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**Caulum, Rose M.** ***Egg Inventory Management with Flock Factors***


## Abstract

Egg inventory management is critical for the poultry industry. For accurate egg inventory management, accurate projections of layer flock performance are necessary. This study found that there are some pullet flock factors that correlate with adjusted egg production percentage, which may assist in developing an accurate egg production projection system. Previous research has not included how to predict base off of early flock performance indicators. This approach will allow for more accurate projections and better egg inventory management. Due to the size of the sample utilized for this study, it is recommended that further study is conducted to verify findings.

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# Chapter I: Introduction

Company XYZ, name has been withheld to protect confidentiality, is a fast food poultry company that produces broiler birds for processing at approximately four pounds. This company raises chicks that were purchased from another company to become layer hens and roosters, also referred to as broiler breeder birds. The layer hens will then produce eggs for hatching. The chicks that are hatched are the ones that are raised for approximately 35 days before being processed at the processing plant and delivered to customers at the wholesale level. Priority customers purchase large quantities of product in a single order, which requires continuity of bird weights for flocks processed in the same processing day.

The company raises two different product types for their broiler birds. They raise antibiotic free birds as well as conventional birds. A conventional flock will have the ability to have different types of vaccinations and probiotics compared to what an antibiotic free bird is able to receive. The difference in these programs impacts the weight gain for the broiler birds and how the eggs for these birds are set and hatched (Gholami et al., 2017).

Company XYZ has begun the process of altering their priority customers. Previously, the priority customers of this company were focused primarily on location of the customers being near the processing plant. The company has begun switching focus on customers to give priority to those who have consistently larger orders of the same product. Company XYZ has altered who they sell their birds to and have begun working with other processing plants in order to minimize the different product codes being produced at the different processing plants. By minimizing the number of product codes, the processing plants are able to focus on larger orders of similar products for fewer customers. They have begun to sign contracts with larger customers to replace several smaller customers. Company XYZ ranks its customers by the frequency and size of their orders in order to focus more on those that provide the most sales. Part of this process includes increasing production of broiler birds and changing the target live weight. The increased production increases the number of hatched chicks that are required, while the change in target live weight impacts the age of processing for birds and the number of flocks that will be placed on each day of the week.

When reviewing priority customers, Company XYZ began the conversation of possibly eliminating one of the product types, either conventional or antibiotic free birds. By eliminating one of these products, Company XYZ would have the ability to place barns with an equal distribution of days between flocks. Equal distribution of days is referring to providing the same length of time from the day one flock is processed to the day the next flock is placed within the barn. An equal distribution of days between flocks will raise the overall time for the conventional flocks, since historically it is the antibiotic free barns that receive the most days between flocks.

In order to ensure that there are enough birds when required to meet customer orders six weeks after the hatch, Company XYZ needs to manage their egg inventory. Eggs take 21 days to hatch after being placed in the setter machine and should not be held in the cooler for more than a few days before being set (FAO Agricultural, 2003). Pullet barn placements and layer barn placements are staggered to ensure continuous supply of eggs to meet production demands. Pullet placements refer to the placement of broiler breeder birds right after hatch, while layer barn placements refer to the barn that raises the broiler breeder birds from approximately 20 weeks until when they are sold. Increased production demands increase the importance of maintaining the egg inventory at the appropriate level throughout the entire year.

In the last year, Company XYZ has changed procedures for the pullet and layer facilities, which impacts the performance of the flocks raised with the new procedures. A few of these changes included decreased target weight changes for pullet and layer flocks. Feed formulations were also altered, in addition to the placement of alternative breeds in pullet barns. Another example of changes implemented to procedures included a no clean system in which reused bedding for the barns was implemented for new flock placements in order to promote an environment of good bacteria rather than harmful bacteria and to save on the cost of bedding.

These changes were based on best practices for other companies that produce similar broiler birds. The performance of the laying hens and roosters has been impacted due to the changes in the procedures. The procedure changes for layer barns included feed programs, walking schedules, weight targets, and lighting schedule. These procedure changes have increased the difficulty in predicting the egg production rate of a layer barn, which has led to less than ideal egg inventory management. While these changes have made it more difficult to currently manage egg inventory, they were implemented to increase performance and to have this one location of Company XYZ conform to the same program the other locations of the company had already been following.

Information utilized for flock performance directly impacts the effectiveness of predicting flock performance and of managing egg inventory for a complex. Currently, the only information that is used for predictive measurement of layer flocks is the standard performance of the breed provided by the company that supplies the laying hens as chicks for placement in the pullet barns. The standard performance factors for the breeds of birds are determined by performance at other companies with potentially different flock management programs and environmental factors. The performance factor that is provided by the company for egg inventory management is the rate of production of eggs per hen per production week.

**Statement of the Problem**

Management of egg inventory was critical to ensure that there will be the right number of broiler birds to raise and process in order to meet customer orders without flooding the market. Not meeting the budget for processing of broiler birds can reduce the company's profitability, while processing too many birds can flood the market and reduce the price per pound for the birds sold. Proper egg inventory management requires predicting the performance of several layer facilities. At the Company XYZ, layer flock performance has been different than predicted, which ultimately caused shortages to the customers of the desired product. From January 1, 2018 to August 26, 2018 the prediction of egg production has been off an average of 46,800 eggs per week for the one complex of Company XYZ that was included in this study. Shorting customers caused loss of sales without a reduction of cost, leading to reduced profitability for the company. Company XYZ has been working under the assumption that predictions have differed from actual results due to the many changes in management programs and the feed program for the pullet and layer flocks.

**Purpose of the Study**

The purpose of this study was to determine any potential correlation between pullet flock factors and layer flock performance. The intent was to utilize any determined correlation in the creation of a database that will predict layer flock performance based off of its source pullet flock factors. Data used to determine correlations will be collected through historical flock records supplied by the Breeder Department.

Developing and implementing a database for prediction of layer flock performance will streamline egg inventory management. Increasing accuracy of the egg inventory management will allow operations to work with other locations to purchase or sell eggs as needed. Reduction of excess eggs will decrease costs associated with maintaining inventory. Eliminating egg shortages when needed for egg sets will prevent shorting customers their orders nine weeks from when the eggs are set. Reduction of customer shortages is important to maintain sales, profitability, and positive customer relationships.

**Significance of the Study**

Results of this study has the potential to be utilized to develop a larger scale study with the purpose of applying the results for all complexes within Company XYZ. Utilizing an accurate projection module in addition to current egg projection systems could improve long-term planning for pullet purchases and layer flock sell dates. Better egg inventory management would allow the scheduling of longer duration between flock placements for the layer facilities. With these potential improvements, Company XYZ would have the opportunity to save money and reduce customer shortages through better implemented planning modules. A successful database to manage egg inventories would allow Company XYZ to reevaluate the work responsibilities of several employees throughout the company, potentially eliminating positions or redirecting workloads to increase time spent on continuous improvement.

**Assumptions of the Study**

This study assumed that the method of how a pullet flock is raised will impact how the broiler breeder males and females will perform throughout their life cycles. The type of breed of the broiler breeder birds was assumed within this study to have an influence on how they perform at different flock ages. Feed formulations, the amount of feed, and the feeding schedule of pullet birds was assumed within this study to impact the development of the broiler breeder birds which in turn will impact performance later on as a layer flock.

The study also assumed that the type and timing of vaccinations provided will impact the health of the flock and that the health of the flock will impact its performance. Proper training of all employees of Company XYZ is assumed by the researcher. When collecting data for this study, it was assumed that all reports were accurate and all formulas were the best to utilize to determine the performance numbers.

**Definition of Terms**

The poultry industry and poultry specific research has several terms that are only applicable in these specific areas. Understanding these terms was critical in understanding the research that is available for poultry.

**Broiler breeder birds.** These are chickens that are raised for the purpose of producing hatching eggs that will produce broiler chickens (FAO Agricultural, 2003).

**Coefficient of variation.** Calculation is used for determining how uniform a flock is in bird weight (Hy-Line, 2016). The number produced by this equation will indicate how different body weights are from the average body weight. The equation is CV = (Standard deviation / average flock body weight) X 100.

**Egg production.** The number of eggs produced by a broiler breeder flock (FAO Agricultural, 2003).

**Fertility.** The productiveness of the poultry through reproduction and was shown as a percentage (Soltanmoradi et al., 2014).

**Hatchability.** Shown as a percentage and was calculated by total chicks hatched divided by the total number of eggs set (Hy-Line, 2016).

**Probiotic.** This is bacteria that has been determined as beneficial and is added to feed for consumption with the intent of lining the digestive tract with the desired bacteria to prevent the spreading of harmful bacteria (Kabir, 2009).

**Pullet.** This is a broiler breeder bird at the brooder-grower stage of a flocks' life cycle from placement as a chick until 20 weeks of age (FAO Agricultural, 2003).

**Uniformity.** Measures the spread of weight within one flock, most often calculated with a goal of 80% (Hy-Line, 2016).

## Limitations of the Study

The pullet and layer flocks utilized in this study were only located at one complex of Company XYZ. This limitation reduced variability of the sample and limited the population that the results of the study can be applied to. One reason that the population that the results were based on cannot be applied to all pullet and layer facilities is due to the environment of the area and the specific management programs that are utilized at this location are not identical to all other locations of pullet and layer facilities. One major limitation of this study was that only historical information was utilized, without the capability of having obtained additional information for flocks that had been processed.

## Methodology

Pullet flocks and layer flocks that were placed with Company XYZ between the placement dates of March 24, 2016 and November 3, 2017 were included in the study. These specific flocks were selected due to the availability of flock reports for data gathering, with a total of 26 pullet flocks and 38 layer flocks included. The information pulled from these samples was pulled from the Pullet flock report (Appendix A) for the pullet flocks' information and from the Egg Receiving by Entity report in Mtech for the layer flocks' information.

All information collected in this study was owned by Company XYZ and was approved for use in this study. The information that was compiled and was used in this study was originally collected by service representatives employed by Company XYZ. The information collected by the service representatives was then collected by the researcher of this study, the researcher's primary job responsibilities included live production scheduling and continuous improvement. Since the information used in this study only included flocks raised for Company XYZ, this information cannot be applied to flocks raised in different geographical areas or for another poultry producing company.

Data analysis was conducted through the use of descriptive statistics and inferential statistics. First, it was analyzed on if egg production was predictable, before moving on to test whether or not there was any correlation between individual pullet flock factors and the egg production of the layer flock that received the pullet birds. In order to determine if egg production was predictable, regression was calculated between age of flock and eggs produced. The Pearson correlation coefficient was calculated to determine the strength of the correlation between egg production and the individual pullet flock factors after first running regression lines.

**Summary**

Company XYZ raises broiler breeder birds to produce eggs for hatching of broiler chicks. The broiler chicks are then raised for approximately 35 days until processing to be sold at bulk quantities to customers. Historically, this location of the company has had smaller quantities of product sold to customers at a time, which has led to a need to increase projection accuracy as flexibility in the schedule changes with increased order sizes for new customers. Company XYZ has made changes to their breeder broiler program, which has impacted performance and these changes line up with the reduction egg projection accuracy.

With egg management being crucial to its business, Company XYZ needs to find a better way to predict egg production of layer flocks for accurate egg management. Without proper management, customers could have their orders shorted. This would damage company relationships and reduce the profitability of Company XYZ. The purpose of this study was to develop a better egg projection tool to use for Company XYZ. In order to fulfill this purpose, it had to be determined if egg production was predictable and if pullet factors would be predictive of layer flock performance.

When reviewing the data, this study assumed that that how the flocks were raised would impact their performance, both as a pullet flock and layer flock. This assumption included feed and vaccinations. Also included in this assumption is that the breed and health of a flock would ultimately impact the end performance of that flock. This study was limited by only including flocks for Company XYZ at one geographical location and the data gathered for this study was historical information, preventing the ability for the researcher to design the reports that would be used for data collection.

The data analyzed using descriptive statistics and inferential statistics was collected by employees of Company XYZ at the time of the flocks and recorded for future use, including use for this study. The analysis was designed to determine if egg production was predictable. Once that was established, the data was used to determine if there was any correlation between individual pullet flock factors and the egg production of the layer flock that received the pullet birds.

The literature review completed for this study covered several articles that impacted broiler breeder performance as well as approaches to scheduling and financial impacts. Factors that were found to impact broiler breeder performance and were reviewed in this study included feed, vaccinations, and the environment for the birds and house design. All of this information is important to understand in order to realize how the process of raising pullet flocks and layer flocks ultimately can impact the egg production of the layer flocks. Both the egg production of the layer flocks and how the flock placements and loadouts are scheduled can impact the processing plant schedules and financial success of the company.

# Chapter II: Literature Review

Poultry producing companies are continuously looking for ways to improve their processes with broiler breeder birds and with their broiler birds. An improvement made in these areas can reduce costs and improve performances of the birds. Both the broiler breeder bird performances and broiler bird performances can be impacted by making changes with programs for just the broiler breeder hens. A broiler bird is the progeny of the broiler breeder birds.

Several factors can be altered to impact broiler breeder performance, including the feed program, vaccinations or probiotics provided, and the birds' environment and housing design. Understanding production scheduling and financial cost analysis are also both important for developing the most effective and financially stable broiler breeder program. To develop the best broiler breeder program, all of these factors and tools must be used in conjunction.

## Feed and Flock Performance

The largest variable in cost for raising broiler breeder birds is feed. Since feed is the most expensive controllable variable for raising broiler breeders, it is often reviewed on a regular basis by companies to ensure that the cost of the feed balances with the performance of the birds. When it comes to broiler breeder birds, egg production, feed conversion, and fertility are the performance factors examined the most when evaluating feed programs.

**Feeding schedule.** One study sought to determine how altering the feeding schedule of the breeder broiler hens would impact the growth of the progeny produced (Gholami et al., 2017). Seven different dietary regimens were designed to determine how the different regimens impacted the growth of the progeny produced. The different feed schedules varied from one feed up to four separate feeds, all targeting the same total amount of feed. Each feeding schedule had the initial feeding at 4 AM, and the latest that any of the feeding schedules were scheduled for was 4 PM. The different feeding schedules and percentage of feed delivered at each feeding are outlined in Figure 1.

| Dietary regimen (%) | Daily diet (%) | Feeding time (h) | Daily diet (%) | Feeding time (h) | Daily diet (%) | Feeding time (h) | Daily diet (%) | Feeding time (h) |
|---|---|---|---|---|---|---|---|---|
| 100 | 100 | 0400 | - | - | - | - | - | - |
| 50:50 | 50 | 0400 | 50 | 1600 | - | - | - | - |
| 75:25 | 75 | 0400 | 25 | 1600 | - | - | - | - |
| 33:33:33 | 33 | 0400 | 33 | 1200 | 33 | 1600 | - | - |
| 50:25:25 | 50 | 0400 | 25 | 1200 | 25 | 1600 | - | - |
| 33:22:22:22 | 33 | 0400 | 22 | 0800 | 22 | 1200 | 22 | 1600 |
| 50:17:17:17 | 50 | 0400 | 17 | 0800 | 17 | 1200 | 17 | 1600 |

*Figure 1.* Dietary regiment with the frequency and feeding schedule. (Gholami et al., 2017)

Sample size included 224 broiler breeder hens and 28 roosters (Gholami et al., 2017). The birds were evenly distributed within four cages per feed treatments. The feed that was distributed to each feed program was the same feed formulation and formulated to meet the nutritional needs of the birds. The light and ventilation programs were maintained the same for all birds in the different feed treatments.

In order to determine the impact on the progeny growth, a total of 280 broiler chickens were raised (Gholami et al., 2017). There was one broiler chicken hatched and raised for each broiler breeder cage. This equaled to four broiler chickens per broiler breeder feed treatment. There were additional broiler chickens that were raised in conjunction with the 280. The purpose of these extra broiler chickens was to replace any mortality that occurred for the total number of chicks per feed treatment of the broiler breeders to remain consistent.

When running the General Linear Model, Gholami et al. (2017) found that the breeder broiler treatments were considered the main effect on performance. Six of the treatments were compared against the one broiler breeder treatment in which all feed was fed at one feeding.

The progeny of the broiler breeders that received three to four feedings a day had improved feed conversion in comparison to progeny of the broiler breeders who only received one or two feedings a day (Gholami et al., 2017). For this study, the same amount of total feed was fed to the birds no matter the number of feedings that were provided. Improved feed conversion for broiler birds provides the opportunity for a poultry company to potentially save a significant amount of money through reformulating feed to a lower calorie formula or reducing the total amount of feed that the birds consume in order to meet the company's desired weight. The company can save money because a lower calorie formula costs less per ton compared to a feed formula with higher calorie content. While this study examined seven different feeding scenarios, the results found from this controlled study calls for additional research in real life application (Gholami et al., 2017). The reason that additional research in real life application needs to be examined is due to the differences between the clinical setting and what would occur in actual practice.

Gholami et al. (2017) found that three separate feedings a day led to the best possible performance for the laying hens' progeny, however in a related study conducted three years prior by Soltanmoradi et al. (2014) it was found that fertility and hatchability was negatively impacted when the broiler breeder birds were fed more than twice a day. The fact that the 2014 study found that fertility and hatchability was negatively impacted by feeding the broiler breeders more than twice a day, coupled with the 2017 findings that feeding the birds only twice a day has the best impact on weight uniformity, suggested that in a controlled setting broiler breeders are most effective and economical when on a feeding schedule in which the set amount of feed is distributed between two separate feedings.

**Feed treatments.** The purpose of the Soltanmoradi et al.'s 2014 study had been to "determine the relationship between the feeding frequency and timetable on egg quality parameters of broiler breeder hens" (Soltanmoradi et al., 2014, p. 154). For this study, 15 different feed treatments were applied to Ross-308 strain broiler breeders. Each feed treatment had the same feed formulation and the same total amount of feed. The different feed treatments varied in the total amount of times fed throughout the day and the percentage of feed provided at each of the feedings.

Through the use of a one-way analysis of variance, egg production during peak was shown to increase for the flocks that were fed more than once a day (Soltanmoradi et al., 2014). There is a great financial incentive for poultry companies to trial distributing their feeding program twice a day to the broiler breeder hens. Having an increase in the laying hens and broiler birds' performance without increasing the actual cost of feed consumed by the birds can potentially save millions of dollars for a large poultry company on an annual basis.

**Feed formulation.** When determining how feed and the broiler breeder hen performance interact, it is not just the frequency of feedings that needs to be evaluated. The actual feed formulation and ingredients used within the feed is also important on how the feed will impact the birds' performance. Commercial poultry companies work to best balance nutrition, performance, and the cost when determining the feed formulas to provide to their broiler breeder flocks. Many feeding programs have used maize or corn as the primary source of energy for the broiler breeders, depending on the location in the world. The reason for the difference is due to cost of the different feed ingredients in the area of the company.

The costs of the feeding programs that utilize maize in developing countries depend greatly on the company's location and accessibility to purchasing maize. Since maize is not always the most cost-effective option, Rama Rao, Reddy, Prarharaj and Shyam Sunder (2000) tested alternative options to determine the performance and cost impact of using an alternative energy source in the feed.

Rama Rao et al.'s study included four hundred source broiler breeders, beginning at 27 weeks of age during their pullet stage (Rama Rao et al., 2000). Five different feed programs with different main sources of energy were utilized in the study, including maize, pearl millet, finger millet, foxtail millet, and broken rice. These options that were used are not the only option for the main energy source that could be utilized in broiler breeder feed. The selection of these sources for testing was greatly influenced by the options available in the geographical location of the source of the study in India.

Rama Rao et al. (2000) found that utilizing pearl millet or broken rice in the broiler breeder feed instead of maize is less costly per 100 eggs. This is utilizing the pricing of the different products in 2000 and for commercial companies producing in India. Costs of these products vary depending on the location of the company purchasing the products. The largest variable that would impact the cost of feed ingredients is shipping costs and market value in the different locations.

Several broiler breeder performance factors were analyzed on the different feed formulations. Egg production, amount of feed consumed per 12 eggs produced, feed cost per 100 eggs produced, energy within the feed consumed per 12 eggs, final weight, egg weight, and livability were all taken into account when analyzing the performance of the broiler breeder hens on the different feed programs (Rama Rao et al., 2000). Quality of the eggs produced was also analyzed for the different feed treatments.

Egg production was shown to be greatly impacted by the main energy source in their feed formulations (Rama Rao et al., 2000). The feed formulations that included foxtail millet or finger millet as the main source of energy had significantly reduced egg production compared to the feed formulations with maize, pearl millet, or broken rice as the main energy source. Foxtail millet and finger millet also showed a required increase of energy consumed per 12 eggs produced and had lower final weights compared to the other feed formulations.

The differences in broiler breeder performance and the costs of the feed formulations should be taken into consideration for any company determining their feed formulation (Rama Rao et al., 2000). Least cost feed does not necessarily mean it is the financially best approach to raising broiler breeders. The reason that least-cost feed may not be the most financially smart choice is due to the impact that the feed formulation has on the birds' performance. Assigning value to performance factors allows a company to fully evaluate what is best for their operations based off of performance needs and feed costs. One factor that this study did not take into consideration for the results of the different feed formulas is how they impact breeds of broiler breeders differently.

**Vaccinations and Probiotics Impact on Flock Performance**

Understanding the impact vaccination and probiotics can have on flock performance is crucial in determining the broiler breeder program that best fits within the operation and the needs of the company.

**Type of vaccinations.** Determining which type of vaccination and probiotics to use for a broiler breeder flock is a critical part of the management program of the birds. There are several different factors to take into consideration when determining the best approach for a broiler breeder flock, including the cost of the product and the impact it has on the health and performance of the flock. Several studies have been conducted focusing on both vaccinations and probiotics in order to determine how the products impact the broiler breeder birds and their performance.

A study was conducted with Ross-308 breeder birds for the duration of their flock up until 58 weeks of age and their progeny (Herdt et al., 2016). The purpose of the study was to analyze the use of two different reovirus vaccines on the hatchability of the eggs from the breeder birds. Performance factors of the broiler bird progeny of the two different groups of breeder birds were analyzed to determine the impact of the vaccination schedules.

Since breeder flocks range over such a long period of time, broiler breeder chicks had staggered placements to minimize the environmental and seasonal impact on performance of the birds (Herdt et al., 2016). While this approach does assist in minimizing the impact, the control group and experimental group did not have any of their flocks placed in the same months. For practicality purposes, there would be a benefit for the organization running this study to have the breeder flocks placed in different months for a more continuous inventory of eggs throughout the year. That being said, to truly say that the comparison between the control group and experimental has as limited variation outside of the independent variable it would be best to have one of each placed on the same day and to ensure that management of the barns adheres to the same management program. Placement of the barns is not mentioned in the article, which is an important factor to take into consideration due to the impact external environments can have. Also not mentioned is the barn design of the barns utilized in the study.

Vaccinations were distributed similarly for all birds included in the study (Herdt et al., 2016). The control group had intramuscular administration of live Nobilis Reo Vaccine 1133 at eight and Nobilis Reo Inac vaccine at sixteen weeks of age, while the experimental group received the Nobilis Reo Inac vaccine at both eight and sixteen weeks of age. Samples were taken at 30 weeks of age to test for reovirus using the Idexx Reo Ab test. All eggs produced by the broiler breeder hens were collected on a daily basis.

*T*-tests were utilized when determining that the trial breeder flock showed significance in the difference of averages of hatchability of eggs (Herdt et al., 2016). The average hatchability of the trial flock was 2.88% higher than the control flock. An improvement of 2.88% in hatchability could equate to additional birds placed each week for processing after the life of the broiler flock, leading to a potential increase in sales and profitability. The progeny of the trial broiler breeder flocks showed lower mortality rates by 18.2% for the life of the flock; however, mortality after the first week to the end of the flock did not show any significance (Herdt et al., 2016). This difference clearly shows that the improvement in livability in the broiler chicks takes place in the first seven days of the flock, which is often the targeted period of time for vaccines (FAO Agricultural, 2003).

**Probiotics.** Bozkurt, Kűcűkyilmax, Ayhan, Cabuk, and Catil (2011) conducted a study to determine how preparing probiotics in three different ways would impact the performance in broiler breeder hens. There were 480 layer hens equally distributed with four different feed treatments in the study. Three of the feed treatments had different probiotics included, while the fourth was a control without any added. Adjustments were made throughout the 28 weeks of the trial as needed based off of mortality.

The performance factors focused on in the study was body weight, livability, egg production percentage, egg weight, egg mass, feed consumption, feed conversion ratio, cracked-broken egg rate percentage, shell weight percentage, shell breakage strength, shell thickness, settable egg rate percentage, total number of settable eggs per hen, fertility percentage, hatchability of fertile eggs percentage, hatchability of total egg set percentage, chick weight, and total number of chicks per hen (Bozkurt et al., 2011). These performance factors are similar focuses to what was studied by Yuan, Roshdy, Y. Guo, Wang, and S. Guo (2014). The conclusion was that the different feed treatments, with probiotics in the trial feeds, caused differences in the performance factors of the hens (Bozkurt et al., 2011). This conclusion is followed up with a call for more research, which is appropriate since there are too many outside factors that could be impacting the performance of the hens besides the feed treatments.

This study does not discuss the costs of implementing the different feed treatments in order to obtain the improved performance of the layer hens. There needs to be further study supporting the statement that the feed treatments caused the performance improvement. Even if it would be determined that the feed treatments caused performance improvement, there is no financial analysis included in this study to determine what the rate of return would be for implementing the probiotic treatments. While least cost formulation of feed has the potential to lead to lowered performance for layer hens, the financial justification of adding additives and probiotics would depend on what the performance increase would be for the layer hens.

**Level of vitamin A and the impact on vaccination success.** One study had conducted two experiments with broiler breeder hens trialing feed treatments (Yuan et al., 2014). Different levels of vitamin A in the broiler breeders' feed were trialed in the first experiment. While performance factors were measured, New castle disease virus was also tested for at 12 and 20 weeks of age. The second treatment had four different feed treatments trialed with different levels of vitamin A, but instead of Newcastle disease, peripheral blood lymphocyte proliferation, total bilirubin, and aspartate amino transferase were all tested for at 12 weeks of age. The second experiment focused on higher levels of vitamin A than the first experiment.

The broiler breeder hens were artificially inseminated, rather than keeping the roosters in the same location as the hens for natural fertilization (Yuan et al., 2014). This approach allowed the researchers to standardize the fertilization, rather than adding in an additional factor of rooster performance. However, this approach for fertilization may cause variances in the results compared to what would happen in a real-life design.

Based off of the results of the study, the recommendation was that broiler breeder hens receive no more than 35,000 IU/kg of daily supplementation of vitamin A (Yuan et al., 2014). With the results of the study showing that hatchability of eggs produced by broiler breeder hens on 45,000 IU/kg of daily vitamin A supplementation, the combination of increased cost for feed produced and reduction in eggs hatched would have a negative financial impact on a poultry producing company. The higher levels of vitamin A were shown to negatively impact the ability for calcification of the eggs produced, which is in contrast to companies providing additional calcium to breeder broiler hens as they become an older laying flock to improve egg shell quality. Too thin of egg shells can cause cracking which leads to an entry point for bacteria. With bacteria present in the egg shells, the broiler chicks will exhibit increased three-day mortality.

**Environment and Housing Design Impact on Flock Performance**

The raising of poultry and their production of eggs has a significant impact on the environment. The level of impact that raising poultry and their production of eggs has on the environment depends greatly on a varied amount of factors that have already been taken into consideration for the best performance and financial impact for a company. A study conducted in the Alborz province of Iran used the life cycle inventory method of determining the environmental impact that the raising of poultry can have (Ghasempour & Ahmadi, 2016). The method that was used takes all inputs and outputs of the process into consideration to determine how much of an environmental impact there is.

The purpose of the study was to determine the environmental impact for feed production that is consumed by chickens and to determine the environmental impact of egg production at the location of the producing (Ghasempour & Ahmadi, 2016). A total of 52 active farms were included in this study. The life cycle assessment was conducted through the use of SimaPro software, which has the necessary information and capability to take the raw data and develop the final assessment.

While many different factors were taken into consideration for the life cycle inventory, the water consumption and feed consumed are two factors that have been shown in many other studies to impact the performance of the broiler breeder birds and their progeny (Ghasempour & Ahmadi, 2016). Water consumption has been shown to increase with the increase of feed consumption, therefore indicating that a greater impact on the environment is being made dependent on the diet and feed composition. To be environmentally conscious and still produce the most effective broiler breeder management program, the feed composition must be critically analyzed for minimal impact through the spreading of the manure (Pelletier, 2017). Strict adherence to manure spreading needs to be followed closely to reduce contamination. Ghasempour and Ahmadi (2016) discussed the impact of transportation in agriculture production. Understanding this correlation allows one to draw the conclusion that the negative impact of raising poultry can be reduced through limiting distances for travel and the performance factors of the eggs that the layer birds have produced can also be improved through strategic placement of layer facilities and hatcheries.

While the study conducted in Canada by Pelletier (2017) is not an exact comparison to companies in other countries due to the fact that the farms used in the study are not as vertically integrated as companies in other countries such as the United States, it does discuss important aspects of the life cycle of raising broiler breeders. The level of vertical integration will influence the supply chain activities that impact the environment in the raising of broiler breeder birds through placement of facilities and programs implemented in the management of the birds. With closer placement between company facilities and farms, the impact done to the environment through transportation can be reduced by reducing the amount of travel. Feed programs in broiler breeder management can be impactful due to the composition of the feed. This is because depending on the feed formulation, the type of product that is grown for the feed can either be more or less harmful than other options.

For broiler breeder facilities, Pelletier (2017) included chicks, feed, water, energy, manure management, and spent hen disposal as the factors that impact the environment. While this is a good list, it does not take into consideration the impact of feathers shedding on the surrounding environment and how rodents that burrow into the facilities are impacted. This list includes spent hen disposal but does not mention culls or mortalities that occur during the life of the flock.

Down feathers are also not included in the life cycle assessment by Pelletier (2017) for hatcheries. This would be one factor that would need to be assessed for hatcheries in the United States, due to the requirement of the Environmental Protection Agency of all hatcheries including the down feathers in their environmental audits conducted (Environmental Protection Agency, 2000). Overall it appears that the assessment that Pelletier provides has missing characteristics that need to be taken into consideration in the management of poultry operations.

Similar to the study conducted by Ghasempour and Ahmadi (2016), Pelletier found that the feed used in raising of broiler breeders has the most impact on emissions to the environment.

**Production Scheduling**

With the transition to lean production, companies have had to rethink how they schedule their production lines. The more levels to a production system for a company, the more crucial it becomes in a lean world to schedule appropriately. One example of a lean tool that can be implemented in a production environment is just-in-time (JIT), which is an example of a pull system to reduce excess within the production system (Miltenburg & Sinnamon, 1989).

The study focused on discussing production systems with multiple levels of production (Miltenburg & Sinnamon, 1989). Figure 2 shows an example of what a multi-level production system may be outlined as, but it is only one example on how a production system may be designed. With the JIT approach to a multi-level production system, the final level of production becomes the level that controls production of all other products and components at the other layers of production. What this would mean for a live production environment of poultry is the orders for processed chickens would work its way backward in the system to determine the number of breeder hens that need to be purchased to produce the broiler chickens at the correct time for processing the correct amount for the number of customer orders placed. Backward scheduling is the most appropriate form of scheduling to implement in a live production environment, in order to allow the company to take advantage of utilizing a JIT production system. This form of scheduling is when one begins at the end goal of products produced, and work backward to determine when the different points of the processing should take place.

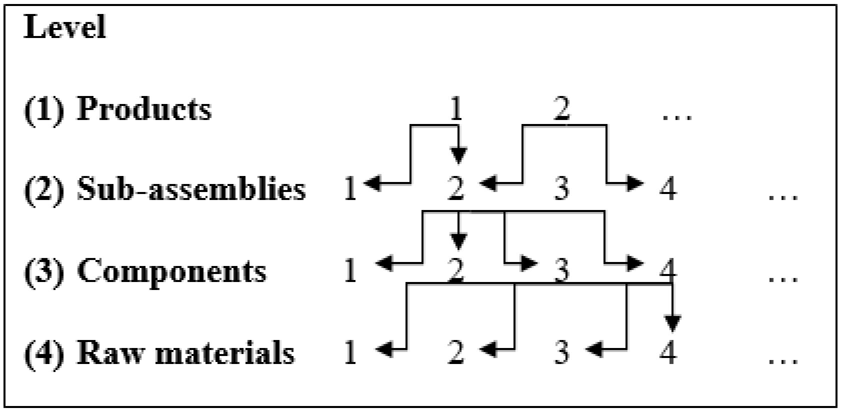


*Figure 2.* Multi-level just-in-time production system. (Miltenburg & Sinnamon, 1989)

The problem in JIT production system scheduling that Miltenburg and Sinnamon (1989) focused on was how to determine the sequence schedule when there are multiple products being produced at the facility. They discussed focusing on the goals of leveling the total time on the assembly to have a more even time spent at each station and another goal of how to maintain predictability of how many of each part is to be used in each level of the multi-level production system. In order to determine how to fulfill the first and second goals, they developed algorithms and heuristics that could be utilized in a multi-level production system. Their algorithm can be compared to the one that was first proposed by Toyota in 1983.

Toyota's algorithm only focuses on two levels of a production system, which is in contrast to Miltenburg and Sinnamon's (1989) algorithm that is usable for up to four levels. Li, Susarla, Karimi, Shaik, and Floudas (2010) analyzed short-term scheduling for non-continuous processes. This analysis is a different approach to scheduling production of live product compared to the algorithms discussed by Miltenburg and Sinnamon (1989).

Li et al. (2010) conducted a study that examined five different production scheduling approaches developed in previous studies in order to determine any potential limitations of the different scheduling approaches for the unit-specific event-based models. An important take away of this study is that the best approach to scheduling for different processing environments is often times specific towards that particular processing environment. Capacity limitations and product variation for a company will impact which algorithm in production scheduling is the most effective.

**Financial and Cost Analysis**

For a company to be successful, leadership takes on a role to perform financial and cost analysis within the areas the lead. Different industries often times require different approaches to looking at the financials of the company. This requires that financial and cost analysis conducted for a company is to the appropriate formula, algorithm, and analysis for the situation.

The poultry industry is often times designed for individual farms to raise birds and they sell to a processing plant through an arrangement, often times a contracted relationship. In order to begin evaluating how this relationship works in Brazil, Mendes et al. (2014) conducted a study that compared performance of farmers and their socioeconomic status. This study also analyzed 15 different factors that the farmers rated for the researchers to calculate the impact utilizing a Problem Faced Index developed by Ali and Hossain (as cited in Mendes et al., 2014). The PFI was analyzed through the use of descriptive analysis and through the use of Pearson's coefficient of correlation at a 95% confidence interval.

All of the data used in this study was collected using a survey (Mendes et al., 2014). The surveys were distributed to 91 randomly selected farms that raised broiler chickens. All of the farmers lived and farmed in Brazil during the time of the survey in 2011.

The results of the analysis showed that the average age of the farmers fall around 45.25 years and tended to have lower education (Mendes et al., 2014). This study showed that 78.02% of the farmers received family help on their farm. The study conducted by Mendes et al. (2014)

found that while environmental difficulties was rated as the biggest challenge for the poultry producing farmers, it was found that unfavorable feed conversion was the second biggest challenge. Feed conversion is the second biggest challenge faced by the farms. It makes sense that these are the two biggest concerns faced by farmers, no matter their location in the world.

The outside environment essentially has the power to impact how the barn needs to be managed in order to maintain as optimal as possible of an environment within the barn for raising poultry (Hy-Line, 2016). Humidity, heat, and wind outside of a barn can impact how heating and ventilation is managed within the barn for an optimal poultry development. External environment is essentially the biggest factor that is outside of the farmers' control in the raising of the poultry, besides the genetics and conditions of the birds when hatched and placed in the barn. Also, indicating that feed conversion is the second biggest impact on financial success is consistent with the fact that the largest cost in producing poultry is feed. Also, another reason on why it would make sense that feed conversion is one of the biggest challenges for farms is because feed conversion for poultry is impacted nearly all factors when raising poultry.

In most companies that produce a product, ordering for products and a production schedule need to be compiled and reviewed on a regular basis. There are various algorithms to choose from in order to calculate costs and quantities in production environments. Wang, Tang, and Zhao (2010) discuss economic order quantity formulas. They compared five different economic order quantity formulas with different equational approaches to determining costs of the fuzzy variables. For the fuzzy variables included in the comparison of formulas, only ordering cost, annual holding cost, and annual demand were included as fuzzy variables (Wang, Tang, & Zhao, 2010).

Since not all types of potential fuzzy variables were included in the study, it limits the validity of the conclusion that the new formula for calculating economic order quantities with fuzzy variables is the most effective compared to the other for formulas that were included in the study (Wang, Tang, & Zhao, 2010). This comparison of these formulas and the potential use in algorithm simulations provides the opportunity for companies to formulate advanced production scheduling and accurate budget planning in advance. The usage of one of these formulas, or a similarly designed algorithm simulation provides the opportunity to develop a zero based budget with the most accurate information possible and allows leaders of the company to identify areas of improvement through variation between budget and actual costs.

**Summary**

There are several different factors that can impact the performance of a broiler breeder flock. A few of the performance factors that can be impacted include egg production, uniformity, fertility, hatchability, and mortality (Hy-Line, 2016). Feed formulations and frequencies that it is distributed at can often times impact several of the performance factors of a broiler breeder flock. Probiotics are something that can often be used as an additive within feed for the birds with the intent of maintaining a healthy flock (Bozkurt et al., 2011).

The health of the flock is yet another area that impacts how that flock can perform. Types of vaccinations used, how it is administered, and the age at which it is administered can impact the success at the vaccines for maintaining a healthy flock (Herdt et al., 2016). Beyond these factors, the environment that the birds are kept in has an impact on how that flock performs (Hy-Line, 2016).

In order for a company to take advantage of the different ways to improve performance, the must first be able to determine where performance is needed. Utilizing the different methods of financial and cost analysis utilized within the poultry industry is the first step to determining areas that can use improvement and what a reasonable goal for improvement should be. Before any of this can take place, leadership within the company must first make the critical decision on how they will schedule their production. With broiler breeder flocks, it is critical for the company to understand the pipeline of their product and the timeline in which final products of broiler chickens are needed to meet customer orders.

# Chapter III: Methodology

Company XYZ requires proper egg inventory management in order to best plan for their production schedule and meet customer orders on time. There has been a decrease of eggs produced compared to the predicted eggs produced for the active layer flocks, which has led to fewer eggs than needed and ultimately providing customers less than their orders placed for processed broiler birds.

Previous research focused on performance of flocks rather than best practices for management of egg inventory. While some predictive measures are mentioned for specific breeds, these predictions are heavily based on the average performance for a bird of that breed rather than predicting actual performance for a live bird. There has been limited study predicting a layer flock's performance based on pullet performance factors. Another purpose of this study was to determine if it would be possible to predict egg production of a layer flock based on performance factors of the source pullet flock.

The study tested whether or not egg production was predictable for layer flocks at Company XYZ through the use of descriptive statistics. Also tested was if there was a significant correlation between any of the source pullet flock performance factors and the egg production of the layer flock. In order to collect the data for these tests, historical data managed by Company XYZ on flocks was obtained.

## Subject Selection and Description

The sample of this study was all pullet flocks and layer flocks that were raised for Company XYZ between the placement dates of March 24, 2016, and November 3, 2017. Pullet flocks refer to flocks from the age of chick placement until they are moved into a layer barn at 20 to 21 weeks of age. Layer flocks refer to flocks of broiler breeder hens and roosters that are placed at 20 to 21 weeks of age and remain active until they are moved out as spent hens typically for Company XYZ at 63 weeks of age. This sample is a part of the larger population of all pullet and layer flocks of Company XYZ.

Included in this sample for the study, there were a total of 38 layer flocks and 26 pullet flocks. Each of the pullet flocks used in this study raised pullets to be placed in one of the layer barns that were also included in this study. Layer flocks were only included if all source pullet information could be located and included. These specific flocks were selected due to the availability of flock reports for data gathering.

**Instrumentation**

The pullet flock report, shown in Appendix A, was created and utilized by Company XYZ to collect pullet flock performance factors. Egg production numbers were collected at the hatchery and entered into the company's system, which allowed the information to be pulled through the egg receiving by entity report within the company's system. The egg receiving by entity report pulls the following information out: farm name, received date, flock age, complex entity number, eggs, egg class number, and hatchery number.

In order to determine the source pullet flock for each of the layer flocks, the pullet placement schedule was referred to and checked against the bonus report. The bonus report stated the information for the layer flocks' bonus, as well as the source pullet flock they received their birds from. The pullet placement schedule is what is utilized by the breeder department to track movements of birds from pullet placement to layer placement and layer load out. All of the data collected for this study was entered into single table for ease of analysis. Appendix B shows an example of how the table was designed for the final analysis.

**Data Collection Procedures**

The data for this study was collected through pullet flock reports and eggs received in the hatchery over a period of 99 weeks. All pullet flocks were placed between March 24, 2016, and June 6, 2017. All layer flocks were placed between August 15, 2016, and November 3, 2017. A total of 26 pullet flocks and 38 layer flocks were included in the study. The pullet flock report is completed weekly by service representatives of Company XYZ during their weekly visits to the flocks. Informed consent and privacy was not required since all flock information belongs to Company XYZ. All names of the growers for each flock and identification numbers were removed from the raw data to be reviewed by anyone other than an employee of Company XYZ. All information used was already accessible to employees of Company XYZ and not privileged information.

The pullet flock reports are kept by Company XYZ in physical paper copies. This information is in the process of being entered into a digital database for future utilization. Information pulled from the pullet flock report includes: farm name, dates, breed, beginning number of birds, weekly weight target, weekly actual weights, weekly mortality, weekly total live head, weekly total feed consumed, and weekly coefficient of variation. The adjusted egg production is determined by the number of eggs brought into the hatchery from the layer barn facility and then adjusted to assume all flocks at the same age for load out.

The data used for this study was collected during the flock's life each day. This information was validated by service representatives for the flocks to ensure accurate information required by contract and company standards. All service representatives and growers are trained for proper record tracking of information. There are three documents shown in Appendices C, D, and, E that are utilized for training new service representatives in order to ensure that all procedures were understood and followed properly. These documents are also utilized for regular verification that processes are followed for each individual barn. It is the breeder manager's responsibility to ensure that the broiler breeder service representatives are consistent and adhere to the procedures at all times.

The bonus paperwork for each individual layer flock that is prepared by the breeder accountant was collected to obtain the chicks per hen, adjusted hatch percentage, mortality from placement in the layer barn until 25 weeks of age, adjusted egg production percentage and the hatching eggs per hen housed performance factors. Figure 3 shows an example of the bonus paperwork that was utilized in this study to obtain critical information. Adjusted hatch percentage is when the breeder accountant adds the good hatching eggs in that were disposed in with all of the good hatching eggs that were not disposed and applies the standard hatch percentage by age of the bird provided by the company that the broiler breeder birds are purchased from. All of this information is calculated by the breeder accountant with information obtained during the life of the flock from the service representative. The breeder accountant receives the information from the service representative.

| | |
|---|---|
| Breed | COBB X COBB MX |
| Age at Time of Sale | 249 |
| Hens Housed (at time of Cap / 25 weeks) | 13,749 |
| Hatching Eggs Set | 2,109,345 |
| Hatching Eggs Sold | 68,640 |
| Production Adjusted to 280 hen days of age | 157,267 |
| Production Performance at time of sale | 172,462 |
| Adjusted Egg Production | 2,350,447 |
| Eggs per Hen Housed | 170.95 |
| Chicks hatched | 1,807,858 |
| Chick Adjustment for Eggs Sold | 53,539 |
| Hatch Adjustment for Machine Problems | 0 |
| Hatch on Eggs Set and Sold | 84.46% |
| Hatch Adjusted to 280 hen days of age | -0.93% |
| Hatch Performance at time of sale | 118.56% / -0.78% |
| Adjusted hatch | 84.68% |
| Chicks per Hen Housed | 114.76 |

*Figure 3.* Example layer flock bonus sheet.

Figure 4 shows an example of the capped flock report that is prepared by the breeder accountant is where the coefficient of variation information and bird weights for males and females can be found at 25 weeks of age. The number of weeks a flock is in a pullet barn is calculated by taking the difference between layer barn placement date and the source pullet barns' placement dates. The percent of weight increase from 16 to 20 weeks of age is calculated by taking the difference between the 20-week weight and the 16-week weight before dividing that number by the 16-week weight. The 4 week weights, 12 week weights, 16 week weights, and 20 week weights could be found on the pullet flock report that is filled out by the service representatives.

| | | |
|---|---|---|
| Breed Code: COBB MV | | |
| Number Capped | Hens: 13,051 | Cox: 1,059 |
| Weight 4 Weeks | Hens: 1.24 | Cox: 1.32 |
| Weight 12 Weeks | Hens: 2.72 | Cox: 3.75 |
| Weight 16 Weeks | Hens: 3.42 | Cox: 5.07 |
| Weight 20 Weeks | Hens: 4.75 | Cox: 6.52 |
| Weight Capitalized | Hens: 6.41 | Cox: 7.64 |
| Feed Left on Farm | Hens: 11 Tons | Cox: 0 |
| Pullet Age 20% Production: | 25 weeks and 3 days | |
| Coefficient of Variation at Capitalized | Hens: 9.7 | Cox: 6.2 |

*Figure 4.* Example capped flock report.

The information needed to calculate the amount of feed fed to a good female pullet capitalized was found in the capped flock report. This the total consumed pounds of feed from hatch until 25 weeks divided by the total number of hens capped. Feed fed to a good female pullet capitalized is important to understand the hens' feed conversion and the impact that has on egg production.

The information collected by the service representatives was obtained during the duration of the flocks. All broiler breeder service representatives are trained to perform their job, typically lasting approximately one year before operating completely on their own. In order to collect the information, all flocks are visited a minimum of once a week. During their weekly visits while the birds are in the pullet barns, service representatives gathered the necessary data to complete the pullet flock report. The information gathered to complete this report included age of the flock, target weight for the flock at the current age, actual weight of the birds, mortality, number of live birds at the current age, feed consumed, coefficient of variance, and the uniformity of the flock.

Broiler breeder service representatives gathered data during the life of the flock while the birds were placed in layer barns. The information that they gathered on a weekly basis included mortality, feed consumed, number of cull eggs, and the overall health of the flock. Service representatives collected weights, uniformity, mortality, coefficient of variation of all layer flocks when they capped at 25 weeks old.

**Data Analysis**

The first analysis was analyzed through the use of descriptive statistics to determine egg production predictability. This included reviewing the following information: mean standard error, median, mode, standard deviation, sample variance, skewness, range, minimum, maximum, and confidence level. Determining if egg production was predictable was completed through using Minitab 18 Statistical Software to run an I-MR Chart and determine if data points indicated a predictable process. Regression was calculated to determine if correlation between age of flock and eggs produced were significant.

Inferential statistics were utilized to determine whether there was any relationship between the different factors and egg production. Regression lines were run between egg production and each individual pullet flock factor to determine if any correlation was significant. The Pearson correlation coefficient was calculated to determine the strength of the correlation.

Minitab 18 Statistical Software was utilized to run all analyses for this study. Rights to utilize this program were held by Company XYZ and maintained by the coordinator of operations excellence. Appendix F displays the graphs created within Minitab 18 Statistical Software. These graphs were utilized to interpret the data and determine the meaning of the analyses. In order to create these graphs, all data was entered into Minitab and regression analyses were run for adjusted egg production percentage compared to the other factors.

Figure 5 shows an example of a process behavior chart in which the process is predictable. This type of chart will be run for egg production to determine if egg production is a predictable process. Should the process behavior chart show that egg production is predictable, it is at that time that analyses can be conducted to determine if there are correlations with other factors and egg production. Without a predictable process, a correlation with other factors would be not statistically indicate a predictive relationship.

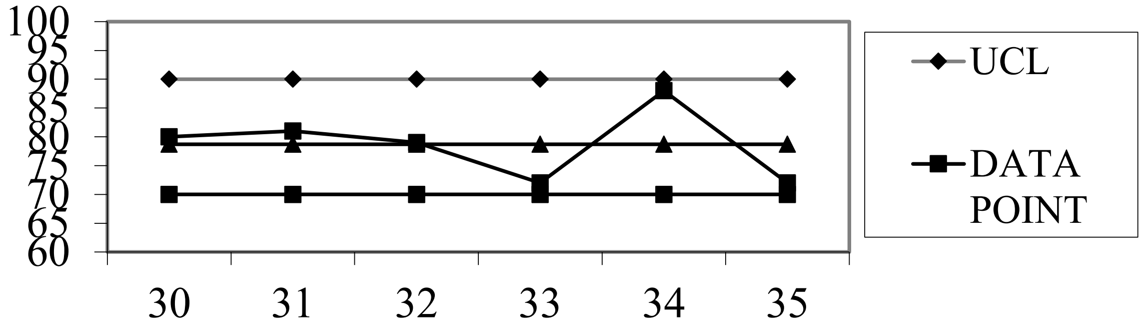


*Figure 5.* Example of a predictable process behavior chart.

Figure 6 shows a relationship between two factors that is not statistically significant. The higher the p-value in the analysis, the less statistically significant of a correlation there is between the two factors. Should the results of the pullet factors and adjusted egg production have a graph that is similar to Figure 4, the correlation will be found to be not statistically significant and therefore the pullet factor would not be predictive of what adjusted egg production would be.

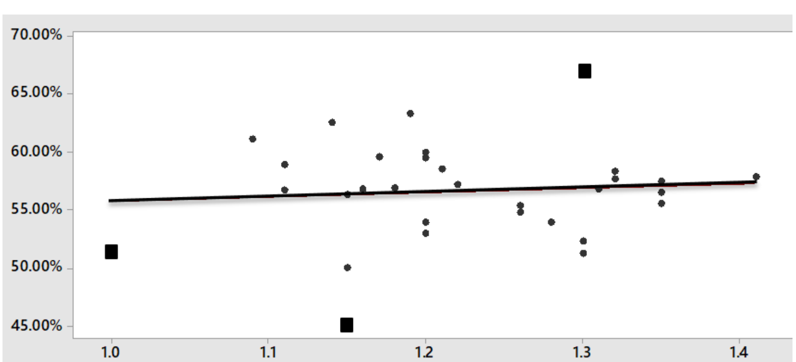


*Figure 6.* Example of a correlation not statistically significant.

Figure 7 displays a graph in which two factors have a correlation that is statistically significant. When analyzed, if the pullet factor and adjusted egg production percentage shows a correlation similar to Figure 7, the correlation will be found to be statistically significant. This correlation will not necessarily indicate causation, but may be utilized to predict adjusted egg production percentage based off of the pullet factors exhibited.

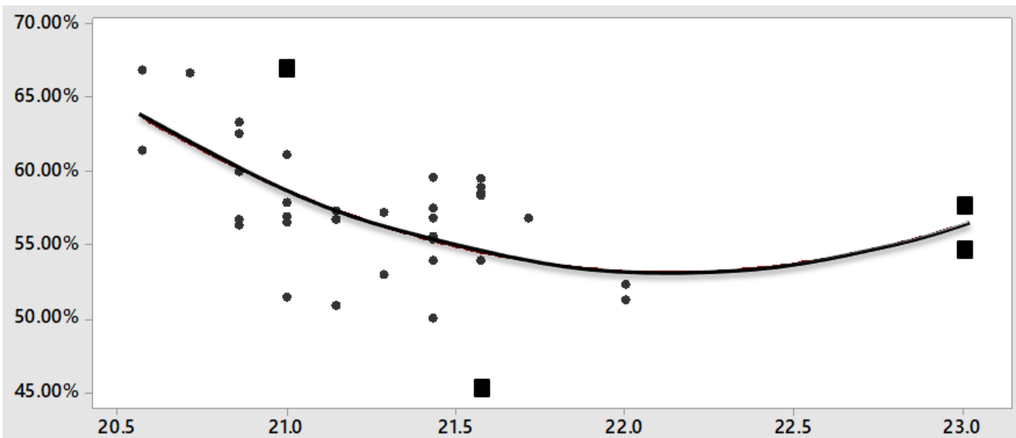


*Figure 7.* Example of statistically significant correlation.

**Limitations**

Only flocks that were raised for a specific complex of Company XYZ were included in this study, and, therefore, the results are only applicable to flocks raised for this complex of the company. Due to the longevity of flocks included in the study, there were potential differences in flock management and feed programs. Only 38 layer flocks were included in this study. A larger sample is needed for a strong case towards all of the statistical analyses that were ran for this study.

**Recommendations**

For better data analysis, the study should be designed before placing the flocks rather than pulling historical data to analyze. This will prevent any management changes that could impact the results of the different flocks. The type of feed and vaccination schedules should be determined at the beginning and kept standard for all pullet and layer flocks. For ease of analysis, one pullet barn should be placed in one layer barn. Also, a layer barn should receive all of their hens from one pullet barn. The reason it would be beneficial to have a layer barn receive all of their broiler breeder birds from one pullet barn is for an ease of analysis and assurance that all of the broiler breeder birds would come from a barn with the same pullet factor numbers.

A larger study should be conducted to increase statistical strength of the results. With a larger sample size, results of a larger study would have the potential to be applied to a whole population. Company XYZ should run this study utilizing information from all of its complexes in order to apply the information gained to all future flocks placed.

**Summary**

The subjects included in the sample of this study were 26 pullet flocks and 38 layer flocks raised for Company XYZ, placed between March 24, 2016, and November 3, 2017. The data used in this study was historical data pulled from pullet flock reports, egg receiving by entity reports, pullet placement schedule, capped flock reports, and flock bonus reports. This information had been collected during the duration of the flock by employees of Company XYZ.

The information utilized in this study was collected through the breeder accountant, who is responsible for calculating the flock bonus reports. The information utilized by the breeder accountant for calculation and record keeping is originally provided by the broiler breeder service representatives.

Minitab 18 Statistical Software was utilized for all data analysis for this study. The first intent was to determine if egg production is predictable. Once that was calculated, inferential statistics were used to analyze the relationships between adjusted egg production and the pullet factors that were collected. In order to interpret the results, the graphs and raw data produced by Minitab 18 Statistical Software were reviewed.

# Chapter IV: Results

Company XYZ requires egg inventory management in order to produce the proper amount of broiler birds for processing at the weights required by the sales department. The current egg inventory management system is not as accurate as the company would prefer. Company XYZ needs to determine which factors would assist in accurate egg production predictability.

Company XYZ will utilize the results of this study to hopefully improve egg inventory management through an improvement in predicting egg production of layer flocks. In order to achieve this, several analyses were run to determine if any correlations between pullet flock factors and adjusted egg production percentage existed. Utilizing pullet flock factors to predict egg production would allow Company XYZ to predict egg production a few months in advance of the end of the flock.

Minitab 18 Statistical Software was utilized to determine the results for all analyses. Since egg production was determined to be predictable, pullet factors were then tested for correlation with adjusted egg production. Adjusted egg production is when egg production for each flock is adjusted to what the number would be at 65 weeks. This allows all flocks to be analyzed with data for the same production age.

## Subject Selection and Description

Pullet flocks and layer flocks selected for this study were placed between the dates of March 24, 2016 and November 3, 2017. A total of 26 pullet flocks and 38 layer flocks were included in the data. All broiler breeders included in this study were from Company XYZ located at the same facility. Selection was based on the availability of flock reports for data gathering through the reports utilized.

## Instrumentation

Pullet flock performance factors were gathered off of the pullet flock report (Appendix A). Mtech Systems is utilized by Company XYZ to maintain performance and flock information for all broiler breeder flocks. The Egg Receiving by Entity report within Mtech was used to pull the egg production information for each flock to determine egg production predictability and whether the process is in control.

Pullet move documentation from the breeder department was utilized to pull information regarding which pullet flocks were moved into which layer facilities. This information was entered into an Excel document to assist in utilizing inferential statistics to determine the relationship between any of the performance and flock factors with egg production.

## Data Collection Procedures

Each broiler breeder flock required the total eggs produced per capped hen in order for the egg production to be determined as predictable. First, an Excel document was created that arranged information so that the total number of eggs received into the hatchery by a flock within one week was recorded as a data point. The total number of hens capped for that flock was inserted in a column next to the flock identification information, the age at the time of the eggs received, and the total number of eggs received. One column had the formula of total eggs received divided by the total number of hens capped for that flock. This allowed the number to be a fair comparison between flocks.

Data for determining if egg production is predictable was collected through the company system from the receiving date of May 21,2017 up to the date of July 8, 2018. Age of the flock at the time of the eggs received was recorded. Each data point was for the total eggs received at each week of age for the flock.

## Data Analysis

Egg production was first analyzed to determine predictability. Once the results were reviewed, pullet flock factors were then analyzed in conjunction with adjusted egg production percentage.

**Egg production predictability.** Determining that egg production is a predictable and normal process is necessary before determining if there is any correlation between adjusted egg production and pullet flock factors. Adjusted egg production is the egg production equalized to the same age for all broiler breeder flocks included in the analysis.

***Analysis.*** To determine if egg production is predictable, an analysis of variance was run. This analysis was run in Excel, utilizing the data analysis feature. The following information was reviewed in relationship to egg production: mean standard error, median, mode, standard deviation, sample variance, skewness, range of values, minimum value, and maximum value. All other analyses for determining egg production predictability were run in Minitab 18 Statistical Software. Process behavior charts by age and an individuals' moving range chart were run to determine predictability of adjusted egg production percentage of layer flock. A normality test was run for adjusted egg production.

***Results.*** The analysis of variance provided a 6E-176 p-value. This indicates that the age of the broiler breeders significantly correlates with the flock's egg production. The result of the process behavior charts by age indicated that within each age group the egg production was predictable, as shown in Figure 8. The first and second graphs of Appendix F review both of the graphs produced for egg production analysis. There were 12 outliers out of 1,402 data points, which is 0.86 percent of the data points. The individuals moving range chart for adjusted egg production percentage of a layer flock showed that the process is predictable. The normality test shown on the third graph of Appendix F of adjusted egg production showed a p-value of 0.124. These results indicated that it is possible to analyze for correlation of pullet flock factors with the adjusted egg production percentage.

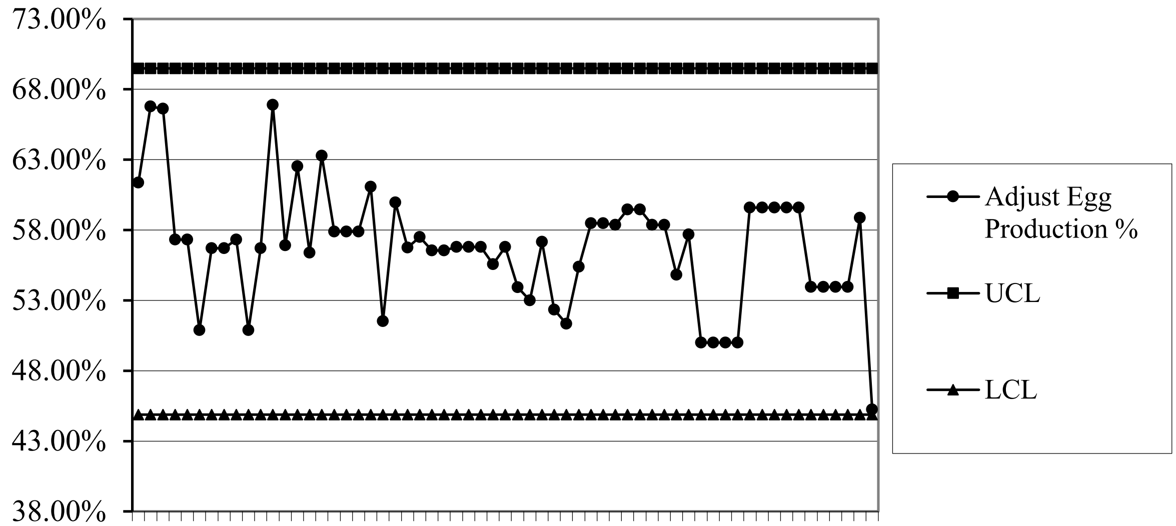


*Figure 8.* Individual moving range chart for adjusted egg production.

The mean standard error for eggs produced per hen was 0.0288. The median eggs produced per hen was 3.8809. The mode for eggs produced per hen was 3.1038. The standard deviation for eggs produced per hen was 1.0802. The sample variance for eggs produced per hen was 1.1669. The skewness for eggs produced per hen was -0.3102. The range for eggs produced per hen was 7.4257, with a minimum of 0 and a maximum 7.4257. The purpose of this analysis was to determine if egg production was a predictable process within the sample in order to analyze for correlations with pullet flock factors. Based on the individual moving range chart, with all points falling within the upper and lower control limits, egg production of this sample is considered predictable.

**Pullet flock factors and adjusted egg production relationship.** Determining the correlation relationship between pullet flock factors and adjusted egg production is critical for improving egg production projections.

***Analysis.*** All analyses for evaluating the correlation relationship between pullet flock factors and adjusted egg production percentage were run in Minitab 18 Statistical Software. The number of weeks that the broiler breeders were in the pullet barn before being moved to the layer barn was compared to adjusted egg production utilizing simple regression with an alpha level of 0.10. Female broiler breeder weights at week four were compared to adjusted egg production utilizing simple regression with an alpha level of 0.10.

Female broiler breeder weights at week 12 were compared to adjusted egg production utilizing simple regression with an alpha level of 0.10. Female broiler breeder weights at 16 weeks were compared to adjusted egg production utilizing simple regression with an alpha level of 0.10. Female broiler breeder weights at 20 weeks were compared to adjusted egg production utilizing simple regression with an alpha level of 0.10. The weight turn-up percentage for female broiler breeders from weights at 16 weeks to weights at 20 weeks were compared to adjusted egg production utilizing simple regression with an alpha level of 0.10. Female livability from placement at the layer barn until 25 weeks of age at cap were compared to adjusted egg production utilizing simple regression with an alpha level of 0.10.

Only one data point per layer barn was utilized for each of the analyses since all of the factors. A fit model and optimize response was run using adjusted egg production percentage as the response variable and the continuous variables were weeks in pullet barn, female broiler breeder weights at 20 weeks, and the capped female broiler breeder weight at 25 weeks. The weeks the birds were in the pullet barn and the female broiler breeder weights at 25 weeks were included in this analysis due to their significance found with adjusted egg production percentage. Female broiler breeder weights at 20 weeks of age were included in this analysis due to the p-value of the correlation between this factor and adjusted egg production percentage was the lowest out of all of the analyses found to be not statistically significant in the correlation.

***Results.*** Several of the analyses ran were found to be not statistically significant. Those that were found to be not statistically significant in correlated with adjusted egg production percentage included female broiler breeder capped mortality from layer placement to 25 weeks, female broiler breeder weights at 4 weeks, female broiler breeder weights at 12 weeks, female broiler breeder weights at 16 weeks, female broiler breeder weights at 20 weeks, and the female weight turn up percentage from 16 weeks to 20 weeks.

The relationship between adjusted egg production percentage and female broiler breeder bird's capped mortality from layer placement to 25 weeks is not statistically significant with a p-value of 0.256, as shown on the fourth graph of Appendix F. With a p-value this high, there is not enough of a relationship between the mortality and adjusted egg production percentage to utilize this information for predicting what egg production will be based off of the mortality of the pullet flock. Female broiler breeder weights at four weeks and adjusted egg production percentage was shown to not be correlated with a p-value of 0.656, as shown on the fifth graph of Appendix F. With an even higher p-value for weights at four weeks compared to the mortality, this pullet flock factor is even less likely to accurately predict egg production based off of the weights at four weeks.

The relationship between adjusted egg production percentage and the female broiler breeder weights at 12 weeks is not significant with a p-value of 0.87, as shown on the sixth graph of Appendix F. With a high p-value there is very little correlation between the weights at 12 weeks and the adjusted egg production percentage, indicating that the weights at 12 weeks would not assist in predicting the value of the adjusted egg production percentage. The relationship between adjusted egg production percentage and the female broiler breeder weights at 16 weights is not statistically significant with a p-value of 0.118, as shown on the seventh graph of Appendix F. While the p-value is lower than many of the other pullet flock factors analyzed, the 16 week weights do not have a low enough p-value to indicate that adjusted egg production percentage could be predicted only with this information.

The relationship between adjusted egg production percentage and the female broiler breeder weights at 20 weeks is not statistically significant with a p-value of 0.165, as shown on the eighth graph of Appendix F. Having a p-value higher than 0.15 indicates that the weights at 20 weeks cannot be utilized on their own to predict adjusted egg production percentage of the flock. The relationship between adjusted egg production percentage and female weight turn-up percentage is not statistically significant with a p-value of 0.836, as shown on the ninth graph of Appendix F. A p-value of 0.836 is very high and indicates that the weight turn-up percentage cannot be utilized to predict adjusted egg production percentage for a flock.

The only two variables that were statistically significant included the number of weeks the broiler breeders were in the pullet barn and the female broiler breeder weight at 25 weeks. Figure 9 shows adjusted egg production percentage and the number of weeks in the pullet barn with a correlation of p-value of less than 0.005. This analysis can be seen on the tenth graph of Appendix F. A p-value under 0.05 indicates that the number of weeks the birds are in the pullet barn can be utilized to predict adjusted egg production percentage accurately for most flocks and should be included in any egg projection system. However, since the number of weeks a bird is the pullet barn is depended on the program being run, it is not recommended to utilize this number on its own for projections.

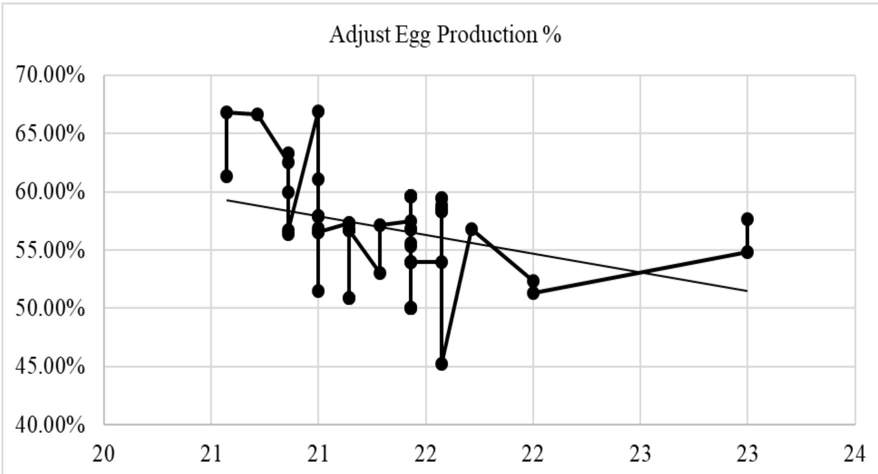


*Figure 9.* Adjusted egg production percentage and the number of weeks in the pullet barn.

Figure 10 shows the relationship between capped pullet weight and adjusted egg production percentage. The correlation is statistically significant with a p-value of 0.0017, as shown on the eleventh graph of Appendix F. The pullet weight at 25 weeks had the lowest p-value out of all of the pullet flock factors for determining the correlation relationship with adjusted egg production percentage. This factor is the best to include in a projection system for managing egg inventory due to its high correlation with adjusted egg production percentage.

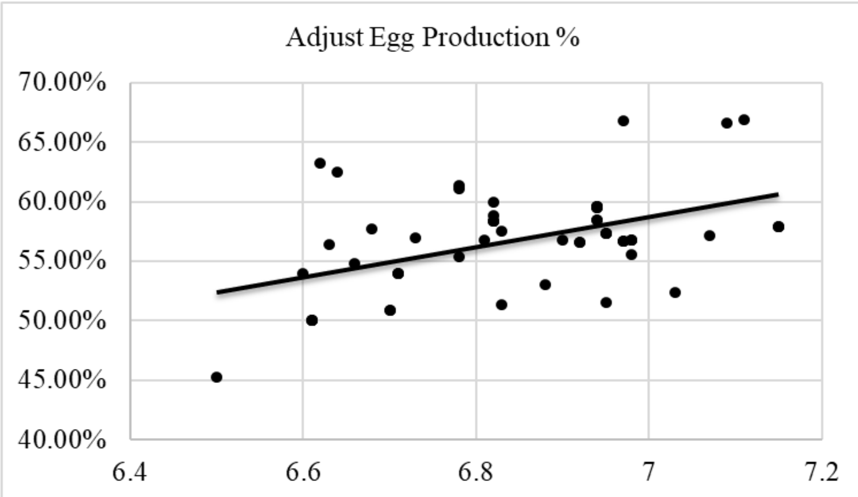


*Figure 10.* Adjusted egg production percentage and capped pullet weight at 25 weeks.

When combining the variables of weeks in pullet barn, capped pullet weight at 25 weeks, and female broiler breeder weight at 20 weeks; the correlation with adjusted egg production percentage is statistically significant with a p-value less than 0.001. To maximize adjusted egg production percentage, the prediction and optimization report shown in Appendix F on graph 12 reveals that 20.57 weeks in the pullet house, a target weight of 4.4 pounds for the female broiler breeders at 20 weeks, and a target of 7.15 pounds for the female broiler breeder hens at 25 weeks shows a prediction of 78.5 percent adjusted egg production. The correlation relationships that adjusted egg production showed with weeks in the pullet house, weights at 20 weeks, and weights at 25 weeks can be used to predict adjusted egg production of a flock with these pullet flock factors. By being able to predict the adjusted egg production numbers, egg inventory management potentially could be more accurate.

**Limitations**

Due to the time required for a broiler breeder to be raised from chick placement until spent hen loadout, only historical data was used for this study. This limitation means that the study could not be designed in advance and only the information that had been recorded could be used for the analysis. The number of different growers was limited in this study since the historical data collected was limited to those that grew for one complex of Company XYZ. This also prevents the applicability to other locations since external environments would be different at different locations.

**Summary**

Despite a recommended sample size of 100 for a quantitative study, this study was only able to include 26 pullet flocks and 38 layer flocks. The data used for analysis in this study were collected from reports maintained by Company XYZ. This information was collected by the broiler breeder service representatives and maintained by the breeder accountant.

First analyzed was egg production to determine if it is predictable in order to verify that it is possible to test for potential correlations between pullet flock factors and egg production of the layer barn. Egg production was found to be predictable and the correlation was statistically significant with the age of the layer flock. Only two pullet flock factors were found to statistically correlate with adjusted egg production percentage. These two flock factors were the number of weeks the broiler breeders were in the pullet barns before transferring to the layer barns and the female broiler breeder weight at 25 weeks of age.

## Chapter V: Discussion, Conclusion and Recommendation

This study was conducted at a poultry company with the intent of finding a way to improve egg inventory management. The purpose was to determine if there were pullet factors that could be utilized to predict egg production performance for the life of the flock. Ultimately, being able to identify correlations between egg production performance and pullet factors may eventually lead to developing a predictive database to improve egg inventory management.

The first chapter detailed the reason egg inventory management is critical for Company XYZ, ultimately impacting profitability for the company. Developing a database to predict layer flock performance is assumed that it would improve the accuracy of egg inventory management. Beyond egg inventory management, success in determining correlation between pullet flock factors and egg production performance would lead to areas of research to find ways to improve egg production by manipulating the source pullet flock.

Related literature was reviewed in the second chapter. The related literature included studies regarding feed and its impact on broiler breeder flock performance. The articles that were reviewed provide a general insight into how feed and, therefore, weight gained, can impact how the broiler breeder birds develop. In addition to how feed can impact broiler breeder performance, articles covering the impact of vaccinations and probiotics on broiler breeder performance were reviewed. How the design of the broiler breeder flocks' environment and housing impacts performance was reviewed in articles, showing that having different barn designs in different geographical areas has the potential to skew results of any study conducted with various types of barns in various areas. One can conclude from the review of related articles on these topics that changing how broiler breeders are raised will impact how they perform.

In order to connect the concept of broiler breeder performance and inventory management, articles were reviewed regarding production scheduling. This information assists in showing the impact inventory management can have on company performance. Further review of research articles on financial analysis was included in order to give a general understanding of how financial and cost analysis is utilized in the poultry industry.

The methodology of the study was discussed in Chapter III. The sample for the study was selected based on the availability of data. Multiple reports were used to gather data for the selected sample. The pullet flock report, egg receiving by entity report, pullet placement schedule, capped flock report, and the bonus report were all utilized for gathering the necessary data.

The information gathered from the reports for analysis was originally collected by broiler breeder service representatives during the life of the flock. This information was then maintained and inputted into the reports by the breeder accountant. The broiler breeder service representatives were trained to ensure consistency in reporting of information and visited the pullet and layer facilities to gather data on a minimum of a weekly basis.

An individual moving range chart was run in Minitab 18 Statistical Software to determine if egg production was a predictable process for the sample of data collected. Also analyzed for egg production were inferential statistics. In order to determine if the age of the flock and eggs produced were correlated, an analysis of variance and process behavioral chart was run in Minitab 18 Statistical Software. The Pearson correlation coefficient was utilized within Minitab 18 Statistical Software to analyze any potential correlation between adjusted egg production percentage and pullet flock factors. The pullet flock factors included number of weeks in the pullet barn, female broiler breeder weights at four weeks, 12 weeks, 16 weeks, 20 weeks, and 25 weeks; weight turn-up percentage for female broiler breeder weights from 16 weeks to 20 weeks, and female broiler breeder livability from placement until cap.

Chapter IV presented the results of the study. The correlation between egg production and with the age of the broiler breeder was statistically significant. Also, egg production was shown to be a predictable process. The only pullet flock factors that were found to be statistically significant it their correlation with adjusted egg production percentage were the number of weeks the broiler breeder birds were in the pullet barn before being moved to the layer facility and the female broiler breeder weight at 25 weeks.

The final chapter will discuss what is to be done with the results of the study. The conclusions drawn from the results of the analyses will be outlined. Also covered will be recommendations on how to improve upon the knowledge gained from this study.

This study sought to determine if there were any correlation between pullet flock factors and layer flock performance in regards to egg production. The results have shown that there are pullet flock factors that correlate with adjusted egg production percentage. Another purpose of was to determine if it was possible to create a projection database that was more accurate than the current system in place. With the results showing correlation between some pullet flock factors and adjusted egg production, a potential database could be created to accurately project egg production for layer flocks at the time of their cap at 25 weeks of age.

The creation of a database based off of this study's findings has the potential of increasing accuracy of egg inventory management and ultimately reducing excess eggs and egg shortages in the field, both of which impact the profitability of the company. Excess eggs can reduce the profitability by increasing egg-holding time at the hatchery which reduces the hatchability of the eggs and increases contamination. Egg contamination leads to increased mortality in the field. Egg shortages can lead to loss of profitability due to not filling orders placed by customers.

Adjusted egg production percentage was found to not be correlated with any of the following pullet factors: female broiler breeder capped mortality from layer placement to 25 weeks, female broiler breeder weights at 4 weeks, female broiler breeder weights at 12 weeks, female broiler breeder weights at 16 weeks, female broiler breeder weights at 20 weeks, and the female weight turn up percentage from 16 weeks to 20 weeks. This is supported by the p-values for each of the pullet factors resulting in a number above 0.05 in a simple regression in which each pullet factor was run against adjusted egg production percentage. The number of weeks the broiler breeders were in the pullet barns was found to correlate with adjusted egg production, as found with a p-value less than 0.005. Female broiler breeder weights at 25 weeks old correlated with adjusted egg production with a p-value of 0.0017.

The pullet factors of weeks in the pullet barn, capped pullet weight, and female weights at 20 weeks were used to determine their relationship and how they interacted with adjusted egg production percentage. A formula was found to predict adjusted egg production based off of the pullet factors of weeks in the pullet barn, capped pullet weight at 25 weeks, and female broiler breeder weight at 20 weeks. This formula was found utilizing a prediction and optimization report that found the correlation between these pullet factors and adjusted egg production was statistically significant with a p-value less than 0.001.

The information gained through the data and analysis of this study provides additional information in the relationship between the raising of the broiler breeders in the first 25 weeks and how that impacts egg production performance later in their life. While a specific formula based off of pullet factors is not prevalent in current literature, there is an emphasis on determining best practices for maximum performance with minimal financial investment. The information gained from this study can be used to design a larger study for creating a formula in order to maximize production and increase egg projection accuracy.

**Limitations**

One limitation of this study was that it was only conducted at one complex of Company XYZ which limited the population that the results can be applied to. With only historical information being used for this study, the information to be used could not be determined in advance. Without having control over the data gathered, the ability to analyze various factors has been limited.

**Conclusions**

Egg production was found to be predictable and, therefore, should be utilized for creating a system of accurate prediction for egg production. This study has shown that the number of weeks in a pullet house, female broiler breeder weights at 20 weeks, and female broiler breeder weights at 25 weeks correlate with adjusted egg production percentage for the duration of the layer flock. The correlations found in this study applied to only 38 broiler breeder layer flocks included and, therefore, is not strictly applicable to all pullet and layer flocks in poultry production. Since only one location was utilized for this study, the results are only applicable to flocks raised within the same location. This is primarily due to the breeder programs utilized by this location and the variation potentially found within other companies or complexes that can lead to variation in performance.

Based off of these results, there is possibility a of successfully creating an egg production projections system that can be tailored to predict based off of pullet factors. There were not enough data points to develop a projection formula that can be as accurate as required for accurate egg inventory management. More information is needed for additional conclusions to be made.

**Recommendations**

Company XYZ will test the formula developed by this study to determine the accuracy of predicting egg production of the layer hens based off of the pullet factors. The company will also continue to collect the data each time a layer flock is sold and run the regression analyses for each pullet factor against adjusted egg production to monitor if additional data points assist in a more accurate projection.

For future studies, it is recommended that the study be fully designed in advance to account for all independent and dependent variables. These flocks should be tracked over the length of the broiler breeder flock's life until spent hen load out. To test this study's questions again, it is recommended that future studies be designed so that the independent variables may be compared to control groups. If it becomes feasible, it is recommended to have pullet and layer flocks raised throughout the year and at different locations to account for environmental influences.

All flocks included in future studies should adhere to the same operating procedures and feed programs. For the clearest analysis and results, one pullet barn should fully place one layer barn. This may not be feasible for some operations and, if not possible, a plan should be made in advance to address the variations for the data collection and analysis.

A future study should be conducted with a larger sample size to verify the results of this study. This larger study may need to be extended to multiple complex locations in order to gain at least 100 data points within less than two years. It is not recommended to have a study that spans too long of a period of time since genetics of the broiler breeders change over time.

An additional factor to consider in future studies would be the breed of the broiler breeder pullets and the hatchery that they came from. The weight turn-up percentage should be looked into further with various weights included, to determine if egg production or fertility is impacted by the weight of the broiler breeder more or less than the actual weight of the birds at the time of first lay. In general, though by designing the study in advance it would be best to collect more data in order to conduct a detailed analysis in how the various factors impact egg production.

**References**

Bozkurt, M., Küçükyilmaz, K., Ayhan, V., Çabuk, M., & Çatli, A. U. (2011). Performance of layer or broiler breeder hens varies in response to different probiotic preparations. *Italian Journal of Animal Science, 10*(3), 162-169. doi:10.4081/ijas.2011.e31

Environmental Protection Agency. (2000). Protocol for conducting environmental compliance audits for municipal facilities under U.S. EPA's wastewater regulations. *Enforcement and Compliance Assurance, 2221*. Retrieved from https://www.epa.gov/sites/production/files/documents/apcol-wastewater.pdf.

FAO Agricultural. (2003). *Egg marketing: A guide for the production and sale of eggs*. Rome, Italy: FAO.

Ghasempour, A., & Ahmadi, E. (2016). Assessment of environment impacts of egg production chain using life cycle assessment. *Journal of Environmental Management, 183*, 980-987. doi:10.1016/j.jenvman.2016.09.054

Gholami, M., Seidavi, A., Oshea, C. J., Akter, Y., Dadashbeiki, M., & Bahar, B. (2017). Feeding regimen of breeder broiler hen influences growth performance of the broiler chickens. *Livestock Science, 203*, 132-135. doi:10.1016/j.livsci.2017.07.010

Herdt, P. D., Broeckx, M., Driessche, F. V., Vermeiren, B., Abeele, G. V., & Gorp, S. V. (2016). Improved performance of broilers and broiler breeders associated with an amended vaccination program against reovirosis. *Avian Diseases, 60*(4), 841-845. doi:10.1637/11464-070416-reg

Hy-Line. (2016). *Growing management of commercial pullets*. Retrieved from http://www.hyline.com/userdocs/pages/TU_PULLET_MGMT_ENG.pdf

Kabir, S. M. (2009). The role of probiotics in the poultry industry. *International Journal of Molecular Sciences*, *10*(8), 3531-3546. doi:10.3390/ijms10083531

Li, J., Susarla, N., Karimi, I. A., Shaik, M. A., & Floudas, C. A. (2010). An analysis of some unit-specific event-based models for the short-term scheduling of noncontinuous processes. *Industrial & Engineering Chemistry Research, 49*(2), 633-647. doi:10.1021/ie801879n

Mendes, A., Gudoski, D., Cargnelutti, A., Silva, E., Carvalho, E., & Morello, G. (2014). Factors that impact the financial performance of broiler production in southern states of Paraná, Brazil. *Revista Brasileira De Ciência Avícola*, 16(1), 113-119. doi:10.1590/s1516-635x2014000100016

Miltenburg, J., & Sinnamon, G. (1989). Scheduling mixed-model multi-level just-in-time production systems. *International Journal of Production Research, 27*(9), 1487-1509. doi:10.1080/00207548908942636

Pelletier, N. (2017). Life cycle assessment of Canadian egg products, with differentiation by hen housing system type. *Journal of Cleaner Production, 152*, 167-180. doi:10.1016/j.jclepro.2017.03.050

Pilgrim’s Pride. (2018). Minitab Statistical Software (18) [Computer software]. Retrieved from www.minitab.com

Rama Rao, S., Reddy, M., Praharaj, N., & Shyam Sunder, G. (2000). Laying performance of broiler breeder chickens fed various millets or broken rice as a source of energy at a constant nutrient intake. *Tropical Animal Health and Production, 32*, 329-338.

Soltanmoradi, M. G., Seidavi, A., Dadashbeiki, M., Laudadio, V., Centoducati, G., & Tufarelli, V. (2014). Influence of feeding frequency and timetable on egg parameters and reproductive performance in broiler breeder hens. *Avian Biology Research, 7*(3), 153-159. doi:10.3184/175815514x14025828753279

Yuan, J., Roshdy, A. R., Guo, Y., Wang, Y., & Guo, S. (2014). Effect of dietary vitamin A on reproductive performance and immune response of broiler breeders. *PLoS ONE, 9*(8), e105677. doi:10.1371/journal.pone.0105677

Wang, C., Tang, W., & Zhao, R. (2010). Analysis of economic order quantity under fuzzy environments. *Transactions of Tianjin University*, *16*(3), 229-234. doi:10.1007/s12209-010-0040-3

## Appendix A: Pullet Flock Report

| FEMALES | | | | | | | | | | MALES | | | | | | | | |
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## Appendix B: Data Table Design

| Layer Flock Number | Pullet Flock Number | Hatch Date | Weeks in Pullet Barn | 4 Week Weight (Female) | 12 Week Weight (Female) | 16 Week Weight (Female) | 20 Week Weight (Female) | 25 Week Weight (Female) | Weight turn Up % (Female 16-20 Weeks) | Hen Days | Adjusted Egg Production % |
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## Appendix C: Checklist to Achieve Goals – Egg Management

1 Egg sets should be calculated off of weekly broiler slaughter by complex.

2 Pullets should be calculated based off of company goal estimates on hatching eggs per hen.

3 Pullets and BREEDERS should be managed FOLLOWING PILGRIM'S BREEDER RECOMMENDATIONS AND PILGRIM'S ANIMAL WELFARE STANDARDS.

4 Production should be monitored weekly and action plans should be implemented on flocks that fall outside production goals.

5 Comparisons between actual production and projections will be performed weekly.

6 Curtain drops must be verified to be operational between flocks, and verified to be hooked up weekly.

7 Weigh bins/scales must be calibrated before each flock according to manufacturer recommendations.

8 Each house should have (depending on size) at least 2 fans set up on a timer to run during feed time, weather permitting. Fans should come on approximately 30 minutes before lights and run for 2-3 hours.

## Appendix D: Checklist to Achieve Goals – Fertility

1 A pre-placement check will need to be completed by the service tech prior to placement. If the conditions are not adequate for placement then an action plan will need to be carried out during the flock.

2 All nest pads must be cleaned or replaced when necessary.

3 Service techs will be required to weigh and flesh the necessary amount of birds to gain an accurate average according to the weigh schedule.

4 Weekly meetings between the service techs and breeder manager will be required to discuss the performance of the flocks inspected that week.

5 Male feeders will be lowered 10-15 minutes after lights come on until all hens are trained to the hen feeder

6 HEN feed must be RUN and CHARGED before lights come on.

7 Spiking will be used to maintain male ratios and optimum fertility.

8 Spiking males need to be moved directly from the pullet farm when being utilized on the farm for spiking

9 RESTRICTIVE GRILLS should be in place at the time of placement to prevent males from accessing female feed.

10 BIRDS NEED TO BE CAUGHT BY THE WINGS DURING VACCINATION AND MOVING. Birds should be transported at the proper times and temperature to ALLEVIATE stress. No more than two birds per hand will be handled.

11 All LIGHTING and ventilation programs must be followed in accordance with the standard program.

12 All cage doors must be in good working order to allow pullets to easily slide out when cage is rotated or cage doors will need to be opened manually.

13 Strive to have 10 males per feed pan or fewer. Feed levels in pans should be uniform and set to ensure the maximum number of pans are used. Pans need to be level from side to side and lines need to be level from end to end. The height of feeders and nipples need to be adjusted based on bird growth and the SOP.

14 Male feeder scales should be calibrated monthly. Hand weigh male feed when weights or fleshing do not correspond with current feed amounts. Female scales should be checked at beginning of flock.

# Appendix E: Breeder Playbook

## PLACEMENT TO 4 WEEKS OF AGE

1. Complete pullet pre-placement checklist
2. Flush and disinfect water lines
3. Calibrate feed AND bird scales prior to placement
4. Placement floor temps should be 90F
5. Place paper under nipple drinkers- remove after 3 days if not disintegrated
6. Starter feed crumble: 2.5 lb. per pullet, 3.0 lb. per male
7. Place 1 feeder lid per 85 chicks in comfort zones, or equivalent amount of feed paper- keep full and even at all times. Feed should last all day long through 2 weeks.
8. Place 1 supplemental drinker per 150 chicks, minimum, or equivalent placement of snap-on drinkers, easy-fills, or egg flats.
9. Placement targets: 14 birds/pan maximum; 4.7" chain/female minimum, 6"/cockerel, or manufacturers' recommendation. Future housing upgrade programs should address feed space deficiencies.
10. Hand-fill or flood the pan rows lowered at placement
11. Start picking-up drinkers on day 3, one third per day.
12. Start picking-up feed lids on day 7, removing 1/3 per day. If you are not able to get <u>all of the morning feed volume out</u>, you will need to use the lids longer than day 7. DO NOT FEED SMALL INTERVALS DURING THE DAY.
13. Weigh daily feed amounts after the first week
14. Feed every day until 4:3 or skip-a-day begins @ approximately 3 weeks.
15. While feeding every day, make sure 100 percent of feed distributed evenly in the morning feeding time. Hand filling may be required to accomplish this. Very important for early uniformity.
16. A minimum of sixty pullets (1 percent) and 20 males should be weighed weekly, three weeks and beyond, on the off-day. Birds can be group (bucket) weighed up to 3 weeks.
17. Lighting- .50-.75 foot-candles, evenly distributed with no gaps or shadows on the floor. Uneven lighting will cause hills and valleys in the litter, which impacts feed access.
18. There must be NO light leaks in the pullet house.
19. 23-24 hours of light x first 3 days (3+ foot candles). Then, 12 hours until skip feeding begins, then move to 8 hours.
20. Observe birds feeding as often as possible to verify even consumption and space
21. <u>Do not turn birds into the whole house until cocci cycling is complete and verified</u> by your vet (over time with your program).
22. Achieve 4 week body weights and CV's per guide, 1.0 for females and 1.5 for males.

## 5-15 WEEKS OF AGE

1. Pullet developer mash should be made from corn ground to approximately 1300 microns. If a consistent pullet mash cannot be manufactured, ask the mill to pellet/crumble the pullet developer feed. This should be discussed and remedied at the local level.
2. Developer feed should be free flowing, with no separation of ingredients, and should be uniformly consumed on all lines. Make sure fill pipes discharge feed into the center of the hoppers to prevent separation.
3. Verify that the outside to inside fill system can "keep-up" with all internal feed lines and keep them charged.
4. Maintain 8 hours of light, with no shadows on the floor, and zero light leaks.
5. Tech should observe feeding at least once every two weeks, or as often as physically possible.
6. Ventilation should accomplish comfortable bird behavior and dry floors. There should be no huddling, or panting pullets, at any age.
7. Water restriction should be used only as absolutely necessary to keep floors dry.
8. Handle and weigh each week. Sixty (1 percent) pullets and 20 males each time. Adjust feed amounts to accomplish weight goals. Birds should always be gaining, and we must not allow them to lose weight.
9. The key to this time period is achieving good uniformity. We must not get pullets heavy during this maintenance phase, or it will create over-fleshing of the breast, and under-deposition of fat reserve. Keep your pullets and males on standard.
10. Continue on skip-a-day feeding, or 4:3 for maximum feed volume and distribution.

## 16 WEEKS TO MOVE

1. Developer feed should be fed until 17$^{th}$ week of age, then begin on pre-breeder feed.
2. Continue to handle and weigh each week. Sixty, or 1 percent of pullets and 20 males.
3. Continue with 8 hour lighting program, no shadows, no leaks.
4. It is critical to achieve a minimum weight increase or "turn-up" of 30+ percent from the 16$^{th}$ week birthdate, to the 20$^{th}$ week birthdate.
5. 20 week female targets should be achieved: 4.70 lb. for female Cobb, 4.50 for female Ross, and 6.15 for males. WE ARE NOW ON THE THRESHOLD OF MOVING THESE PULLETS AND THEY MUST BE ON WEIGHT STANDARD WITH < 12 CV.
6. Remain on skip-a-day or 4:3 feeding until choking issues become a problem.
7. Within 7 days of move, pullets should be on 6:1, 5:2 or daily feeding.
8. Move flock between 21-22 weeks of age.
9. At move, the pullets should appear smooth and well feathered, with a uniform healthy appearance, and with uninjured foot pads

**MOVE TO 5 PERCENT PRODUCTION**

1. Flush and disinfect water lines, and calibrate all scales
2. Complete the breeder house pre-placement checklist; double check all equipment for stray voltage, check condition of nest pads, and rear nest skirts, and belts. All should be in great condition.
3. We should have a max of 5 hens per nest hole, ideally. If not, future housing updates should address this.
4. If slats are more than 20”, steps should be installed or some sort of intervention to ease the stress of high slats.
5. On move day, all female and male feeders should be charged with feed upon arrival, or as soon as possible after the birds are moved.
6. Pullets should get accustomed to being on the slats immediately, whether by hand-placing or driving them up. Hens should be fed immediately after they are all placed. Remain on pre-breeder until first egg, then move to B1 feed.
7. BOTH SEXES SHOULD BE TRAINED ON THEIR FEEDER AS QUICKLY AS POSSIBLE.
8. Do not be too aggressive with feed between moving and 25 weeks of age. Weekly increases of 0.5-.75 pounds per hundred should help keep mortality from becoming an issue.
9. Begin running hen feeder a minimum of 5 minutes before lights-on (<u>a complete loop</u>). Lower male feeder after lights come on. Make sure male pans are low enough for all males to access.
10. Watch the birds feed immediately after move, to make sure of good distribution and consumption.
11. <u>Techs should watch birds eat every 2-3 weeks</u>. Continue to assess feed quality, consistency, and consumption.
12. Start birds on 14 hours of light at move, always making sure to cover natural day length. Raise to 15 hours at 23 weeks, 16 hours at 25 weeks, and 16.5 at 26-27 weeks. Keep it simple.
13. Watch for slatting of the females, especially 24-25 weeks. Intervention must be used immediately if slatting recognized. Water management in scratch area, driving hens down to scratch area, removal and penning of males, etc. <u>This will dictate your flock’s fertility for the rest of their laying lives.</u> Slatting within a complex should be predicted and recognized and prevented before it starts!
14. We must be on-standard at 25 weeks. Cobb females 6.50, Ross 6.30. Males 7.70-7.90. This will help socialization and mating.
15. Handle and weigh approximately 60 females or 1 percent, and at least 20 original males each week.

**<u>5 PERCENT PRODUCTION THROUGH 32 weeks</u>**

1. Feed according to production.
2. Peak feed should be achieved no earlier than 70 percent production.
3. Peak feed should be 440-450 calories, approximately 34 pounds/100, both breeds.
4. Feed should be distributed as quickly as possible. <u>Make sure all lines stay primed from the fill system.</u>
5. Watch and record daily feed clean-up times. "Clean" is a dusting of fines remaining in the pan or chain trough. Feed times should be consistent and only vary slightly.
6. Make sure "cool down" ventilation begins about 1 hour before feeding. <u>Birds must not be panting while eating</u>. The number of tunnel fans needed to establish the "cool down" effect will be dictated by time of year.
7. Peak production will follow peak double yolk production by 12-14 days.
8. You may make the first feed cut the week after DY peak production. No more than ½ pound initial cut. Cuts should be gradual from that point forward. Some locations opt to cut feed AFTER peak hatching egg production. The key: birds must continue to gain incrementally, but not get heavy.
9. Track daily water consumption throughout the flock and make sure of no changes in pattern.
10. Farm egg coolers should be clean, well ventilated, maintained at 68-70F and 75-80 percent RH.
11. Place floor eggs in the racks so that they will be in bottom of hatchery setter (bottom of farm rack with Chickmaster, middle with Jamesway.
12. Hatching eggs=normal shaped eggs weighing 19 oz. per dozen (45 grams), minimum.
13. Hens and males must be kept on standard. Handle and weigh ½ percent of hens and 20 original males each week.
14. Hen mortality should not exceed .35 percent.
15. Hen and male fleshing should be 2.5-3.0.

**<u>32 WEEKS TO DEPLETION</u>**

1. Continue to observe birds feeding every 2-3 weeks, or as often as needed, to confirm distribution and that all hens and males have equivalent crop fills and that feed is not separating. Feed times should not drift, and should be maintained by adjusting feed volumes.
2. Females and males should continue to be weighed and handled every week until 45 weeks of age. Weigh ½ percent of the females (60 birds minimum) and 20 original males.
3. At 45 weeks of age, males and females should be weighed every 2 weeks.
4. We must keep hens and males ON STANDARD to achieve the best production and fertility. <u>Birds must make fractional, incremental gains in weight each week</u>.
5. House temps should not drift from the 65-75F range, ideally.
6. Continue using a cool-down program during feeding.
7. Scratch areas should be fully occupied, especially late morning and afternoons, with visible mating activity.

8. Males that are not active or unhealthy should be killed, including pretty boys.
9. Make sure dead birds are collected frequently. NO BIRDS UNDER SLATS.
10. Spike at whatever ages are necessary to keep 9-9.5 percent males, or you can use fertility as your marker for where the spikes need to go.
11. Difference in feed volume at peak production and depletion should about 10 percent. The key: do not let birds lose weight, or gain excessively.
12. Egg collection should occur at least 4 times/day, with the final collection in late afternoon.

**NOTES TO THE PLAYBOOK**

**Summary of Handling/Weighing Schedule (minimums):**

| | | |
|---|---|---|
| Placement to 32 weeks | weekly | 60 females, or 1 percent*<br>20 males |
| 32-45 weeks | weekly | 30 females, or ½ percent*<br>20 males (original) |
| 45 weeks to sell | semi-weekly | 30 females, or ½ percent*<br>20 males (original) |
| | | Whichever is less* |

**Using automatic scales (pullets and adults):**

Automatic scales are a great tool and are permissible for gathering weight data. However, the handling schedule to judge fleshing and development stays the same. Each breeder manager at complexes where auto scales are used should require some type of report or scorecard each time birds are handled, even if weights are obtained automatically.

**Weighing males:**

We cannot determine how to feed males simply based on weights alone. Make observations on posture (standing erect, good head development), number of culls, pretty boys, and overall uniformity. Also, if deficiencies in fleshing are observed, birds will need a feed bump regardless of weights. Use the weights in conjunction with developmental observations to determine how to bump feed. The goal is to keep birds on standard, but they must remain healthy, gain weight each week, and must not become emaciated or cully.

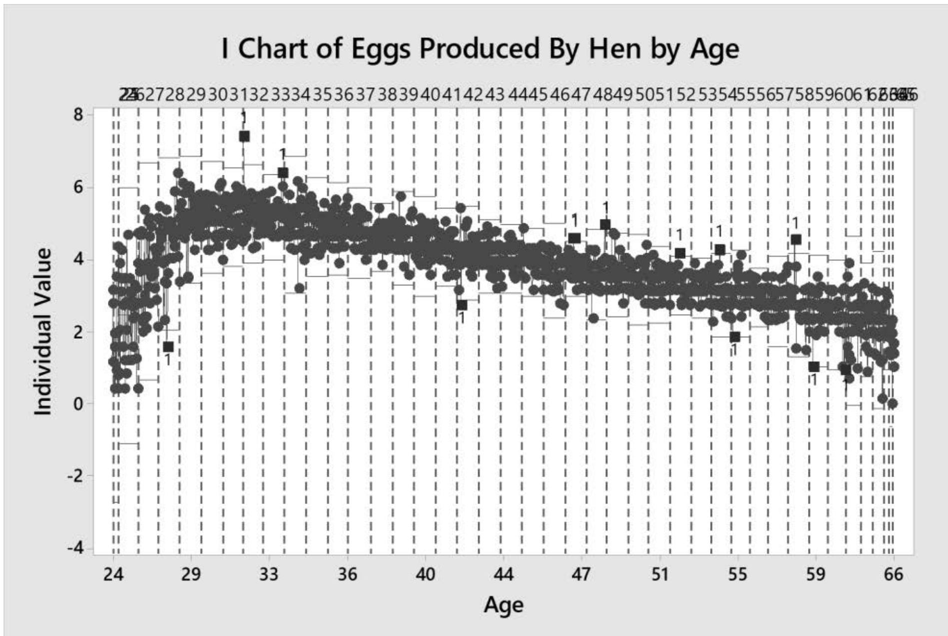
**Watching birds eat:**

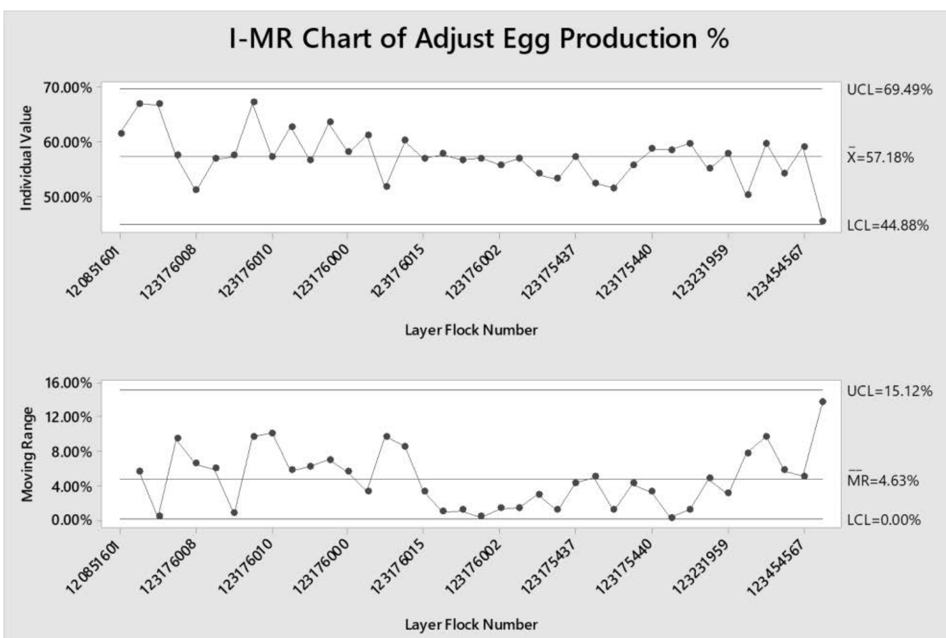
Observing feeding at all ages is fundamental to our program. The 2-3 week frequency is a guideline. Watch flocks eat as often as needed. This will be especially important in poorly managed flocks and where growers are not as involved. Adjust service tech hours to stress early morning involvement, and let them depart earlier in the day.

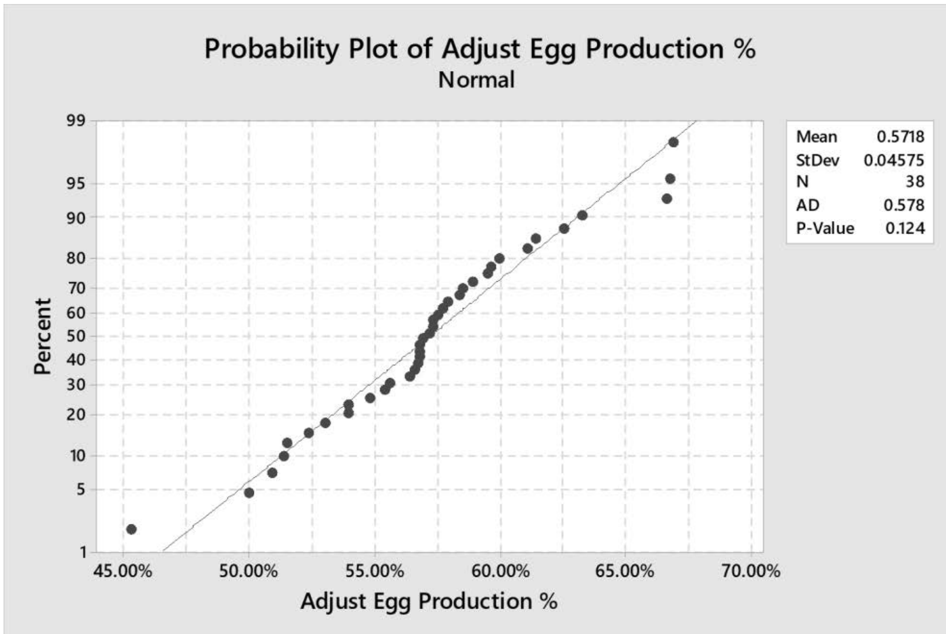
**Water consumption:**

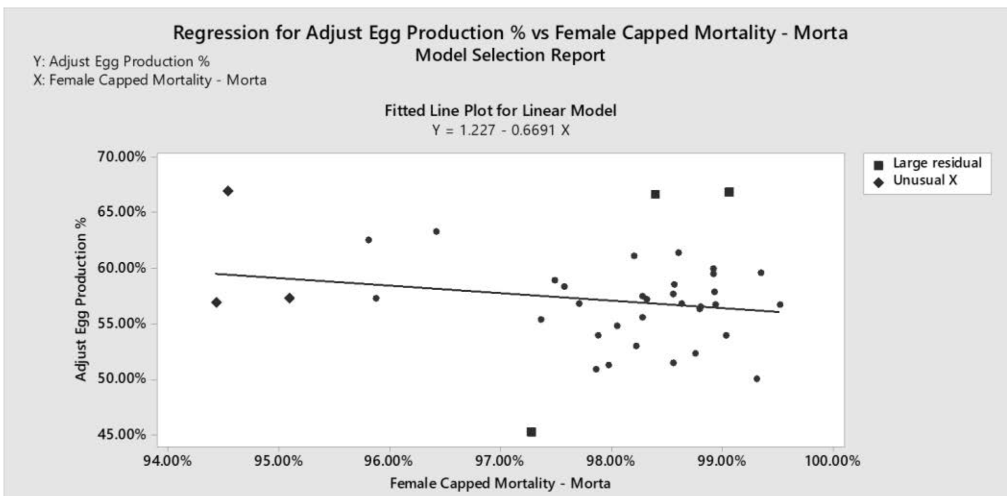
Records of water consumption should be maintained and visible on all pullet and breeder farms. This is a NCC welfare policy.

# Appendix F: Analysis Graphs



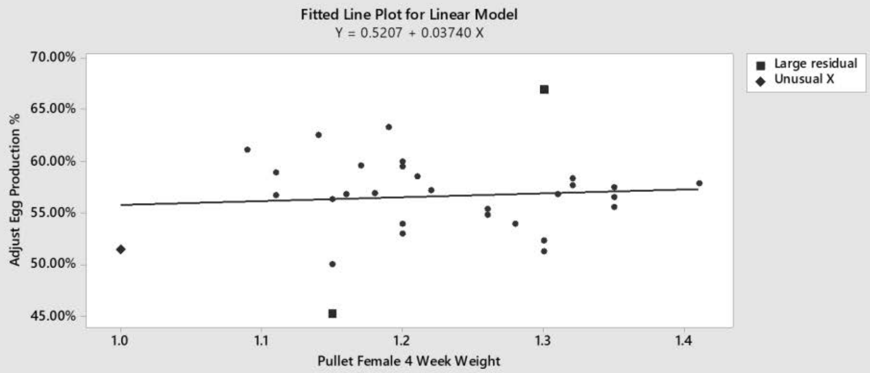



| Statistics | Selected Model Linear | Alternative Model Quadratic |
|---|---|---|
| R-squared (adjusted) | 0.89% | 3.69% |
| P-value, model | 0.256 | 0.196 |
| P-value, linear term | 0.256 | 0.159 |
| P-value, quadratic term | — | 0.161 |
| Residual standard deviation | 0.046 | 0.045 |

**Regression for Adjust Egg Production % vs Pullet Female 4 Week Weight**
**Model Selection Report**

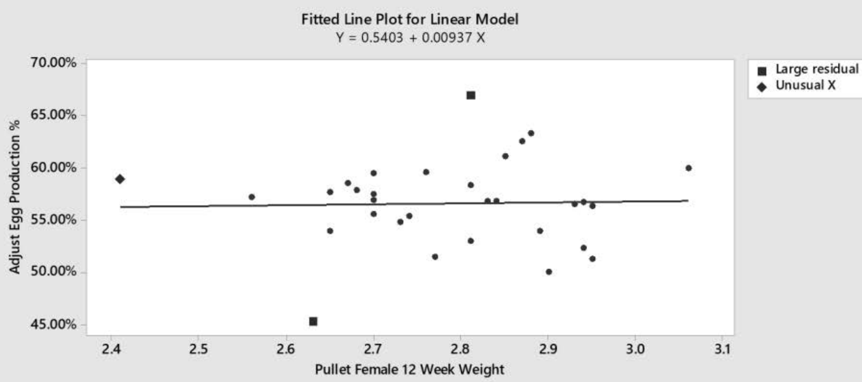
Y: Adjust Egg Production %
X: Pullet Female 4 Week Weight




| Statistics | Selected Model Linear | Alternative Model Quadratic |
|---|---|---|
| R-squared (adjusted) | 0.00% | 0.00% |
| P-value, model | 0.656 | 0.804 |
| P-value, linear term | 0.656 | 0.612 |
| P-value, quadratic term | — | 0.626 |
| Residual standard deviation | 0.042 | 0.043 |

**Regression for Adjust Egg Production % vs Pullet Female 12 Week Weight**
**Model Selection Report**

Y: Adjust Egg Production %
X: Pullet Female 12 Week Weight

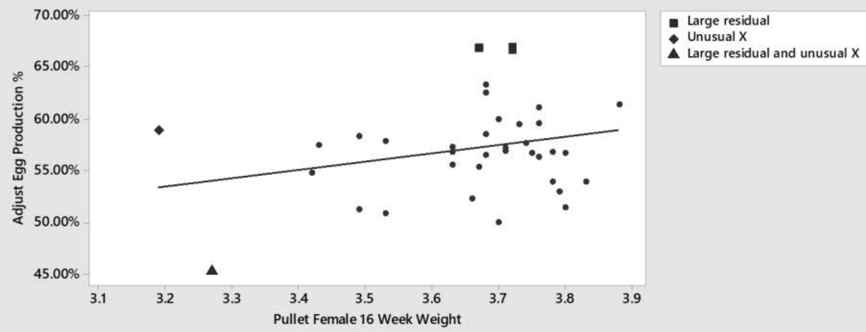



| Statistics | Selected Model Linear | Alternative Model Quadratic |
|---|---|---|
| R-squared (adjusted) | 0.00% | 0.00% |
| P-value, model | 0.870 | 0.969 |
| P-value, linear term | 0.870 | 0.854 |
| P-value, quadratic term | — | 0.849 |
| Residual standard deviation | 0.043 | 0.043 |

## Regression for Adjust Egg Production % vs Pullet Female 16 Week Weight
### Model Selection Report

Y: Adjust Egg Production %
X: Pullet Female 16 Week Weight

**Fitted Line Plot for Linear Model**
Y = 0.2795 + 0.07992 X

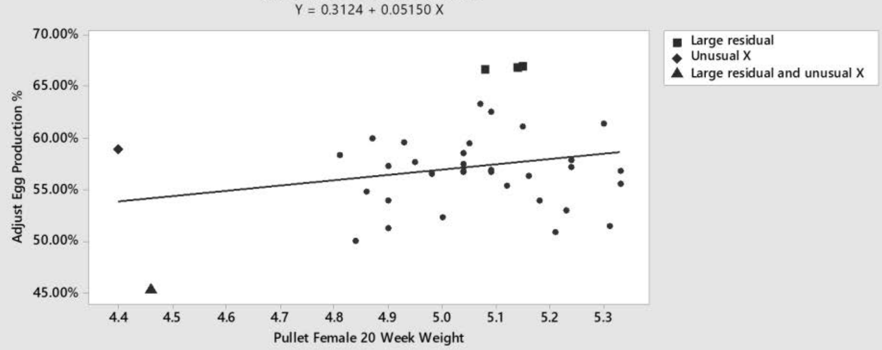



| Statistics | Selected Model Linear | Alternative Model Quadratic |
|---|---|---|
| R-squared (adjusted) | 4.07% | 2.13% |
| P-value, model | 0.118 | 0.260 |
| P-value, linear term | 0.118 | 0.565 |
| P-value, quadratic term | — | 0.595 |
| Residual standard deviation | 0.045 | 0.045 |

## Regression for Adjust Egg Production % vs Pullet Female 20 Week Weight
### Model Selection Report

Y: Adjust Egg Production %
X: Pullet Female 20 Week Weight

**Fitted Line Plot for Linear Model**
Y = 0.3124 + 0.05150 X



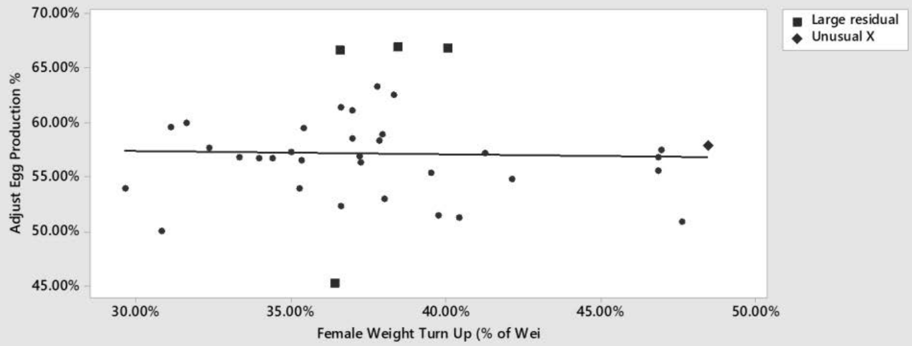

| Statistics | Selected Model Linear | Alternative Model Quadratic |
|---|---|---|
| R-squared (adjusted) | 2.65% | 3.73% |
| P-value, model | 0.165 | 0.194 |
| P-value, linear term | 0.165 | 0.226 |
| P-value, quadratic term | — | 0.244 |
| Residual standard deviation | 0.045 | 0.045 |

## Regression for Adjust Egg Production % vs Female Weight Turn Up (% of Wei

### Model Selection Report

Y: Adjust Egg Production %
X: Female Weight Turn Up (% of Wei

**Fitted Line Plot for Linear Model**
Y = 0.5846 - 0.0337 X



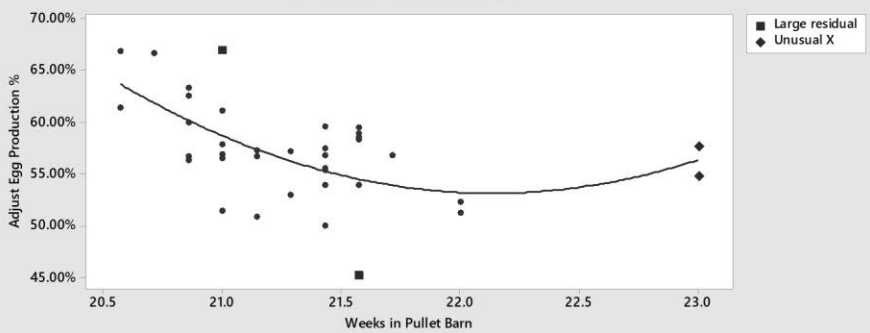

| Statistics | Selected Model Linear | Alternative Model Quadratic |
|---|---|---|
| R-squared (adjusted) | 0.00% | 0.00% |
| P-value, model | 0.836 | 0.433 |
| P-value, linear term | 0.836 | 0.211 |
| P-value, quadratic term | — | 0.204 |
| Residual standard deviation | 0.046 | 0.046 |

## Regression for Adjust Egg Production % vs Weeks in Pullet Barn

### Model Selection Report

Y: Adjust Egg Production %
X: Weeks in Pullet Barn

**Fitted Line Plot for Quadratic Model**
Y = 21.58 - 1.902 X + 0.04296 X^2



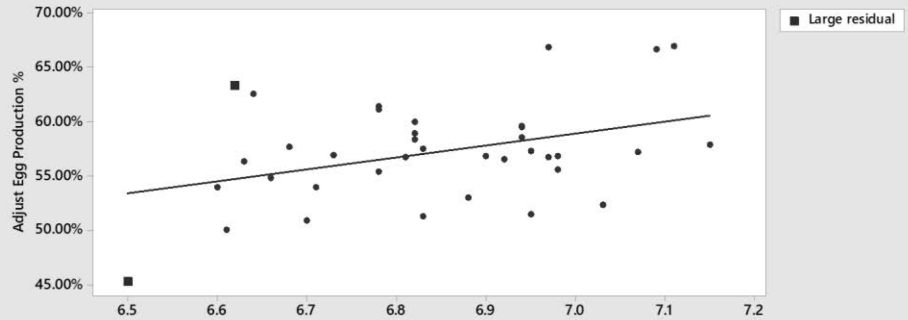

| Statistics | Selected Model Quadratic | Alternative Model Linear |
|---|---|---|
| R-squared (adjusted) | 31.95% | 14.73% |
| P-value, model | <0.005* | 0.010* |
| P-value, linear term | 0.003* | 0.010* |
| P-value, quadratic term | 0.003* | — |
| Residual standard deviation | 0.038 | 0.042 |

** Statistically significant (p < 0.1)*

**Regression for Adjust Egg Production % vs Capped Pullet Weight (Weight at**
**Model Selection Report**

Y: Adjust Egg Production %
X: Capped Pullet Weight (Weight at

**Fitted Line Plot for Linear Model**
Y = - 0.1811 + 0.1100 X



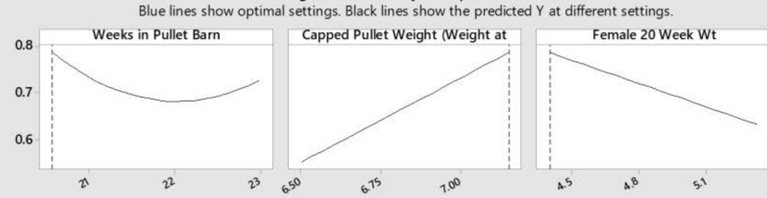

| Statistics | Selected Model Linear | Alternative Model Quadratic |
|---|---|---|
| R-squared (adjusted) | 12.47% | 10.33% |
| P-value, model | 0.017* | 0.056* |
| P-value, linear term | 0.017* | 0.686 |
| P-value, quadratic term | — | 0.709 |
| Residual standard deviation | 0.043 | 0.043 |

** Statistically significant (p < 0.1)*

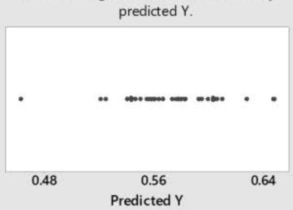
**Multiple Regression for Adjust Egg P**
**Prediction and Optimization Report**

| Goal: Maximize Adjust Egg P | | Solution: Optimal Settings | |
|---|---|---|---|
| Predicted Y | 0.785209 | X1: Weeks in Pul | 20.5714 |
| 95% PI | (0.66840, 0.90202) | X2: Capped Pulle | 7.15 |
| | | X3: Female 20 We | 4.4 |

**Settings and Sensitivity for Optimal Solution**
Blue lines show optimal settings. Black lines show the predicted Y at different settings.

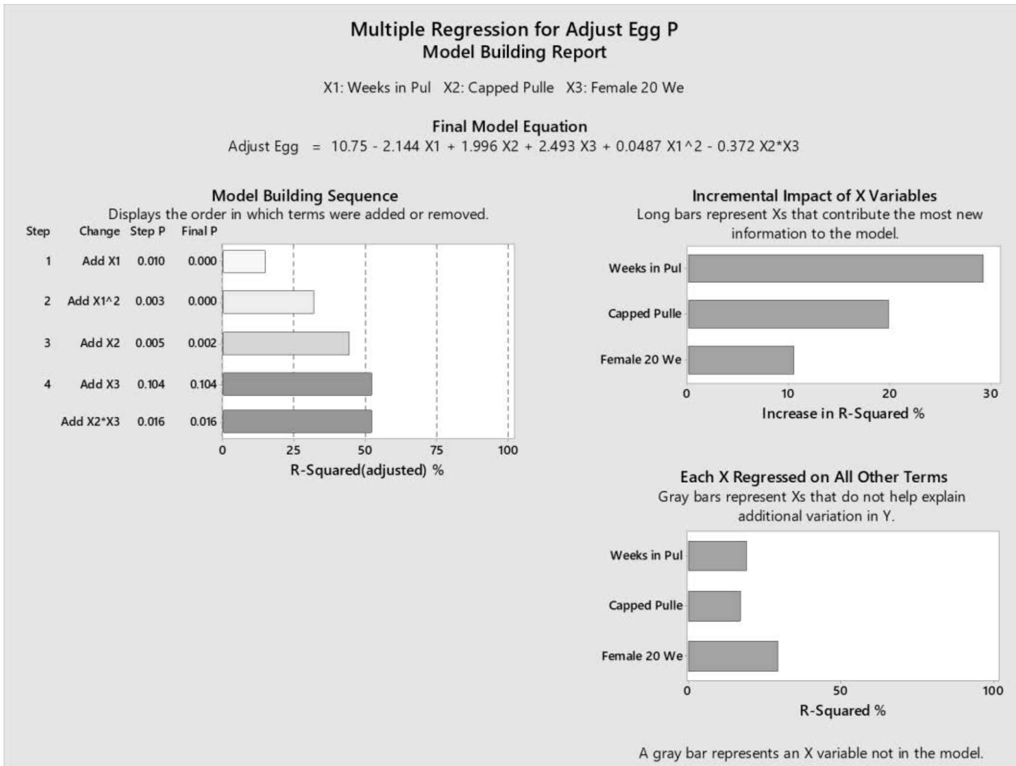



**Predicted Y for All Sample Points**
Use brushing to see the X values for any predicted Y.




**Top Five Alternative Solutions**
Sample points with predicted Y values closest to the optimal solution. Evaluate these and the optimal solution to determine if any are adequate.

| X1 | X2 | X3 | Predicted Y |
|---|---|---|---|
| 20.5714 | 6.97 | 5.14 | 0.647654 |
| 20.7143 | 7.09 | 5.08 | 0.647119 |
| 20.5714 | 6.78 | 5.3 | 0.627071 |
| 20.8571 | 6.82 | 4.87 | 0.609717 |
| 21 | 7.11 | 5.15 | 0.606067 |



Multiple Regression for Adjust Egg P
Model Building Report
X1: Weeks in Pul X2: Capped Pulle X3: Female 20 We
Final Model Equation
Adjust Egg = 10.75 - 2.144 X1 + 1.996 X2 + 2.493 X3 + 0.0487 X1^2 - 0.372 X2*X3
Model Building Sequence
Displays the order in which terms were added or removed.
Step Change Step P Final P
1 Add X1 0.010 0.000
2 Add X1^2 0.003 0.000
3 Add X2 0.005 0.002
4 Add X3 0.104 0.104
Add X2*X3 0.016 0.016
0 25 50 75 100
R-Squared(adjusted) %
Incremental Impact of X Variables
Long bars represent Xs that contribute the most new information to the model.
Weeks in Pul
Capped Pulle
Female 20 We
0 10 20 30
Increase in R-Squared %
Each X Regressed on All Other Terms
Gray bars represent Xs that do not help explain additional variation in Y.
Weeks in Pul
Capped Pulle
Female 20 We
0 50 100
R-Squared %
A gray bar represents an X variable not in the model.