve management decisions.
- Consider adopting technologies that lessen air emissions (heat exchangers, air scrubbers) as they become more affordable. Understanding how these technologies work may assist farmers in developing similar systems at a lesser cost.
- The egg laying industry would benefit from the eggXYT technology. The ability to limit the need for euthanizing male chicks would be an improvement financially and socially.
- Poultry growers need to connect and communicate with consumers. Those connections may be on social media, friends, community groups, non-agriculture related interactions to share their story. Seek opportunities to share the truth about how animal agriculture has evolved and the improvements that have been made.

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Plain English Compendium Summary

Project Title:	**Innovation in Poultry Production: Increasing the Sustainability of Commercial Poultry**
Nuffield Project No.:	1704
Scholar:	Georgie Cartanza
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Objectives	This study aims to identify technologies to improve the sustainability of commercial poultry production. The following areas are key challenges: • Technologies that improve and address concerns about animal welfare. • Technologies that improve or help reduce the impacts on the environment. This includes air, water, and residents on surrounding properties. • Find ways to connect with consumers to build understanding and belief in the quality, safety and humanness of commercially raised poultry.
Background	There are many challenges facing the sustainability of animal agriculture. The challenges of consumer demands, environmental challenges and increased legislation. Social media and organizations that are anti-animal protein consumption are well funded and seek to undermine the integrity of the people producing animal protein. It is critical for farmers to share their story and engage with non-agricultural groups. This will assist in bridging the farm to fork gap.
Research	The author visited Brazil, Netherlands, Israel, Germany, New Zealand, and various area of the United States of America. On these trips, she visited farms, service techs expos, universities, poultry summits and attended meetings exploring new technologies, climate change and the sustainability of animal agriculture.
Outcomes	There are technologies that benefit animal welfare and the environment. Adopting innovations like Solar Brood and precision livestock farming technologies improve the quality of life for the birds and for the environment. In-vessel composting and advanced composting technologies improve the quality of composted materials and improve biosecurity. More advanced methods of air emission control are too costly for U.S. farmers to adopt. Precision livestock farming empowers farmers and assists in documenting conditions.
Implications	The poultry industry and farmers need to become more in proactive engaging with the public. Poultry Integrators need to evaluate their pay scale to take into account the cost of adopting technologies designed to improve animal welfare and the environment. Poultry farmers need to be open to new technologies and strive for continuous improvement.
Publications	Presented at the Nuffield Contemporary Scholars Conference, March 2019, Ames Iowa.