The broiler production systems of Sweden and the United States

– A comparison of the processing systems and health and welfare programs

Slaktkycklingsproduktionssystemen i Sverige och USA – En jämförelse av processystemen och hälso-och välfärdsprogrammen

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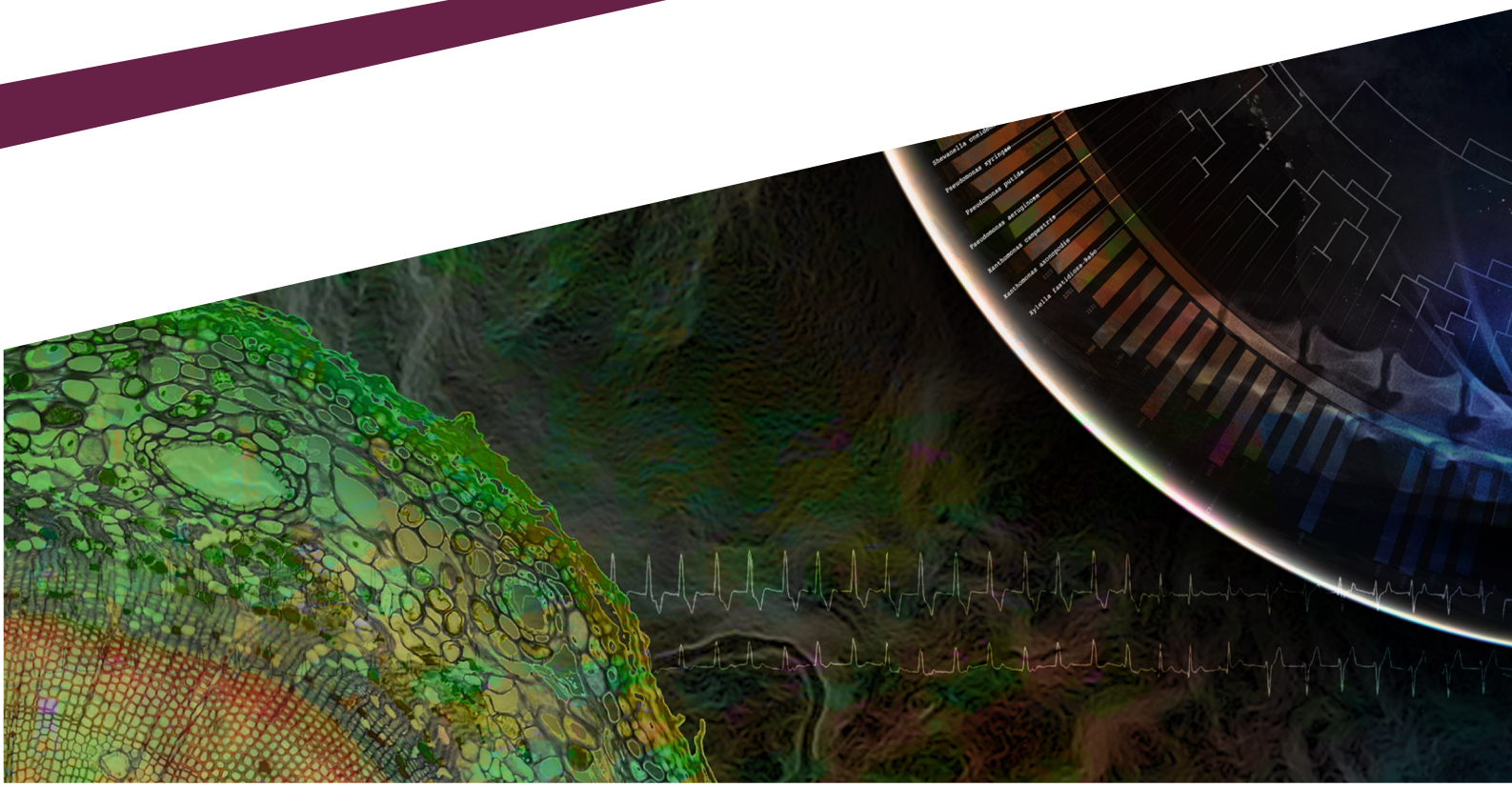

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Abstract

The aim of this thesis was to research broiler production in Sweden and the United States and to evaluate their processing systems as well as their health and welfare regulations. Sweden produces 110 million broilers a year and the United States produces 9 billion broilers a year. There are 120 broiler farms and 7 large slaughter plants in Sweden and there are 25,000 broiler farms and 180 slaughter plants in the US. Sweden has an 80% hatching rate with an average chick weight of 40 grams. The US has an 85% hatching rate and an average chick weight of 44 grams. Sweden's flock density for conventional broilers is 36 kilos per square meter. The USDA's flock density for conventional broilers is 35.7 kilos. Sweden has one of most effective *Salmonella* programs with less than 0.1% infection rate in its broilers. The Unites States has a 4.3% *Salmonella* infection rate in its broilers. The feed conversion in the United States is 1.60 and the feed conversion in Sweden is 1.65. The US organic broilers are reared a bit longer than Sweden and have a little lower weight. The US has a little bit longer conventional rearing time than Sweden but they weigh more.

Keywords: animal welfare, antibiotics, automation in poultry production, breeders, broilers, , conventional broilers, feed, hatcheries, organic broilers, poultry production, poultry slaughter, poultry vaccines

Sammanfattning

Syftet med avhandlingen var att forska om slaktkycklingproduktionen i Sverige och USA. För att utvärdera deras bearbetningssystem och hälso-och välfärdsbestämmelser. Sverige producerar 110 miljoner slaktkycklingar per år och USA producerar 9 miljarder slaktkycklingar per år. Det finns 120 slaktkycklinggårdar och 7 stora slakterier i Sverige och det finns 25 000 slaktkycklinggårdar och 180 slakterier i USA. Sverige har en kläckningsgrad på 80% med en genomsnittlig kycklingvikt på 40 gram. USA har en 85% kläckningsgrad och slaktkycklingarnas genomsnittliga vikt är 44 gram. Sveriges flockdensitet för konventionella slaktkycklingar är 36 kilo per kvadratmeter. USDA flockdensitet för konventionella broilers är 35,7 kilo. Sverige har ett av de mest effektiva *Salmonellaprogrammen* med mindre än 0,1% infektionsfrekvens i sina broilers. Förenta staterna har en salmonella infektionsgrad på 4,6% i sina slaktkycklingar. Foderomvandlingsförmåga i USA är 1,6 och foderomvandlingsförmåga i Sverige är 1,65. De amerikanska ekologiska slaktkycklingarna föds upp lite längre än Sverige och har lite lägre vikt. USA har lite längre konventionell uppfödningstid än Sverige men de väger mer.

Nyckelord: djurskydd, antibiotika, automatisering av fjäderfäproduktion, uppfödare, slaktkycklingar, *Camplyobacter,* konventionella slaktkycklingar, foder, kläckerier, ekologiska slaktkycklingar, fjäderfäproduktion, fjäderfäslakteri, fjäderfävacciner

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Abbreviations

AGP	Antibiotic Growth Promoters
AgMRC	Agricultural Marketing Research Center
AMR	Antimicrobial Resistance
AMS	Agricultural Marketing Service
APHIS	Animal and Plant Health Inspection Service
CAS	Controlled Atmosphere Stunning
CDC	Centers for Disease Control and Prevention
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FDA	Food and Drug Administration
GMO	Genetically Modified Organisms
HACCP	Hazard Analysis and Critical Control point
IB	Infectious bronchitis
IBD	Infectious bursal disease
ND	Newcastle Disease
NCC	National Chicken Council
NOP	National Organic Program
SLU	Swedish University of Agricultural Sciences
SVA	Staten's Veterinärmedicinska Anstalt
US	United States
USDA	United States Department of Agriculture
WHO	World Health Organization

1. Introduction

1.1. Background

Poultry production is predicted to reach about 323 billion dollars this year, globally, and is growing at a rate of 3.8% annually (Markets, 2021). Global poultry meat consumption is set to reach 151 billion tons this year (Global Trade, 2020). The broiler production industry produces chicken meat for consumers all over the globe. It is the rearing of specific breeds of chickens genetically selected for above all else the ability to grow fast. The feed has to have enough nutrients to produce meaty and healthy chickens. The feed contents are usually from regional crops like cereals, corn, and soy and vegetable oils (Cobanoglu et al., 2014). The production of broilers operates under specific and regulated systems. The management of these systems can differ from each producer. This thesis evaluates the broiler production systems in the United States and Sweden. It draws comparisons to the health and welfare systems as well as their processing systems.

1.2. Aim

The aim of this thesis was to compare and evaluate broiler production systems as well as health and welfare regulations in Sweden and the United States. To implement this, the research will be based on the following questions. How does the largest broiler producer the United States compare to a smaller producer like Sweden? Are there any differences in the management programs of each country that could affect the prevention of certain diseases? Are there any strengths or weaknesses in either country that support or hinder their production systems?

1.3. Methods

This was a literature study conducted by researching a collection of scientific articles, publications, and dissertations available at SLU's library and scientific databases such as Scopus, Web of Science, Pub Med, Google Scholar, and other media. The information from the most relevant literature was surveyed, categorized, and used in this thesis. Keywords: animal welfare, antibiotics, automation in poultry production, breeders, broilers, conventional broilers, feed, hatcheries, organic broilers, poultry production, broiler slaughter, broiler vaccines

2. Health and Welfare

2.1. Welfare guidelines

In Sweden they have an animal welfare act which was established in 1988. This legislation protects the animals and ensures that they have a sufficient living space, access to clean food and water, have no unnecessary suffering, and are treated well. The Swedish board of Agricultures poultry welfare guidelines states that poultry should be in an environment that promotes health and natural behavior. If an animal is sick, it will be cared for immediately if their condition is grave, they will be put down. They may also be inspected by a veterinarian. The chicken farmers should keep their broilers clean. Broilers should have a litter bed and checked up on twice a day as well as have at least six hours of darkness a day (Jordbruksverket, 2018a).

In the United States the animal welfare act does not include poultry in its legislation. That means from the start of the production process to the time of slaughter no federal laws concerning the welfare of poultry exists, there are no regulations. On a State level the exclusion of farm and slaughtered animals in the animal anti-cruelty law also leaves poultry unprotected (Hirsch, V., 2003). There are, however animal welfare standards from poultry industry associations like the National Chicken Council (NCC) and certifiers who have conventional animal welfare programs and issue labels accordingly (Karcher and Mench, 2018). Because poultry producers from the United States share different production views from region to region there is no established set of animal welfare standards which could contribute to inconsistencies in the industry (Tabler, G.T., 2006). The NCC welfare guidelines places the responsibility on the company's employees regulating the animal welfare guidelines they have set up. Parts of the guidelines address training programs for employees handling of the broilers, documentation, and zero tolerance for animal abuse. It also includes the managing of hatchery operations addressing temperature and environmental controls, euthanasia, broiler evaluation, and transport. The feed and water systems monitored as well as using licensed feed are addressed just to list a few (PAACO, 2020). The National Chicken council and other companies are independent and have audit and assessment programs that due issue Animal welfare certifications (USDA, n.d.).

2.2. Disease management programs

In the commercial broiler production industry, there are many concerns with diseases. The threat of viral diseases like Newcastle and Avian Influenza are major concerns as well as the protozoal disease and coccidiosis (MSU, 2021). Important safety measures are implemented globally to prevent these diseases from entering the production plants. The increase of poultry production has also increased the risks of infections from the two most common bacterial diseases *Salmonellosis* and *Campylobacteriosis*. During production the risks of broilers being infected with *Salmonella* are elevated. If parent and grandparent broilers are infected there is a risk of vertical contamination. In the production plants the water, feed, and the litter can all be sources for *Salmonella* and *Campylobacter* infections (FAO et al., 2009). Broilers infected with *Campylobacter jejuni*

(*C.jejuni*) in the flock leads to horizontal transmission which can also lead to colonization of the flock. *C.jejuni* contaminations during processing of broilers are more prevalent when plucking, scalding, and disemboweling are performed. It is also vital that any fecal matter or feathers are removed from the carcasses and the machines (FAO et al., 2009).

2.2.1. Salmonella

Sweden started with its *Salmonella* program in 1970. Then started in succession, the *Campylobacter* program in 1988, and the coccidiosis and *Clostridia* program in 1998. To prevent *Salmonella* Sweden has designed a specific control plan for poultry and monitors all levels in the production chain. Samples are taken regularly on the production farms (Jordbruksverket, 2021a). This rigorous sampling program controls the spread of *Salmonella* in the slaughter plants due to sampling before processing. Sweden also imports the grandparents of their broiler flocks, keeps them isolated, and tests them before they enter production (Mead et al., 2010). The *Salmonella* program also includes controlling the hygiene in the stables, heat treating the poultry's feed, stringent feed manufacturing regulations, controlling the hatcheries, cleaning and disinfecting and making sure that no infected meat is consumed (Wall H., 2021). It is mandatory in the United States and Sweden to have a Hazard Analysis and Critical Control point (HACCP) plan for *Salmonella* during processing. Testing is required by law in both countries (Mead et al., 2010). It cost an average of 100 million kronor a year for Sweden's *Salmonella* management program (SVA et al., 2013). According to Svensk Fågel Sweden's *Salmonella* rate is below 0.1% for broilers (Svensk Fågel, 2017a).

The US started a government program that sponsored the traceback of any *Salmonella enteritidis* (SE) outbreaks in 1990. This program investigates the consumers infected with *Salmonella* and traces back to the origin of the contamination. The USDA also requires that flocks of freshly hatched eggs that travel across state lines need to be certified as SE free. Also, the USDA's Food Safety and Inspection Service (FSIS) performs inspections to ensure that broiler producers comply with safety standards to prevent *Salmonella* (Mason, 1994). As with Sweden, the plants are clean, disinfected, rodent free, and the feed is heated to kill any bacteria. According to the NCC the detection percentage of *Salmonella* found after slaughter inspections was 4.3% (NCC, 2013).

Sweden and the United States share similarities in their initial *Salmonella* control measures which are also "standard" in many other countries. Some examples of those similarities are ensuring that grandparent and parent flocks are not infected. Using the all in and all out method and testing samples taken from different stages in the processing chain. Avoiding the spread of contamination with other flocks and equipment by managing slaughter times and keeping transport vessels clean as well as stringent hygiene practices (FAO et al., 2009).

2.2.2. Campylobacter

Due to both country's S*almonella* control plans, and mandatory HACCP programs hygienic and sanitary practices are already in place which also aids in the prevention of *Campylobacter*. But more control strategies are needed because some sources of contamination are different. Broiler chicks do not have *C.jejuni* in their intestinal tracks when they are born but rather, they can become colonized due to the environment of the processing plants. The infection spreads throughout the flock in just a matter of days (White et al., 1997). In 2011 the USDA constituted performance standards to reduce contamination cases from broilers in plants, allowing contamination rates to be no more than 10.4% (CDC, 2019). The USDA-FSIS has a directive given to the inspectors outlining the specifics instructions for sampling procedures (FSIS Directive 10,250, 2021). Protecting the broilers from flock colonization entails preventing contamination. FSIS list HACCP analysis as one of their preventive measure for *Campylobacter*, but it is not mandatory to include it unless multiple problems occur, then the USDA expects the producers to make measures to improve. In other words, a mandatory HACCP is used but not just specifically for *Campylobacter* (FSIS, 2013). The Animal and Plant Health Inspection Service (APHIS) has a list of biosecurity measures that should be followed. Some of the guidelines are, only the poultry farmers should have contact with the broilers cleaning your hands when entering or leaving the plant and use of disposable shoe covers when around the flock. The guidelines also include the disinfection of any tools or machinery as well as wearing protective clothes for one time use (APHIS, 2020). Important to note that Sweden also practices these similar biosecurity guidelines. The yearly prevalence of positive *Campylobacter* in the United States is 5.4% (Williams and Oyarzabal, 2012).

Sweden's program, which Svensk Fågel is mainly responsible for running, monitors, samples, and studies broilers for *Campylobacter*. Funding for this program is provided for and approved by the Swedish board of Agriculture (Svensk Fågel, 2020). The *Campylobacter* program for broiler production in Sweden is voluntary and has been operating since 1988. The program includes taking caeca samples from all flocks that have been slaughtered. Then SVA analyzes them. In 2019 4.6% of the flocks tested positive for *Campylobacter* in Sweden (Höök, 2020).

2.2.3. Antibiotics

Sweden prohibited the use of antibiotics in 1986, only when the broilers are sick can they be administered, which is an average of 0.12% of the broilers produced (Svensk Fågel, 2017b). Sweden was the first country to prohibit the use of antibiotic growth promotors (AGP) (Wierup et al., 2021). The research data provided by Sweden was one part of the deciding factors for deauthorizing the use of antibiotics as growth promoters in the European Union in 2006 (Castanon, 2007). Only as early as 2017 was the use of AGP prohibited in the United States by the Food and Drug Administration (FDA). These antibiotics were deemed medically important and could contribute to antimicrobial resistance (AMR) in people. Broiler producers can still receive this type of antibiotics from their veterinarians if needed (Access Science, 2017). Currently, 51% of broilers

produced in the US are free of antibiotics. Those broilers using feed antibiotics such as bacitracin, bambermycin, and avilamycin make up 24% of the broilers produced. These antibiotics do not require a veterinarian's prescription and are used only for animals and have no medical effect on people. The World Health Organization (WHO) permits ionophores and although they are considered an antibiotic in the US they are not in Europe. This animal only antibiotic is used in the prevention of coccidiosis and 18% of the broilers produced in the US are given them. There are antibiotics administered to poultry that are considered medically important to people such as virginiamycin and 8% of the broilers produced in the US have been administered with them (The Poultry Site, 2019). That means that every year 720 million broilers are given antibiotics that could contribute to antibiotic resistance in humans. That is roughly seven times the number of broilers produced in Sweden. The FDA regulates use of antimicrobials though testing when plant inspections are being held. The FSIS is responsible for the inspections then analyzes and records the results (FDA, 2005).

2.2.4. Vaccines

According to SVA the vaccines for conventional broilers are not routine. When it is necessary the broilers in Sweden do get vaccinated. Conventional broilers can get vaccinated for Infectious bronchitis (IB). IB is a contagious virus that effects the upper respiratory regions in chickens. This is a live vaccination that is given to day old broilers through spraying. If more vaccinations are needed they can be administered through the drinking water or through spraying (SVA, 2021a). Organic broilers could also get vaccinated against coccidiosis and Marek's disease (Odelros, 2018). Coccidiosis is an infection in the intestinal tract of broilers and Marek's disease is contagious and attacks the nervous system. The coccidiosis vaccine is given to the broilers through their water. Coccidiostats are permitted and they are considered antibiotics, but the EU has classified them as a feed additive. Grandparents and parents of broilers could have received vaccines for Marek's disease before they were exported to Sweden or in the hatcheries. Vaccines for Newcastle disease and Avian influenza are not permitted in Sweden (SVA, 2021b). The use of any of these vaccinations varies from each farm and it is always under the guidance of a veterinarian for both Sweden and the United States.

In the United States, a common vaccination program to protect broilers against Marek's disease, Infectious bursal disease (IBD), and fowlpox is through injecting the eggs when the embryos are about 17- 19 days old in the hatcheries (APHIS, 2013). Another common vaccination program is when the broilers are a day old. They can receive vaccines through spraying for Newcastle disease (ND) and IB. The Marek's disease vaccine can also be administered to day old chicks through spraying (Stewart-Brown, 2015). IBD is a viral infection that is contagious and attacks the upper respiratory systems of chickens (Jackwood, 2019). Fowlpox are lesions on the skin that are contagious and painful (Tripathy, 2019). Newcastle disease is a virus that causes respiratory and nerve problems in broilers (Miller, 2014). A revaccination for Newcastle and IB can also be administered when broilers are 14 to 21 days old through spraying or in the drinking water. IBD can also be given through the drinking water when broiler

chicks are 14 to 21 days old (Stewart-Brown, 2015). Depending on the State's approval and/or the breeders the use of vaccines could be considered part of the *Salmonella* control plan. If permitted, the *Salmonella Typhimurium* vaccine is administered in day old chicks at the hatcheries. Contingent upon the producers, there is another possibility for broilers to receive the *Salmonella Enteritidis* vaccine that is administered around 10 weeks (Eskin, 2020).

3. Broiler Production

Sweden produces approximately 110 million boilers a year (SVA, 2021c).The largest broiler producing region in Sweden is Götaland. This Southern region is responsible for 62 % of all broiler meat produced in Sweden (Jordbruksverket, 2019c). Kronfågel is the largest poultry producer in Sweden processing an average of 55 million broilers per year (Jordbruksaktuellt, 2017). There are 120 broiler farms and 7 large slaughter plants in Sweden (Wall H., 2021). Broiler producers in Sweden can have batch sizes of an average of 20,000 to 100,000 (Lärn-Nilsson et al., 2005). They can also have an average of 7 to 8.5 batch turnovers a year (Jordman, 2017).

The United States is the largest poultry meat producer in the world and produces approximately 9 billion broilers a year. Most production takes place in the mid and southeastern regions of the United States. Georgia is the largest broiler producer in the US producing around 1.3 billion broilers a year (NCC, 2019a). Tyson Foods is the largest broiler company in the US, producing around 200 hundred million pounds of broilers in a week (Souza K., 2020). There are 25,000 broiler farms and 180 slaughter plants in the US (NCC, 2019a). An average broiler batch size is 120,000, divided between about 20,000 broilers per house and batch turnover on average every 6 weeks (Harris, 2004).

3.1. Breeding

The breeding companies for broilers operate all over the world. The largest company, Aviagen which has operations in Sweden, and the United States, controls 44% of the global breeding market. One part of their genetics program uses DNA chips for genetic selection. Some of the breeding company's main goals are feed efficiency and growth rate (APHIS, 2013).

The type of breed for the production of broilers needs be meaty, able to grow fast and have a good feed conversion (Lärn-Nilsson et al., 2005). To accomplish this the Swedish poultry industry reared each of the hybrids of the Cobb 500 and the Ross 308. The ross 308 was developed from the American company Aviagen and the Cobb 500 was developed by Tyson foods (Tona et al., 2010). These broilers have been genetically selected for rapid production. They also showed strong immune response against the Newcastle disease vaccine but this vaccine is prohibited in Sweden (Mayahi et al., 2016). Today the broiler farmers in Sweden only use the breed Ross (Wall H., 2021). The parents and grandparents of Swedish production broilers are reared in Sweden. The grandparents are imported from Scotland when they are a day old. The breeding company Aviagen SweChick has the grandparent populations, and the parent populations are born in their hatcheries.

After selection and breeding, Läntmannen SweHatch owns and handles the maternal parent broilers and their eggs. Those eggs will hatch there and then the day old chicks are delivered to any of the 120 broiler farmers across Sweden (Wall, 2021).

Breeders in the United States focus on the growth rate, weight, feed efficiency, and carcass conformation of their broilers. The two breeds most used for broiler production are the White Plymouth Rock and Cornish. The breed White Plymouth Rock are robust, broody, easy to handle, have a lot of protein in their meat and are both meat and egg producers. This is an American breed known for its tasty and sweet meat and has been around since the mid 1800's (Reddy J., 2018). The Cornish Cross broiler is a hybrid of the Plymouth White and the Cornish. The Cornish chicken came from Cornwall, England in the early 1800's. Some of their characteristics are their ability to grow very fast, meatiness and deep breasts (Purely Poultry, 2021). In the United States the breeding companies like Aviagen, own the pureblood, great grandparents, and grandparent populations. The grandparent's off spring will become the parents of the broilers. Commercial broilers companies, Like Tyson foods, own the parent populations and the hatcheries that their eggs are sent to. The day-old chicks are reared either on farms that are owned by the company or the company has contracts with the other farms (APHIS, 2013).

3.2. Hatcheries

In Sweden, the broiler eggs can be held at cooler temperatures and stored between at an average of 5 ½ days to delay growth. When the eggs are ready to be incubated, they are placed in large incubation machines called Petersimes that can hold up to 50,000 eggs at a time. The eggs will stay there for around 18 days at temperatures between 36ºC- 38ºC and the eggs are also turned regularly. After the 18 days the eggs are sorted through candling this is referred to as the turnaround in Swedish hatcheries. Those eggs, that contain fetuses will be placed in hatchers in another part of the plant and will begin hatching within 3 days. Temperatures are also lowered because as the fetuses grow, they produce heat themselves. About 80% of the eggs hatch. Once they are hatched the eggshells are removed by blowers and the chicks are sorted by their mother's age. Their average weight is 40 grams, and they are inspected before they are transported to farms. Some hatcheries like Läntmannen SweHatch, have the ability to hatch around 2 million eggs a week but usually process around 450,000 a week (Secher, 2011).

In the United States the eggs are held at cooler temperatures below 24 ºC no longer than 6 days to ensure hatchability. The eggs are then incubated at temperature around 37ºC-38ºC and turned regularly to improve development. When the eggs have been incubated for 18 days, they will receive vaccines. The vaccines are for the prevention of IBD, fowl pox, and Marek's disease and administered through injection. Then the eggs are placed in hatchers and will hatch on day 21. About 85% of eggs hatch. The day-old conventional broiler chicks often receive spray vaccinations for IB, ND, and coccidiosis. Then, the chicks are sorted and transferred to the broiler farmers (APHIS, 2013). The broiler chicks weight around 44 grams (PennState, 2012). It is important to note that for both countries, the hatcheries temperature, and humidity levels must be in balance. Adjustments are made regularly throughout the process from storage to transport to produce an ideal environment at every stage.

3.3. Rearing Systems

3.3.1. Conventional

Conventional broilers from Sweden are raised inside on liter beds. The litter beds can consist of wood shavings, straw, and peat moss litter. The first few days of the broilers arrival the temperature is 33°C with 50% humidity. When they are around 5 weeks old the temperature is around 20°C, having steadily decreased overtime (Lärn-Nilsson et al., 2005). The climate inside the stalls is critical the temperature and the humidity must be in balance, for example if the humanity is 80% the temperature should be around 10°C (Jordbruksverket, 2018a). The broiler houses are ventilated, the broilers should have a place to perch on, and they should be in complete darkness for at least 6 hours although, it can be more. Sweden does not allow the caging of broilers for conventional or organic rearing (Lärn-Nilsson et al., 2005). There is no genetically modified organisms (GMOs) feed permitted for conventional broilers (Svensk Fågel, 2017c).The statues of the Swedish Board of Agriculture allow a maximum space of 36 kilos per square meter which is around about 20-25 broilers (SJVFS 2017:28, 2017). The European Union allows for a minimum of 33 kilos and a maximum total of 42 kilos per square meter and they also carry out inspections (Directive 2007/43/EC, 2017).

In the United States, conventional broilers are also reared inside on litter beds. The litter beds are mostly made up of rice hulls and/or pine shaving and are 3 to 4 inches thick. They can also be made up of wood shavings, peanut hulls, chopped wheat, pine straw, peatmoss, shredded paper, sand, and sawdust. The temperature when the chicks are a few days old should be 30°C to 32°C and at three weeks old the temperature should be around 20°C and a relative humidity of 60-70%. The heating and ventilation systems are automatedly controlled but can be manually adjusted. Broilers are not reared in cages. The broilers get around 4-6 hours of darkness a day. The USDA's flock density is approximately 36 kilos per meter (APHIS, 2013).

3.3.2. Organic

The production of organic broilers in Sweden consists of strict specific rules regulated by the Swedish government or the European Union (EU) depending on the certifications. The use of synthetic amino acids and just as in the conventional broilers no GMOs are prohibited. All organic broilers, that is to say, all parents and grandparents, have to had come from an and organic farm (Jordbruksverekt, 2021b). The two breeds of organic chickens are Rowan Ranger and Hubbard (Odelros, 2018). Organic broilers in Sweden are raised indoors and outside. The outside pastures must be organic with no pesticides or artificial fertilizers (Ekologiskt Lantbruk, 2005). Sweden regulates that during the months of May through September, broilers should be outside for 4 consecutive months. The stalls should also be open for at least 12 hours a day. The EU regulations are that broilers should be outdoors at least 1/3 their life but they can be kept inside during the winter (KRAV, 2020a). The litter beds can consist of wood shavings, straw, and sand and do not need to be organic. The maximum space per square meter is 20 kilos or about 10 broilers (Waldenstedt, 2005). The organic broilers must have at least

5% of the floor lighted which can come from nature light from the windows in their indoor space. The broilers must be able to have access to a sand bath and something to perch on. The broilers must have 8 hours of darkness a day. The temperature inside should be able to reach up to 35°C for the day-old chicks. The temperature should be lowered by one degree every other day until the broilers are 4 weeks old and then stay at a temperature of 20°C. Indoor housing should have a regulated ventilation system. The broilers can have access to the outside when they are six weeks old. A covered place must be provided for the organic broilers when they are outside. The gravel for the indoor entrance should be changed before a new set of broilers come in (Ekologiskt Lantbruk, 2005). There can be no more than a 1600 square meter space for organic broilers (Odelros, 2018). Feed for both EU and Sweden certifications must be 95% organic and 5% of non-organically grown protein feed for the broilers is allowed (Jordbruksverekt, 2021b). From that 95%, 50% of the organic feed used must have been grown on the producer's own land to be KRAV-certified. An EU certification requires only 30% of the organically grown feed to come from the producer's farm (Odelros, 2018). Approximately 1 % of the total broiler production in Sweden is organic (Jordbruksverket, 2019). Which is an estimated 1.1 million organic broilers a year.

The Organic production of broilers in the United States does share some similarities with Sweden. For example, the United States does not allow the use of synthetic pesticides or fertilizers, nor do they allow GMOs in organic production. Both countries promote natural behaviors, concentrate on the organic broiler's environment, do not allow caging, prohibit the use of growth hormones, and antibiotics (Fanatico et al., 2009). Also, broilers must be raised on organic pastures. However, organic broilers in the US are coming from conventional hatcheries but from there on they are reared under organic management. The USDA's National Organic Program (NOP) requires that all feed must be 100% organic but FDA regulated vitamins and minerals are allowed. In addition, the synthetic amino acid DL-methionine is also permitted as a feed additive. There should also be access to the outside all year round, as well as have something to perch on. The outdoors space should be 2 to 5 pounds per square foot. The inside space should allow 1 to 5 pounds per square foot. The environment inside should also be well ventilated and temperature controlled. There was no specific temperature listed for the organic broilers. The broilers must also have scratch areas (AMS, 2011). The two main US breeds in organic broilers are the Rhode Island Red and the Barred Plymouth Rock (ALI, 2019). According to the agricultural marketing research center (AgMRC) 19 million organic chickens were produced in 2018 (AgMRC, 2018).

3.4. Feed and Water

Contents such as protein, carbohydrates, and fat must be part of the conventional broilers feed to provide nutrition (Darre, 2008). Throughout the broiler's lifecycle different diet proportions and formulations are used based on the broiler's age and needs. One example is that starter feeds for broilers up to 10 days old, usually have more proteins and vitamins because Swedish and American broiler producers want to see an increase in weight from the broiler chicks within the first 7 days. There are also

different types of grower feeds and finisher feeds (APHIS, 2013). The feed ratios and contents vary from each farm to each country. But each country's feed management systems are set up to produce a disease free and meaty broiler.

The Swedish feed for broilers conversion is 1.65 kilos of feed to 1 kilogram of broiler weight. The main contents of Swedish broiler feed are barley, wheat, and oats which makes up about 75 % of the feed, occasionally there is also corn. The protein comes from peas, beans, soy, and rapeseeds (Svensk Fågel, 2017b). Most of the fat can come from soy and corn oils which make up around 4-6%. If extra fat is needed it can be sprayed onto feed (Elwinger, 2013). Coccidiostats are added to prevent against parasites and gut bacteria. Antibiotics and fish meal cannot be added to the feed (Svensk Fågel, 2017d). To receive the proper number of vitamins and minerals they are added to the feed and water. Vitamin additives are A, E, and D_3 and mineral additives are Selenium and Copper (Elwinger, 2013). The vitamin additives and selenium can be given both through the water systems or with feed (Wiromin, 2016). Pure amino acids such as methionine and lysine could also be added to Swedish poultry feeds (Elwinger, 2013). Sweden follows EU legislation that applies to additives in feed. The EU has approved the use of pure amino acids L-lysine-monohydrochloride and DL-methionine in feed ((EC)No 1831/2003, 2016). The feeding and water systems are automated and depending on the age of the broilers they are appropriately sized and proportioned (Jordbruksverket, 2021a). To reach the feeding cups comfortably they should reach about two centimeters lower than the height of the broilers back. The water nipples should not be too high for the broilers either. They should be able to drink standing at a 25° to 45° angle (Blenta AB, n.d.). The water should always be clean and both systems should be controlled daily. The broilers should be able to have food and water whenever they want. However, feed is removed approximately 12 hours prior to slaughter. Access to water and feeding systems should not cause any undue stress (Jordbruksverket, 2021a). Conventional broilers feed and that feed that is not produced on the farm for organic broilers must be purchased from a company that has been approved by the Swedish Board of Agriculture and registered with the County Administrative Board (Jordbruksverket, 2021b).

In the United States, the feed conversion is 1.60 kilograms to 1 kilogram of weight (Best, 2011). The water and feeding systems are also automated. The size of the stall should determine how many feed lines there are. Water systems can also be adjusted for the rate of flow of water desired. It is suggested that water nipples should be at eye level height when the broilers are drinking. Control and care for clean water and full access to feeding systems are also part of the feed management system. Feed management programs may vary depending on the farm, but the nutritional needs are the same. The most common feed proportions consist of 85% corn and soybean meal. The rest is made up of oats, wheat, barley, rye, and sorghum (APHIS, 2013).The liquid fats are mainly from soybean, sunflower, palm, and rapeseed oils (Vine, 2016). The feed also includes synthetic amino acids like methionine, lysine, and threonine. The vitamins A, B, C, D_3, E, and K and minerals potassium, sodium, chloride, magnesium, and phosphorus

are included in a premix that is given at different times during the rearing of the broilers. The feed is removed about 6 hours before the broilers are loaded onto transport trucks. Feed removal should not be more than 12 to 14 hours (APHIS, 2013).

3.5. Slaughter

The Swedish conventional broilers are slaughtered between 30 to 40 days old when they have a live weight of around 1.6 kilos to 2.3 kilos (Wall H., 2021). Slaughter time for Organic broilers is 10 weeks when the broilers are around 3 kilos (Odelros, 2018). There is only one slaughter plant for KRAV broilers. KRAV rules during transport are that it should be calm, and the vehicle's climate adequate for the broilers. Handling of the broilers should also be careful and calm. Inspections could be carried out while loading and unloading (KRAV, 2019). KRAV guidelines also require the slaughter plant must have an animal welfare officer there. The broilers must be slaughtered on the same day they come to the slaughter plant. There must also be a shield so that the KRAV broilers that have not been stunned yet cannot see the carcasses being cut and bleeding out (KRAV, 2020b). Most of the slaughter procedures are the same for Swedish organic and conventional broilers (Schwartz, 2013). Their main differences were the KRAV rules listed above. There are seven slaughter plants in Sweden. The time from the farm to the slaughter is typically not more than 8 hours. The broilers maximum transport time is 12 hours. For the broilers not to become stressed, they are loaded at night either manually or by machine. Then the broilers are transported in climate-controlled trucks to the slaughter plants. The broilers are suspended upside down manually and hung on foot bands. Swedish law requires that the broilers are unconscious before they are slaughtered. For unconsciousness, 50% of the plants use carbon dioxide whereas the other 50% use electric stunning. Electric stunning is being phased out in slaughter plants in Sweden. After being cut, the broilers bleed out, and are placed in scalding water to remove the feathers. The internal organs are removed and examined by a veterinarian. The carcasses are cooled down and sorted (Svensk Fågel, 2017e). The Swedish national food agency (Livsmedelsverket) also performs before and after slaughter inspections at the slaughter plants. These regulations are based on slaughter guidelines, hygiene, and HACCP plans (Livsmedelsverket, 2021). Broiler producers are required to have a contract with the slaughter plants that are near their facilities. Most slaughter plants as well as 98% of all companies in the broiler production chain in Sweden are members of Svensk Fågel (Svensk Fågel, 2017e).

The average age at the time of US conventional slaughter is 47 days and the broiler's live weight is about 2.9 kilos (NCC, 2021). For organic broilers slaughter time is about 81 days and the live weight is approximately 2.8 kilos (Cobanoglu et al., 2014). There are approximately 180 slaughter plants in the US. In the United States the organic processing in slaughter plants must also be carried out by organic certified processers that have complied with all state and federal regulations. The pest control methods need to be organic as well as sanitizers and detergents that are used in the plants. Non-organic products should not mix with organic ones. It is required to have an organic system plan and keeping detailed records of the process to ensure that procedures were

performed according to the rules of the NOP (Fanatico et al., 2009). Except for the above-mentioned organic rules, the processes are similar inside the slaughter plants. It is suggested that during transportation, the broilers travel no more than 60-miles. At the slaughter plant the broilers are suspended by their feet manually and are electrically stunned to become unconscious. There are some plants that use carbon dioxide or atmospheric pressure for stunning these methods are called controlled atmosphere stunning (CAS). The throats of the broilers are cut and they bleed out. From there, the carcasses are placed in a hot water bath, so their feathers can be removed by a picker machine. Afterwards, the carcasses are eviscerated and their feet are removed. Next, they are cleaned inspected by a USDA inspector and someone in the processing plant. Each carcass gets rinsed with water and an organic rinse to prevent bacteria. The carcasses are then chilled and microbiological tests are taken from the processing equipment. The butchery processes also take place at the plant depending on which on type of cuts are needed and then the poultry meat is packaged and labelled. There are a series of inspections during this process as well (NCC, 2017). Almost all commercial broiler production companies also own the slaughter plants where the broilers are processed (APHIS, 2013).

3.6. Automation in production

The first thing that chicks need when they come from the hatcheries is water. Water systems are automated. The most common type of water systems in broiler production is a closed system that uses nipples with or without the cups (Jordbruksverket, 2021a). This water system is hygienic with an automated rinsing system that can drip about 90 milliliters of water a minute (Swedfarm, 2015). The feeding systems are also automated. The augers turn the feed and it disperses out through feed openings onto a plate that is about twelve inches in diameter and can feed a maximum of 80 small broilers. Feed plate sizes can vary from each country to each farm (APHIS, 2013). In a hundred-billion-dollar poultry industry production is fast-paced. One way to compete is with machinery. The use of equipment offers efficiency, speed, and low error rates. The general part of poultry production is similar around the world. What differs are each countries regulations and the breed types and chilling mechanisms after slaughter. In the United States most of the slaughter plants use a water chiller to cool the carcasses down quickly. In Europe and Sweden the cooling is done with air chilling (McMurray, 2013).

3.6.1. Climate, and Hatching

Climate control such as temperature, ventilation, humidity, and lighting are all controlled technically in the hatcheries, housing stalls, and in the slaughter plants (Secher, 2011). There are automated machines in the hatcheries for the rotation of the eggs in incubation that are turned at a 90º angle every hour. The screening and sorting are all automated. Machines are used to administer vaccinations. The injections into the eggs are more accurate and the spray vaccines are an efficient way to vaccinate large amounts of broilers in a short amount of time (APHIS, 2013). The day-old chicks are transported into their crates with a conveyor belt after having been placed there by a light suction mechanism (Lacy and Czarick, 1998). The transport trucks from the

hatcheries are climate controlled and can hold up to 100,000 day-old chicks (Secher, 2011).

3.6.2. Catching, Transport, and Slaughter

The producers use chicken harvesting machines to collect the 6-week-old broilers onto the truck and load into crates. The models and types may vary but these harvesters can pick up around 18 to 26 tons an hour (Ramasamy et al., 2004). One type of harvester used in Sweden has a long rubber finger like tubes that gather the broilers on a conveyor belt to be loaded. The crates weights are monitored so the loader knows that they are at capacity (Björk, 2013). Approximately 6,000 broilers can be loaded with forklifts onto the climate control trucks to deliver to the slaughter plants (APHIS, 2013). Once at the slaughter plant other than manually hanging the broilers upside down before they are stunned everything else is automated. The automation industry is working hard to make this step mechanical because it is difficult work for the employees and therefore the pay is much higher (McMurray, 2013). Mechanical stunning is used for precision and the two side blades for the neck cutting make the killing process fast. The automated scalding bath ensures safety for plant processors and the feather plucker is fast and efficient (Marel, 2020). The plants can eviscerate about 140 to 180 carcasses a minute (McMurray, 2013). Modern slaughter machinery can process 15,000 broilers in one hour. There are also secondary processing which is deboning, sorting into different cuts, and also packaging which is can all be done through machinery (Marel, 2020). It is also important to note that some producers may have automated butchery, but most butchering is done manually.

3.7. Mortality rate

Even though Sweden and the United States have management systems for the health and safety of production broilers casualties are hard to avoid. The mortality rate for Swedish broilers is about 3% of the total production population (Gustavsson, 2021) In the first week of rearing the mortality rate is around 1% (Björk, 2013). Between 0.04%-0.29% of those casualties happen while in transport (Transportnet, 2010). The mortality rate for the broilers produced in the United States is an average of 3.8% of the total production population. The US also has a mortality rate of 1% during the first week. (APHIS, 2013).

4. Discussion

The Swedish government supports testing and regulations for the animal welfare programs, *Salmonella* and *Campylobacter* programs, and HACCP controls (Jordbruksverket, 2018a). Giving the broiler producers a slight advantage over the United States for health and welfare management. Because the support from the government not only aids broiler producers to comply with their regulations but allows Sweden to have better control over the safety of their food, animals, and its citizens. It also contributes to consistency within the industry because all agencies are communicating and working with each other (Wierup et al., 2021). The US also supports food and safety management through the FSIS as well as mandatory HACCP programs and governs what they consider to be standard practices (Mead et al., 2010). What creates inconsistencies is the differing state laws and producers having varying views when it comes to animal welfare for conventional broilers in the United States (Tabler, G.T., 2006). Take for example the United States exclusion of poultry from its animal welfare legislation (Hirsch, V., 2003). It causes a lack of standards that compromises the welfare of its broilers which could consequently affect the safety of its citizens food.

Since there is a constant high risk of infection and contamination for *Campylobacter* and *Salmonella* throughout the production and processing of broilers in US and Sweden both have similar essential control systems in place. The FAO's list of the most crucial steps in prevention of Salmonella are already being carried out by both countries. That is the control of grandparent and parent stocks which are protected and tested by the small number of global breeders. They utilize the all in and all out rule in both countries, have slaughter organization and clean up after the broilers have been removed. (FAO et al., 2009). The *Salmonella* program costs the Swedish government about 100 million kronor a year and Sweden produces about 110 million broilers in that time (SVA et al., 2013). Sweden has one of most effective *Salmonella* programs with less than 0.1% infection rate in its broilers (Svensk Fågel, 2017a). However what works for one country does not always work for the other. The broiler production in the United States is industrial. Just one state like Georgia, in the US, produces more than a thousand times what the whole country of Sweden produces in a year. If the United States had implemented a similar program for 9 billion broilers most of its resources would probably be exhausted. This helps to understand why Salmonella vaccines are sometimes used and even though the *Salmonella* infection rate is not as low as it is in Sweden it is still can be considered effective at a 4.3 % infection rate in its broilers (NCC, 2013).

For the prevention of *Campylobacter* both countries have biosecurity measures in place to prevent contamination. The United States has a 5.4% infection rate of *Campylobacter* whereas Sweden has a 4.6% infection rate. Sweden's rate is high. However, Sweden's *Campylobacter* program takes a sample from every flock that is slaughtered and tests them. Which could also contribute to their comparative percentage to the US. FSIS from the US carries out inspections however it is unclear if every flock batch is tested. Nonetheless both countries have decreased their percentage rates from previous years.

One of the main differences between Sweden's broiler production and that of the United States is that Sweden restricts the use of antibiotics and allows them only when it is completely necessary. Sweden takes an active role to limit the use of antibiotics to prevent AMR in its citizens. Sweden's strength in their management systems come from the support of governmental agencies which acts as the catalyst for the cooperation from the major producers in the industry (Wierup et al., 2021). The weakness factor within the management systems in the US is they still give antibiotics to their broilers and even those that are considered medically important to people (The Poultry Site, 2019). Which means that they could contributes to AMR in their citizens. The fact that the FDA just recently increased regulations to limits antibiotics in their broilers and that only 5 producers make up 60% of the total broiler market could imply that cooperation may not have come as easily for the US as it has for Sweden (Leonard, 2019).

The main vaccinations that Swedish conventional broilers receive are for IB (SVA, 2021a). The Swedish organic broilers receive vaccines for coccidiosis and Marek's disease (Odelros, 2018). The US vaccinates conventional broilers and organic against IB, IBD, fowl pox, ND, and Marek's disease, and in some cases for *Salmonella* (Jacob, 2019) The diseases that both countries vaccinate for can be very contagious and without vaccinations it could infect the whole flock. Sweden has restrictions against vaccinations. One reason could be due to the risk of immunosuppression in its broilers. Sweden relies on their management programs for most disease prevention first, to try and reduce giving vaccinations. Whereas with the United States vaccinations are part of their disease management programs and are relied heavily upon as a preventive tool.

Another similarity with the US and Sweden is that the broiler production market is very concentrated there are only 4-5 major producers in each country. This concentration of the production market could make for better controls of its production systems. At the other end of the spectrum smaller independent farmers often get pushed out unable to compete with them.

Both the US and Sweden have high welfare standards when it comes to the rearing of organic broilers because of strict regulations for certifications. Neither of them allow GMO's, synthetic pesticides, and fertilizers. They do not allow caging, growth hormones, and antibiotics. Both countries organic programs promote natural behaviors and focus on their environments (Fanatico et al., 2009). They both go to extra management practices to ensure that the broilers have a calm relaxed atmosphere before slaughter. Some of the differences are that Sweden has their government regulations and also EU regulations that depending on the broiler certification must be abided by (Odelros, 2018). Sweden's organic broilers have to come from parents and grandparents raised on an organic farm (Jordbruksverket, 2017b). The US can use conventional chicks but on day one they must be reared following the organic regulations. The food for US organic

broilers has to be 100% organic (Riddle, 2020). Sweden allows for 95% of organic and 5% conventional feed (Jordbruksverket, 2017b). However, 50% for KRAV and 30% for EU certifications of the feed must come from their own pasture (Odelros, 2018). What can be seen as a weakness on Sweden's end is the number of regulations that must be followed for organic farmers. This could make farmers reluctant to go into organic production due to strict regulated farming.

The processing of broilers is also quite standardized and both countries have similar rearing systems for both organic and conventional slaughter. One difference in organic rearing is that the US organic broilers are reared a bit longer than Sweden and have a little lower weight. The US has a little bit longer conventional rearing time than Sweden again but their weight is more. The feed conversion in the United States is 1.6 kilograms (Svensk Fågel, 2017b). The feed conversion in Sweden is 1.65 kilograms (Best, 2011). The United States gets a little better return on their feed conversion than Sweden. One reason could be that the genetically selected breeds from the US have a better feed efficiency (Reddy J., 2018).

This literature study showed that the organic production in the United States concentrated more on the health and welfare of the broiler than in conventional rearing. This type of "care" in conventional farming seemed to have been excluded. The US organic broiler seemed to have been represented more through regulations and statues than that of the US conventional broiler. The words animal welfare and health appeared more times during the literature research for US organic production than it ever did for US conventional production. This suggests that an organic rearing can be interpreted from the US as using better animal welfare practices during production.

The mortality percentage rate for the United States is 3.8% whereas Sweden's rate is about 3%. They are within a similar percentage range. One reason for Sweden's comparative mortality rate could be contributed to their limited use of vaccinations and antibiotics.

5. Conclusion

How does the largest broiler producer, the United States compare to a smaller producer like Sweden? One of the main differences apart from the production size between Sweden's broiler production and that of the United States is that Sweden restricts the use of antibiotics and allows them only when it is completely necessary. The United States still administers antibiotics to 49% of its broilers and of that 8% are considered medically important to people which could promote AMR.

Are there any differences in the management programs of each country that could affect the prevention of certain diseases? Since there is a constant high risk of infection and contamination for *Campylobacter* and *Salmonella* throughout the production and processing of broilers in US and Sweden both have similar essential control systems in place. However, their differences lies within how they use their prevention programs. Sweden relies on their management programs for most disease prevention and for the exclusion of the overuse of vaccinations and antibiotics. Whereas with the United States the vaccinations and antibiotics are part of their disease management programs.

Are there any strengths or weaknesses in either country that support or hinder their production systems? The weakness factor within the broiler production systems in the US is that 5 major producers make up about 60% of the total broiler market. This could lead to a weaker cooperation between broiler producers and less of a possibility of stricter animal welfare and antibiotic regulations in the future in the United States. The support from the government not only aids broiler producers to comply with their regulations it also allows Sweden to have better control over the safety of their food, animals, and citizens.

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