THE PENNSYLVANIA STATE UNIVERSITY
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DEPARTMENT OF ANIMAL SCIENCE

# THE EFFECT OF DIFFERENT MANAGEMENT FACTORS ON THE INCIDENCE OF PENDULOUS CROP IN COMMERCIAL TURKEYS

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## ABSTRACT

The incidence of Pendulous Crop Syndrome (PC) is a long standing issue in commercial turkey production[1,6]. Very little has been done in recent years to monitor the occurrence of this disease, while the modern turkey (*Meleagris gallopavo)* has changed dramatically since the majority of pendulous crop research was completed. Two studies were conducted to evaluate the incidence of PC under different management practices. The factors in the first trial that were evaluated for their ability to induce PC lesions were ambient temperature, water space per bird, and dietary energy. The factors in the second trial that were studied in inducing PC were incubation temperature, light exposure, and feed form. In both studies there were six replicates of each combination of the three factors. Each bird showing symptoms of PC was tagged, and examined for severity of the lesion at the end of the experiment.

The first trial used 2592 female Converter poults (Hybrid Turkeys), and was carried out over a period of 6 weeks (Appendix A). The poults were randomized into 4 separate rooms each with 12 equal pens (5 $m^2$) containing 54 birds. Water intake (at all days measured) and incidence of pendulous crop (% of hen housed and % of remaining birds) were significantly greater ($P < 0.01$) for the birds reared on the higher temperature profile when compared to those on the control temperature profile. From these results, it was concluded that ambient temperature during brooding and/or increased water consumption increases the incidence of pendulous crops in female poults (1.56 % vs 0.31 %, $P < 0.001$).

The second trial used 2400 straight-run Converter poults (Hybrid Turkeys), and was carried out over a period of 10 weeks (Appendix A). Turkey eggs (3600) were incubated for 28 days, wherein 2400 of the poults were collected and equally distributed into 4 separate rooms each with 12 equal pens (5 $m^2$) containing 50 birds. Incubation and lighting (for all days measured before 28 days of age) and diet and lighting (for all days measured after 28 days of age) appeared to have the most significant effects on the incidence of PC. From these results, it was concluded that there is a significant interaction between feed form during brooding, and the particular lighting program which can influence the incidence of pendulous crops in poults ($P \leq 0.0114$).

The data collected from both of these studies can be used in current flock management practices to recognize and reduce factors that may induce pendulous crop. This will lead to an improved quality of life for a greater percentage of turkeys in the commercial industry, and will lead to reduced losses during production and at processing facilities.

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## Acknowledgements

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# Chapter 1

# Introduction and Background

## Introduction to Pendulous Crop in Turkeys:

Avian anatomy deviates from the rest of the animal kingdom in many ways, one of which is their gastrointestinal tract anatomy. Birds have a specialized expansion near the base of their esophagus known as a crop[15]. The crop's purpose is to store food and water, and to regulate their entry into the stomach or future regurgitation to feed young[15]. Normally, there is no further digestion taking place during this storage structure, allowing the digesta to maintain its integrity until the bird uses it[16]. Furthermore, this function is only possible if the crop is in its proper internal orientation. The crop should be held in place by a suspensory muscle, which is attached to the subcutaneous dermal layer of the neck and a tendinous attachment on the keel, and should also fixed by dense fibrous tissues between this muscle and the pectoralis[16].

Pendulous Crop (PC) is an abnormal condition where the crop becomes distended from its normal position, falls in front of the supportive tissue layers, and continues to fill with ingested fluid and feed (Figure 1.1)[1,3,5,6,7,10,13,16]. In a true pendulous crop, the condition cannot be naturally corrected and the crop will remain trapped between the skin and the suspensory muscle[16]. In this state, the materials inside the PC stagnate and have the potential to ferment depending on the presence of certain microbes; however, the contents have not been proven to be directly toxic to the birds[2,10,11,16]. The adverse effects are typically due to the physical limitations the PC causes the bird. Since nutrients are not being absorbed by the crop and cannot escape the crop easily, the turkey becomes stunted and emaciated[3,6,16]. Furthermore, there is a higher risk of the crop and associated tissues to become necrotic or infected, if punctured[2,6].

**Figure 1.1: Comparison of Normal Crop v. Pendulous Crop Presentation**

**Figure 1.1:** Normal crop presentation in a commercial turkey (left) allows for a smooth appearance from the neck to the top of the keel bone; however pendulous crop (right) is presented as a large, bulbous structure distending from the base of the neck.

Traditionally, PC is believed to be caused by a genetic predisposition which is enhanced by environmental factors[1,3,5,6,8,13,14,15,17]. However, with the development of the commercial turkeys in today's industry, it is suspected that flock management is having an increasing influence over the incidence of PC[10].

Any management practice that would cause excessive extension of the crop is thought to exacerbate the incidence of pendulous crops[1,6,9,10]. Extension of the crop is usually associated with practices when distension of the crop is commonly found.

Environmental conditions or management practices where increased water or feed, or a combination of the two, would be consumed are often blamed for causing PC[1,4,6,9,10]. These different practices include those which were tested throughout the duration of both experiments carried out for this study (Appendix A).

**Impact of Pendulous Crop on the Turkey Industry:**

Hybrid Turkeys reported that in some cases, 15% of flocks have experienced mortality via PC. The genetic line of birds in this study has shown flock mortalities of 5-8% due to PC. When PC birds are found in commercial flocks, it is more economical and humane to cull them rather than to lose feed efficiencies while the bird is suffering from this condition[10].

Typically, turkeys exhibiting PC will not be taken to the processing facility, as they increase labor and they increase the risk of contaminating other carcasses and the environment if the crop contents would spill out during evisceration. This leads to an economic loss to the processor and the grower, as the birds cannot be used as a premium protein source for human consumption.

**History of Pendulous Crop in Commercial Turkeys**

Pendulous crop has been analyzed by many animal research facilities, primarily around the time when domestic turkeys were beginning to be raised in commercial settings, after the technologies in the agricultural industries started developing. The earliest study on this disease was carried out in 1936 where general observations were made on the anatomical challenges the bird experienced due to the disease[6]. From this study stemmed further research into why the turkeys were susceptible to PC. This question led to a number of experiments for the next thirty years, and varied from genetics to management effects[1,4,9,11,16,17]. The research developed as more commercial strains of turkeys arrived in the marketplace; however, these studies focusing solely on PCs in turkeys came to a close in 1973[11].

Although this is now over 40 years ago, pendulous crop still remains a hindrance to the turkey industry, and no recent studies have been conducted with the commercial birds that have developed since then[2,10,14,15]. Today's birds now grow to heavier weights in a faster time period and in very different conditions from what they were 40 years ago. The research completed for this study pulled several management-based factors that were assumed to be associated with pendulous crop in the past, and which may still have the potential to be causing the disease in the birds we are raising today (Appendix A).

As data has not been gathered recently in regards to PC, the available literature was limited.

**Genetic Origins of PC**

The most commonly accused factor in causing PC has historically been of genetic origin. When these studies began, the commercial turkey was the Broad Breasted Bronze bird; it was from this variety that all other modern, domestic commercial turkeys can be traced back to. Asmundson and Hinshaw are responsible for a majority of these early studies which started with general observations of the disease (1936), to carrying out experiments which led to conclusions of PC being a heritable trait[6]. It was first noted in their 1938 study that the environmental temperature may have influenced a greater expression of the genes responsible for inducing pendulous crop[1]. It was here that the "phenotypic expression of pendulous crop" was considered to vary greatly depending on the amount of water intake due to higher temperatures, drier air and the amount of daylight present[1].

The results of these early trials, which focused primarily on inducing PC through genetics, did result in conclusive data. The strains of birds that were more susceptible to PC did have progeny that also expressed higher rates of PC especially when two lines of "high incidence" turkeys were crossed[1]. It was also noted that pendulous crops that were attributed to genetics were observed after being raised to 12 weeks of age[1]. Furthermore, pendulous crop was found to be in both genders, and therefore if PC is in fact a genetic disease, it is an autosomal trait[1,15]. Due to the ratios of birds with PC, it was also assumed that PC is a homozygous recessive trait that can also be carried and expressed at a lower rate in the progeny of heterozygous birds for the same gene(s)[1,15]. This research has been the referenced by all subsequent studies involving PC in domestic turkeys.

When referenced by poultry disease and genetic manuals from around the time when this research was first released, all publications stated that while there were unquestionable hereditary factors in causing PC, the environment in which the birds were kept greatly influenced its expression[1,5,7,8,13.16.17]. This notion led to the next phase of turkey PC research, where different management factors may be responsible for triggering the phenotypic expression of an innate genetic sequence in all turkeys[9,10,11,16].

A recent study on the genetic impact of survival and fitness on turkeys was conducted, wherein there was evidence that showed that commercial turkeys have a moderate heritability ($h^2$ =0.12) of crop health[14].

**Environmental Factors Associated with PC**

The majority of available past research on PC was conducted to find the genetic causes of pendulous crop; however, in these studies reference has been made to significant differences resulting from varying environmental conditions. A majority of the genetic research implied that there was a higher incidence of PC when higher temperatures were present, or that there were any other conditions that would drastically increase water consumption[1,5,13]. This being said, there has always been the potential to study the manipulation of these management factors on controlling PC incidence, yet none were pursued during the early PC studies.

In addition to overconsumption, another environmental factor that has been linked to PC is the development of certain microorganism colonies in the crop[10,11,16]. These colonies can arise from a number of sources such as feed, litter, or, and can take hold in the crop tissue if its mucosal or epithelial layers are damaged by chemical burns or ulcers[10]. This damage can result from improper cleaning techniques of drinkers, or exposure to feed conditions that would degrade the crop mucosa. It is believed that once this damaged tissue is infected, the microbes will further degenerate the tissues surrounding the crop and thus allowing it to fall out of its normal position[2,3].

While there are infectious agents, there are also microbes that can thrive in the crop environment alone, due to the dark, moist, nutrient rich mixture present here. These include molds and parasites, however the most notable are the fungal species Saccharomyces tellustris, and Candida albicans[2,10,11,16,17]. Saccharomyces was found to be responsible for large amounts of gas production from fermentation which expanded the crop past its normal positioning, and could not be alleviated as birds cannot eructate gasses from their gastrointestinal tract [2,11,16,17]. On the other hand, Candida albicans was found in birds already experiencing PC and was also fermenting the dietary starches; this led to the production of volatile fatty acids[11]. While this does not directly injure the crop, the enzyme action taking place in the crop can degrade the nutrients that should be reaching the bird. Thus the bird may become more nutrient deficient causing it to continue to consume more feed, which could led to a worsened PC condition[11].

**Nutritional Components Causing PC**

Several nutritional aspects of PC incidence have been studied, as PC is an abnormality which directly impacts the gastrointestinal anatomy. Past experiments include supplementing microbes which produce gases when in the crop with a varying the carbohydrate source, or increasing levels of sodium in the diet.

The aforementioned microbes that can be found in the environment were enabled by the nutrient content of the feed, where the colonies would flourish where the diets were supplemented with glucose, cerelose and/or starch as the carbohydrate source[10,11,16,17]. The study which analyzed the difference between these carbohydrate sources found that when the birds given the glucose pre-starter diet showed a 25% incidence of PC after four weeks of age, and 100% induced PC in this experimental group by 10 weeks of age[17]. All of the PCs were attributed to the direct effects of the microbes metabolizing the consumed carbohydrates in the crop.

Yet another dietary influence of PC was found accidentally while investigating aortic rupture in turkeys. Here the blood pressure was being increased with measured increases of sodium from 0.4% to 8.0%, which was positively correlated with significant increases in water consumption; at 4%, the sodium level in the diet began to produce reportable PCs between 8 and 16 weeks of age[4].

# Chapter 2

# Materials and Methods

## Trial 1 Materials and Methods:

This first experiment used 2592 female Converter poults (Hybrid Turkeys), and was carried out over a period of 6 weeks where temperature, water accessibility and available energy in the feed were manipulated. On the first day of life, the poults were delivered to the Penn State Poultry Education and Research Center from the Cargill Turkey Production LLC's hatchery in Harrisonburg, Virginia. Upon arrival the birds were taken directly into the P2 building. Here they were randomly selected from their delivery crates, and then were divided equally into the 4 separate rooms/wings of the building, which each contained 12 pens (Figure 2.1).

The experimental design for the three different factors in this building allowed for a 2x2x2 Factorial set-up with 6 replicates of each combination of factors. The factorials were Experimental High Energy vs. Control, Experimental High Temperature vs. Control, and Experimental Restricted Water vs. Control. In each room half of the pens were fed the Control diet, where the other half was fed the High Energy diet; in each room half of the pens had Control water access, where the other half had Restricted water access; and two rooms were held at the Control temperature, while the other two were held at the High temperature profile. Birds were monitored for PC daily, and were marked if signs of permanent PC were present. All of the collected data was processed through ANOVA, from which the percentage data could be analyzed for results after an arcsine transformation (Appendix B).

**Figure 2.1: Aerial View of Experimental Building Layout**

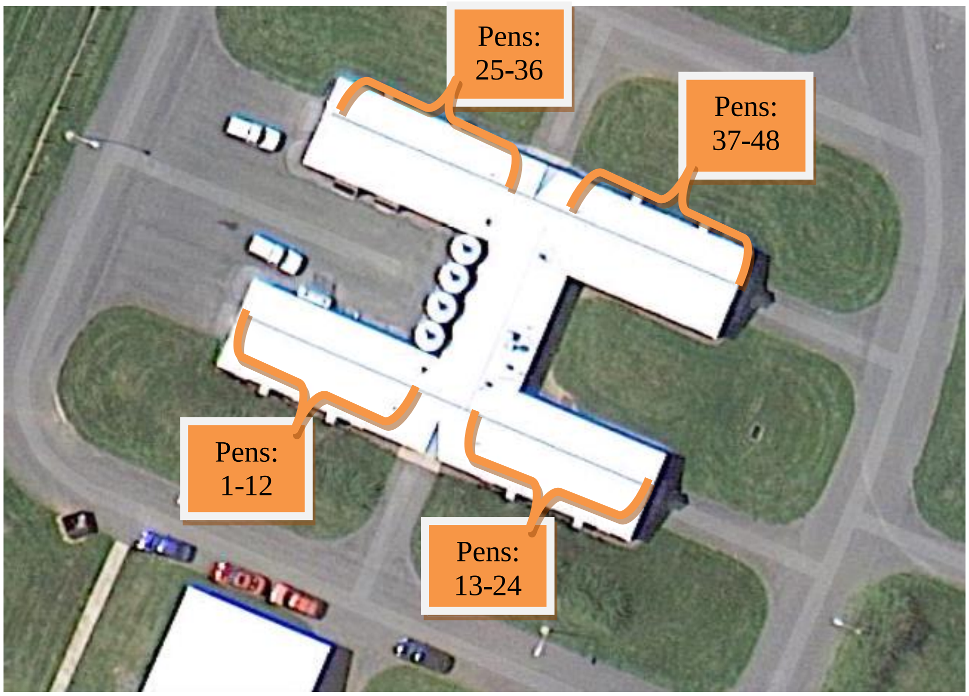



**Figure 2.1:** Arial View of building P2 at the Pennsylvania State University's Poultry Education and Research Center. The poults were raised in this building for the duration of each trial, and were divided evenly into each of the four wings (rooms). The environmental settings in each room were customized for their respective trials, i.e. temperature profiles, and lighting programs.

## Environmental Design

### Pen Set-Up:

Each pen used in this study measured 5m² which met the standard spacing requirements of turkey poults for the first 6 weeks of life. In order to house all 2592 poults, 48 pens were prepared; all of the pens had an identical layout in the standard format of growing pens for the Poultry Education and Research Center

(Figure 2.2). Each pen was supplied with a Plasson® Bell Drinker, two supplemental gallon drinkers, a brooder lamp, a supplemental feed pan, a metal hanging feeder, and adapted cardboard brooder guard in each corner. The Plasson® Bell Drinker was modified for the Control or Restricted water experimental factor; water was available *ad libitum* in both environments. After the first week of life the supplemental drinkers and feed pan were all removed, and after the second week of life the brooder lamps and brooder guard were removed. Feed was provided *ad libitum* in the hanging feeders, and the designated feed was stored in weighed amounts outside of each pen to efficiently feed and monitor feed conversion of the individual pens. Light was provided to industry standards where the poults received 24L:0D on day 1, 23L:1D during the first week of life, then gradually reduced to 16L:8D by day 10 (Appendix A). Pine shavings were used as bedding, as this is the standard floor covering used at the Penn State poultry farm.

**Figure 2.2: General Pen and Wing Set Up**

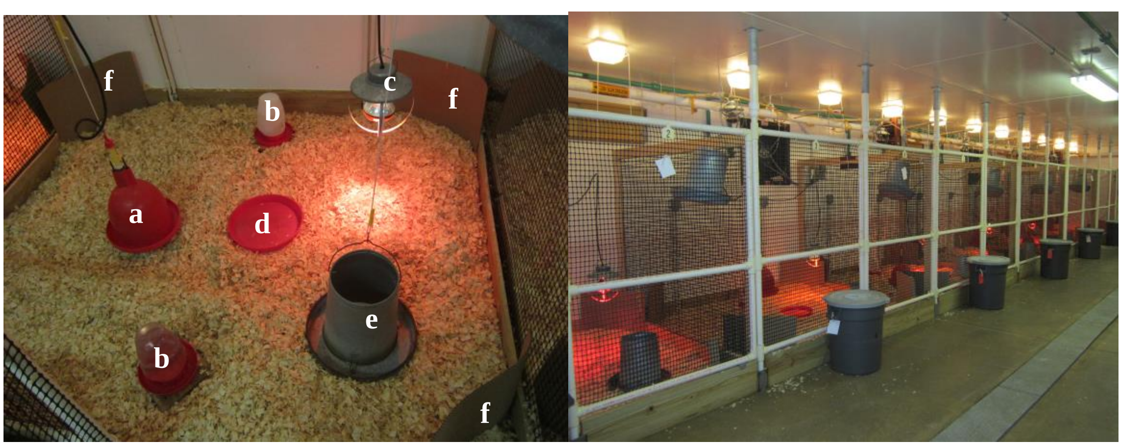



**Figure 2.2: (Left)** Pen Design- a) Plasson® Bell Drinker**,** b) Supplemental Gallon Drinkers- removed 1 week after poult placement, c) Brooder Lamp- removed 2 weeks

after poult placement, d) Supplemental Feed Pan – removed 1 week after poult placement, e) Metal Hanging Feeder, f) Adapted Brooder Corner Guards*. **(Right)** In each room (Fig. 2.1), there were 12 pens total, with 6 on both sides; all pens measured 5m². Weighed amounts of feed were stored in bins corresponding to the appropriate diet being fed to the poults in each pen.
*****Brooder guard was adapted to fit the corners in the pens to prevent the poults from crowding and smothering, since turkeys tend to be more prone to this behavior than other poultry species.

**Specimen Placement:**

As previously mentioned, the birds were randomly selected from the delivery boxes. In order to be evenly divided, groups of 54 poults were selected to be placed in each pen. Several extra birds were sent with the delivery so that any potentially unfit birds (those that are lethargic or are exhibiting excessive umbilical buttons) could be sorted out of the experimental group, so that the 2592 bird requirement could be met with initially sound birds. Prior to placement, the birds were all weighed together so that their growth rates and feed conversions could be monitored throughout the entire study. Once placed in their appropriate pens, the birds were shown the sources of water by briefly dipping their beaks in the drinkers (Figure 2.3). The birds remained in these pens for the duration of the trial, only mortality was removed.

**Figure 2.3: Female Converter Poults in Trial Environment Post-Placement**

**Figure 2.3:** Female Converter Poults just after placement. There were 54 birds placed in each 5m² pen, where area/bird requirements were met for the duration of the study. The poults were randomly selected from the delivery boxes, and were weighed collectively prior to placement.

**Dietary Energy:**

For this study, dietary energy was adjusted for both a controlled diet and an experimental diet which would be formulated with slightly higher metabolizable energy (ME). The energy was differentiated by the percentage of fat in each diet (Table 2.1). A pre-starter diet was fed during the first three weeks of life, where the Control diet contained 3.510% fat and the High Energy diet contained 5.280% fat. From week 4 to week 6 a starter diet was fed, where the Control diet contained 4.180% fat and the High Energy diet contained 5.050% fat. Pens were labeled with white tags if they received the Control diet, and the pens receiving the High Energy diet were labeled with red tags.

**Table 2.1: Nutrient Composition of All Diets Used**

| T2012 PC Study: Diet Composition | | | | |
|---|---|---|---|---|
| Diet<br>Age in Wks<br>Feed/Hen (lbs) | Control<br>(wks 0-3)<br>2.27 | Control<br>(wks 3-6)<br>6.29 | High Energy<br>(wks 0-3)<br>2.27 | High Energy<br>(wks 3-6)<br>6.29 |
| Protein, % | 27.490 | 26.010 | 26.890 | 23.890 |
| Fat, % | 3.510 | 4.180 | 5.280 | 5.050 |
| Calcium, % | 1.390 | 1.400 | 1.460 | 1.310 |
| Available Phosphorus, % | 0.750 | 0.750 | 0.780 | 0.660 |
| Methionine, % | 0.730 | 0.650 | 0.670 | 0.630 |
| Met. + Cys,. % | 1.170 | 1.070 | 1.110 | 1.020 |
| Available Lysine, % | 1.630 | 1.480 | 1.510 | 1.400 |
| Avg ME Poultry, kcal/lb | | 1316 | | 1394 |

**Table 2.1:** Trial 1 diet composition, differentiated by the average energy density profile. The energy density was controlled by the percentage of fat in each diet.

The average metabolizable energy for the Control diet was calculated from a pre-starter diet with an ME of 1293 kcal/lb, and a starter diet with an ME of 1338 kcal/lb. The average ME for the experimental High Energy diet was calculated from a pre-starter diet with an ME of 1383 kcal/lb, and a starter diet with an ME of 1405 kcal/lb. Both feeds were formulated by Cargill's Virginia Turkey operations with AKEY Nutrition and were mixed and delivered into the P2 feed agars by K & L Feeds in Selinsgrove, Pa. The agars were identified by white tags if they contained the Control diet, and by red tags if they contained the High Energy diet so that the appropriate feed would be coordinated with the similarly labeled pens.

The amount of consumed feed was weighed for each individual pen and was compared to the total weight gained by of all of the birds in the respective pens, at the end of the pre-starter diet phase and at the end of the starter diet phase. This allowed for analysis of feed conversion compared to the experimental factors throughout the trial.

**Ambient Temperature:**

Environmental temperature could not be modified per pen, and therefore two of the P2 rooms were designated for the Control temperature program (T1) while the other two were set for the experimental High temperature program (T2) (Appendix A). The T1 profile followed the standard temperature decrease for the first 6 weeks of life from 88˚F to 68˚F, as prescribed by Hybrid to all of their commercial flock growers. The T2 profile followed the experimental brooder temperature profile which begins at 95˚F and was only dropped down to 89˚F by for the remainder of the study (Figure2.4). These temperatures were monitored and maintained by temperature/ humidity probes placed in each room (Appendix B).

**Figure 2.4: Hybrid Protocol for Brooding Room Temperature Progression**

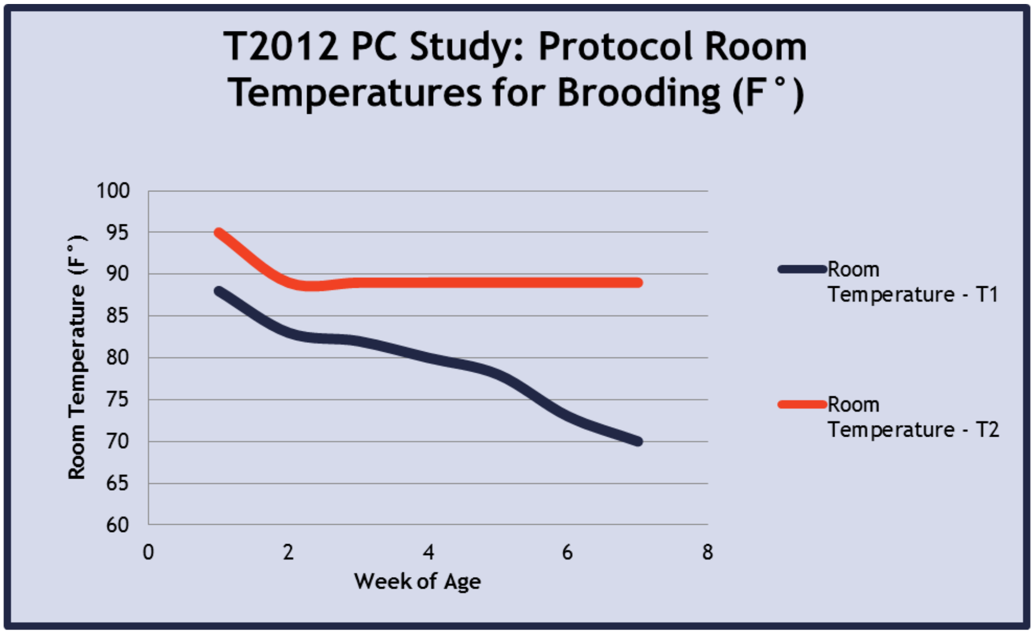



**Figure 2.4:** Protocol for Control (T1) and Experimental (T2) brooding temperatures, as designated by Hybrid Turkeys (Appendix A).

**Water Availability:**

In order to evaluate the impact of water availability on the incidence of PC, half of the pens had Plasson® broiler breeder bell drinkers with the Control drinking area, while the other half had Plasson® bell drinkers with only half of the available drinking area. This deviated from Hybrid's protocol, due to the limitations of required area/bird in each pen, which called for twice the amount of birds to each drinker rather. By reducing the drinking area by half, we were able to obtain the same prescribed ratios of drinking area/bird as the protocol (Appendix A).

The Control setting allowed the poults to have total access to the available drinking space provided by the Plasson® bell drinkers. Water restriction was implemented by placing two customized, metal spacers in the Plasson® drinkers in the experimental environment at equal distances apart (Figure 2.5). The spacers were spray painted with matte gray, waterproof paint to protect against rusting, and to reduce the attraction behavior of the poults to the shiny metal.

The available drinking area provided by the Plasson® Breeder Drinkers meets the requirements for turkeys, where one bell can supply enough water for at least 100 birds.

**Figure 2.5: Method for Restricting Water Intake with Plasson® Bell Drinkers**


**Figure 2.5: (Left)** Custom-fitted, metal spacers made to restrict the amount of available drinking area in Plasson® bell drinkers. **(Right)** In the Control environment there were no spacers used, and in the experimental Restricted Water design two spacers were placed on opposite sides of the drinker to only allow half of the normal drinking area by alternating quarters.

**PC Data Collection and Analysis:**

Every day throughout the trial the birds were monitored at the start and at the end of each lighting period for signs of permanent PC. Birds exhibiting signs of the abnormality were further examined by crop palpation, to verify if a bird had a true pendulous crop. All turkeys with PC were marked with numbered wing tags in the order that they were observed, so that the birds could be easily identified and the progression of their PC could be followed. Also, the doors of the pens containing PC birds were marked with blue tags, and the wing tag numbers of those birds were recorded on them. This enabled an effective method to roughly estimate which factors were associated with the most pendulous crops.

At the end of the six week trial, the birds were scheduled to be moved to a grow-out farm until they reached market age. The birds which were tagged for PC, as well as 10 control hens (non-PC) were separated from the healthy birds and kept at the research facility. These poults were observed for the severity of their lesions, and then blood samples were drawn if Hybrid would want to analyze them (Figure 2.6); after the data analysis Hybrid decided that they did not need these samples at that time.

**Figure 2.6: Marking & Evaluating PC in 6 Week Old Female Converter Turkeys**


**Figure 2.6: (Left)** All birds exhibiting PC were wing tagged on the left wing immediately after their condition was observed. **(Center)** A moderately severe case of PC in a 6 week old turkey hen; comparable to the size of a naval orange. The blue wing marking was applied to all PC birds prior to load out, this was to readily separate the afflicted birds from the others in their pen. **(Right)** The most severe case of PC from this trial, three weeks after the onset of PC; comparable to the size of a grapefruit. The epidermis around the crop was scabbed and bleeding when being moved, this was a case where the bird was immediately culled after drawing a blood sample.

Once the birds were evaluated, those with the most severe PCs were humanely culled via cervical dislocation immediately following the blood collection. The remaining PC birds with moderate to small lesions were grown to market weight, electrically stunned and exsanguinated, and processed so that the crop contents remained separate from the meat. Following the trial, data was collected for the incidence of pendulous crop and the significance of the different experimental factors with the ANOVA software. All of the percentage data drawn from the ANOVA results was then analyzed after undergoing an arcsine transformation (Appendix C).

**Trial 2 Materials and Methods:**

This second experiment used 2400 straight-run Converter poults (Hybrid Turkeys), and was carried out over a period of 11 weeks where incubation temperature, lighting and feed form were manipulated. The study began with 3600 fertilized turkey eggs which were delivered to the Penn State Poultry Education and Research Center from the Cooper Farms Hatchery in Oakwood, Ohio who have Hybrid Turkeys breeder flocks (Appendix A). Upon arrival the eggs were randomly selected and evenly distributed in incubators. After a 28-day incubation period, the eggs were moved into hatchers until their designated hatch time. From the hatch, 2400 of the most viable chicks were randomly selected within each experimental incubation group, and then were divided equally into the 4 separate rooms/wings of the building, which each contained 12 pens (Figure 2.1).

The experimental design for the three different factors in this building allowed for a 2x2x2 Factorial set-up with 6 replicates of each combination of factors. The factorials were Experimental High Incubation Temperature vs. Control, Experimental Intermittent Lighting Program vs. Control, and Experimental Mash Feed Form vs. Control. In each room half of the pens held poults from the High Incubation temperature, where the other half held poults from the controlled incubation temperature; in each room half of the pens had the experimental Mash feed form, where the other half had the controlled Crumble/Pellet feed form; and two rooms were set for the experimental Intermittent lighting program, while the other two were set for the control Standard lighting program. Birds were monitored for PC daily, and were marked if signs of permanent PC were present. All of the data was collected and interpreted based on the experimental factors by the ANOVA software program, from which the percentage data could be analyzed for results after an arcsine transformation (Appendix B).

**Environmental Design:**

**Pen Set-up:**

Identical to the pen layout used in Trial 1 (Figure 2.2).

**Incubation Temperature:**

For the second trial in this experiment, incubation temperature was considered to be a factor in causing PC. In order to test this parameter 3600 eggs were collected, and were then randomly placed into small Chick Master incubators, for the 28-day *in ovo* period. The 3600 eggs were divided in half, where 1800 were placed in 2 incubators set for the Hybrid Standard Temperature Profile (Low Temp.), and 1800 eggs were placed in 2 incubators set for the Experimental Temperature Profile (High Temp.); both environments were set for single stage incubation (Figure 2.7). Once the incubation phase was completed, the eggs were moved to two Chick Master Hatchers, where one hatcher was designated for the poults from the Low Temperature Profile, and the other was set for the High Temperature Profile (Figure 2.8).

Post-hatch, 1200 straight-run poults were randomly selected from both incubation factors, and were separated into respective pen groups of 50 birds (Figure 2.9). Since turkeys do no hatch with pendulous crop, no significant data regarding the incidence of the disease could be collected at this time. The turkeys were divided equally into the 4 rooms of P2, each containing 12 pens (Figure 2.2), where 6 pens of birds would contain poults from the Low Temperature incubation, while the other 6 pens held poults from the

High Temperature incubation in each room. In these group environments, the birds were observed for long term effects of incubation temperature on inducing PC until the end of the trial.

**Figure 2.7: Hybrid Protocol for Incubation Temperature Progression**

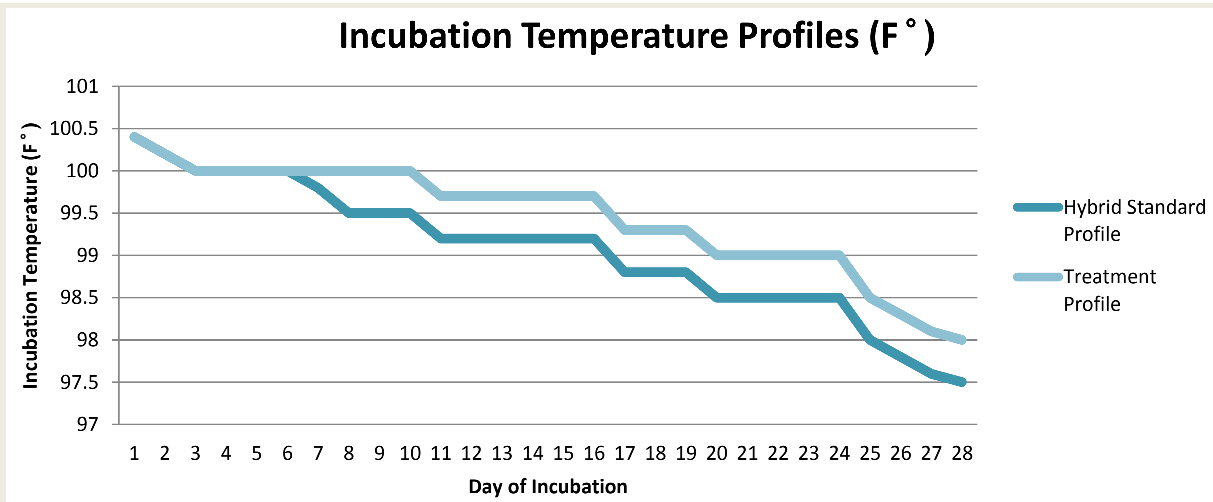



**Figure 2.7:** Protocol incubation temperatures as prescribed by Hybrid Turkeys. The eggs were divided evenly bewteen temperature profiles, where two incubators were set for the standard (control) temperature profile and two incubators were set for the higher (experimental) temperature profile. Both treatments began at 100.4˚F, however after day 7 of incubation a temperature difference of 0.5˚F was maintained until the hatch date.

**Figure 2.8: Incubators and Hatchers Used for Pendulous Crop Trial 2**

**Figure 2.8: (Left)** Four ChickMaster Incubators were used for this trial where 2 incubators were set for the control temperature profile, and the remaining two were set for the experimental temperature profile. **(Right)** Two ChickMaster Hatchers were used for this trial where one hatcher was designated for the control temperature poult hatch, while the other was for the experimental tempature poult hatch.

**Figure 2.9: Poult Hatch**

**Figure 2.9:** After hatching, 1200 fit birds were selected from each incubation profile, divided into respective groups of 50 birds, weighed collectively, and were then placed into designated pens so that an equal amount of birds from each incubation group was present in all other experimental environments.

**Specimen Placement:**

Poult placement methods were identical to those implemented in Trial 1, with the exception of 50 birds rather than 54 birds were placed in each pen (Figure 2.3). Furthermore, the 2400 poults needed for this trial were randomly selected directly from their hatching trays rather than delivery boxes. Poults were not sexed after hatching, and thus this trial compiled results from both male and female (straight-run) birds. This placement met the required 2x2x2 factorial requirements with 6 replicates.

**Lighting Program:**

The amount of light a bird is exposed to greatly influences eating and drinking patterns. Two different lighting programs were tested to see if certain lighting conditions could induce PC by changing the consumption patterns. In this trial the birds were all exposed to two different lighting times. During the first week of life, it is an industry standard to provide poults with 23 hours of light and 1 hour of darkness (23L:1D) so that the birds get acclimated to their surroundings and are encouraged to use all of the available space in the pen. Both lighting programs included this standard procedure, however on day 7 the lighting programs were modified to the experimental profiles.

In 2 rooms the light was modified to be the Control setting, which followed Hybrid's Standard Lighting Program where the birds would receive one continuous period of light in a 16L:8D ratio until the end of the trial (Figure 2.10). The other two rooms were given the prescribed experimental lighting program which followed an Intermittent Lighting Program where the birds had 4 light exposures in a 24 hour time period, in a 1L:5D ratio until the end of the trial (Figure 2.11). Intermittent Lighting was Hybrid's chosen experimental procedure since it is a common alternative lighting program used by those who believe it increases feed efficiency.

**Figure 2.10: Hybrid Standard Lighting Program Used for Control Setting**

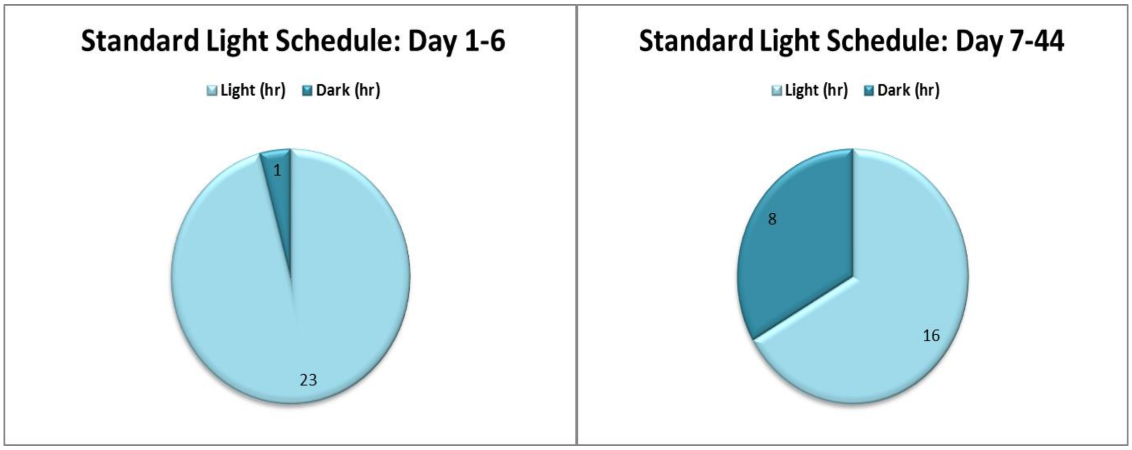



**Figure 2.10: (Left)** During the first week of life, under Hybrid's suggested Standard Lighting program for their commercial converter turkeys, the turkeys received 23 hours of light (L) and 1 hour of darkness(D). **(Right)** After day 7, the poults were placed on a 16L: 8D cycle which continued until the end of the trial.

**Figure 2.11: Hybrid Intermittent Lighting Program Used for Experimental Setting**

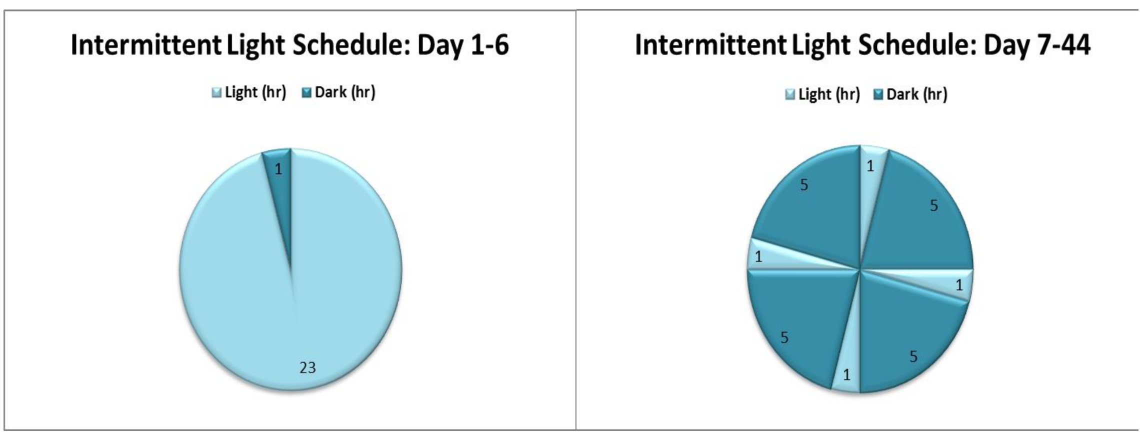



**Figure 2.11: (Left)** During the first week of life, under Hybrid's experimental Intermittent Lighting program for their commercial converter turkeys, the turkeys received the standard 23L:1D. **(Right)** After day 7, the poults were placed on the intermittent program where they experienced 4 cycles of 1L:5D in every 24 hour period; this continued until the end of the trial.

**Feed Form:**

As feed and water consumption directly impact the crop, the feed form was manipulated to change palatability by particle texture. During this trial two feed forms were tested for their ability to induce PC. The experimental diet was a mash, with a very fine particle size when compared to the control crumble/pellet diet (Figure 2.12). In each room, half of the poults were fed the mash feed form as their pre-starter (0-28 days of age) and starter diets (28-44 days of age), while the other half was fed the crumble for their pre-starter diet and then switched to a pelleted starter diet.

Although the feed form was manipulated, both diets were created from the same formula and were nearly identical in their nutritional profile (Table 2.2). Furthermore, feed was available *ad libitum* in all pens for the duration of the study. Barrow-Agee Laboratories in Memphis, Tennessee was responsible for the formulation of the feed to meet Hybrid's turkey nutrition standards, and K & L Feeds in Selinsgrove, Pennsylvania was responsible for the mixing and delivery of the feed.

The amount of consumed feed was weighed for each individual pen and was compared to the total weight gained by of all of the birds in the respective pens, at the end of the pre-starter diet phase and at the end of the starter diet phase. This allowed for analysis of feed conversion compared to the experimental factors throughout the trial.

**Figure 2.12: Mash Feed Form vs. Crumble Feed Form**

**Figure 2.12: (Left)** Experimental mash diet with ultra-fine particles fed to poults for the entire study, as both a pre-starter and a starter feed*. **(Right)** Control crumble diet fed to poults as a pre-starter diet for the first 3 weeks of life; these poults were switched to a pelleted diet for their starter diet*.
*Both feed forms were derived from the same formula (Table 2.2).

**Table 2.2: Nutrient Composition of both Mash and Crumble/Pelleted Diets.**

| | | T2013 PC Study Feed Composition: Chemical Analysis of Feed (%) | | | | |
|---|---|---|---|---|---|---|
| Phase | Diet | Crude Protein | Crude Fat | Crude Fiber | Ash | Moisture |
| Starter: 0-28 d | Crumbles | 27.69 | 4.47 | 2.67 | 6.68 | 12.54 |
| | Mash | 26.63 | 3.20 | 2.80 | 6.32 | 11.81 |
| Grower: 28-44 d | Pellets | 25.39 | 5.11 | 2.73 | 6.47 | 11.71 |
| | Mash | 27.35 | 3.65 | 3.00 | 6.70 | 11.05 |

**Table 2.2:** Feed formula for both the mash/mash and crumble/pellet diets. Composition was fairly similar between all of the diets.

**Data Collection and Analysis:**

Bird identification, PC evaluation, data collection and data analysis were identical to the methods used in Trial 1; however, blood was not drawn from these birds as Hybrid did not need any samples at this time (Appendix B). PC Trial 2 was completed after the 6 week brooding period, thus concluding this series of research projects on pendulous crop by Hybrid Turkeys at the Penn State Poultry Education and Research Center.

# Chapter 3

# Results

## Trial 1 Results:

The following results were compiled after interpreting ANOVA percentage data after an arcsine transformation (Appendix B). Parameters which were evaluated for significance from Trial 1 include average feed intake, water intake, body weight/body weight gain, feed conversion, mortality, and the incidence of PC across all of the experimental factors.

### Feed Intake:

Feed intake was determined by weighing 50kg amounts of feed into designated bins for each pen used in this experiment (Figure 2.2). Each new addition of 50kg to empty bins was recorded. This was done for the pre-starter and starter diets of both feed formulations. After each feed phase, the remaining feed in the metal hanging feeders and bins were weighed back to obtain an accurate weight of feed consumed during each three week period. The feed was removed and weighed 2 hours prior to weighing the birds, so that more accurate body weights could be taken without excess feed in the GI tract. Measurements were taken for the first three weeks (pre-starter), the second three weeks (starter), and were then totaled to determine the overall amount of feed consumed. Once these measurements were taken, they were analyzed against the experimental parameters.

From these results we can see how each factor influenced feed intake and if there was a significant p-value ($P \leq 0.05$) associated with differences in a particular parameter (Figure 3.1). Significant differences in the starter diet intake were influenced by the ambient temperature of the rooms, $P<0.0032$. Significant differences in overall feed intake were influenced by the available energy in the diet, $P< 0.0001$. The only significant difference present while consuming the pre-starter diets, was derived from the amount of available energy in the feed.

**Figure 3.1: Average Feed Intake of Female Converter Turkeys.**

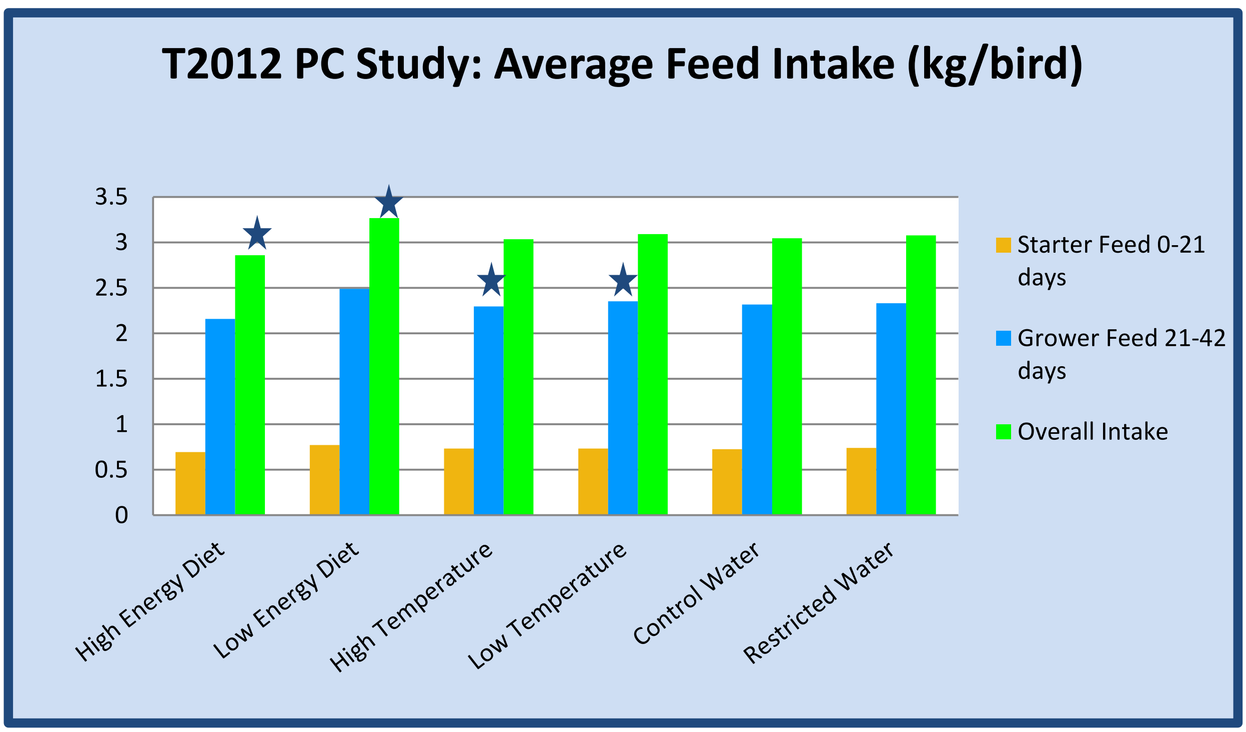



**Figure 3.1:** The average feed intake of female Converter turkeys in kg/bird, evaluated by weighing total feed consumed compared to average bird weights for each pen, during the first 6 weeks of life.
★Means are considered significantly different ($P \leq 0.05$) for factors. When above Overall Intake, factor significantly impacted feed intake throughout the entire study.

**Water Intake:**

Water intake was determined by 5 different measurements throughout the growing period. The recordings took place on day 11, day 18, day 25, day 33, and day 39 of the trial (Appendix B); these days were chosen randomly at intervals that were at least 6 days apart to obtain unbiased readings. In order to get this information 48 customized 5 gallon buckets were filled with water, hung in each of the pens, and were attached to the Plasson® bell drinkers via the drinker hose and a special nozzle on the bottom of the bucket. Once these buckets were attached, the nozzles were opened to fill the drinkers, and to continue to fill the drinkers as needed for one hour. The buckets were weighed before and after the hour time period, and the difference in weight (kg) was determined to be the overall water intake of that pen. These differences were then divided by the number of birds in each pen, and recorded as kilograms of water/bird/hour, and were assumed to represent the average water intake of those birds during that stage of life.

Once these measurements were taken, they were analyzed against the experimental parameters. From these results we can see how each factor influenced water intake and if there was a significant p-value ($P \leq 0.05$) associated with differences in a particular parameter (Figure 3.2). Significant differences in water intake were recorded on all measurement days for the available energy in the feed, as well as for the ambient temperature (Appendix B); here the low energy feed, and the higher ambient temperature both increased water intake. Despite Water Restriction being one of the three main experimental factors, no significant differences were recorded on any measurement days for this parameter on its own. However, the data collected from the day 33 water intake measurement, there was an interaction between Water Restriction and the available energy in the feed, P≤0.0374 (Appendix B).

**Figure 3.2: Average Water Intake of Female Converter Turkeys.**

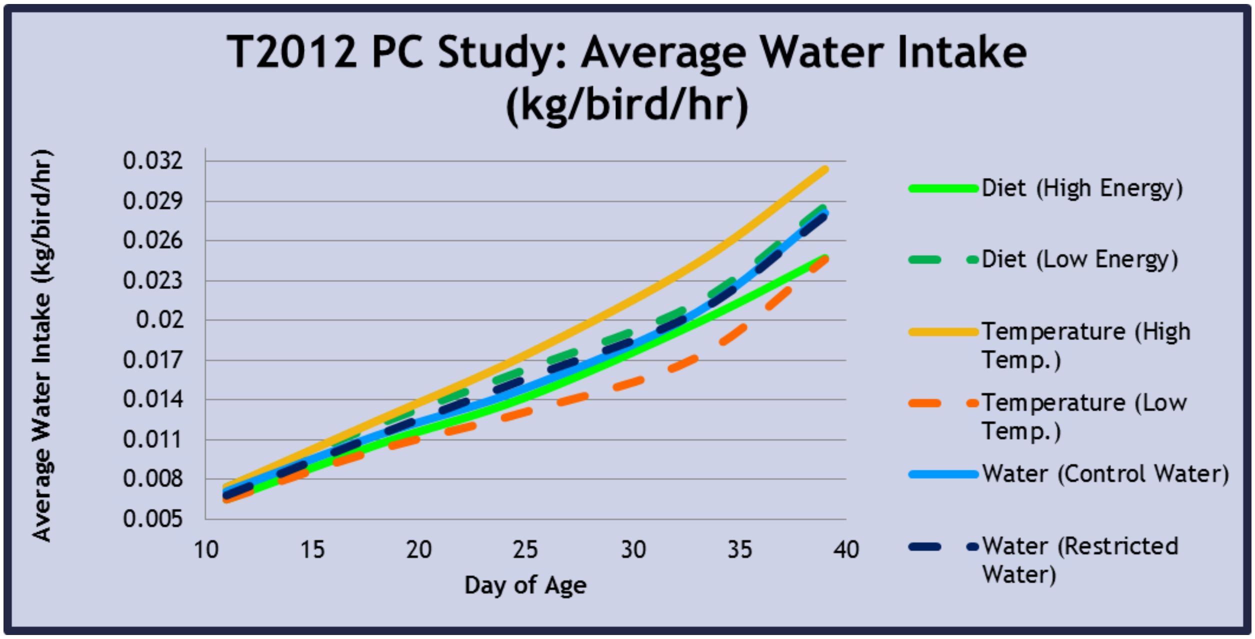



**Figure 3.2:** The average water intake of female Converter turkeys in kg/bird/hour during the first 6 weeks of life. Variations in temperature had the greatest influence over the amount of water consumed. Significant difference is demonstrated in this table depending on the degree of separation within each factor.

**Poult Growth Analysis:**

The growth of a rapidly growing species such as turkeys can be greatly influenced by the environment, depending on what is being varied. The birds used in this trial were weighed prior to placement, at the end of the pre-starter diet (21 days of age), and at the end of the end of the experiment. All of the birds were weighed as a pen group, from which the total weight was divided by the total number of the birds in the pen to get an average weight. It is important to note that upon initial weight measurements, the birds within each experimental parameter had an average weight of 55.65g±0.15g, showing an unbiased starting weight.

Once these measurements were taken, they were analyzed against the experimental parameters. From these results we can see how each factor influenced poult growth and if there was a significant p-value ($P \leq 0.05$) associated with differences in a particular parameter (Table 3.1). No significant differences were recorded for the restriction of water on influencing body weight gain throughout the trial. At 21 days of age, poults being fed the low energy diet showed significant differences, where the lower energy diet resulted in heavier body weights, $P<0.0001$. After the data was collected from the final body weight measurements, there were significant differences in both the diet and temperature parameters for the day 42 body weight measurements as well as the overall body weight gain. The poults being fed the lower energy feed remained heavier than the poults being fed the high energy diet, but this time by a greater margin, $P<0.0001$ for both. Furthermore, the birds kept in the lower ambient temperature weighed heavier than those kept in the higher temperature environment, $P \leq 0.0383$ and $P \leq 0.0384$ respectively.

**Table 3.1: Average Body Weight (BW) and BW Gain Per Bird**

| T2012 PC Study: Average Body Weight (BW) and Body Weight Gain Per Bird | | | | | |
|---|---|---|---|---|---|
| Factor | Level | Initial Chick BW (g) | BW (Kg) Day 21 | BW (Kg) Day 42 | BW Gain (Kg) Overall |
| Diet | High Energy | 55.5 | 0.559[b] | 1.979[b] | 1.923[b] |
| | Low Energy | 55.7 | 0.617[a] | 2.234[a] | 2.178[a] |
| Temperature | High Temp. | 55.5 | 0.591 | 2.09[B] | 2.034[B] |
| | Low Temp. | 55.8 | 0.585 | 2.124[A] | 2.067[A] |
| Water | Control Water | 55.6 | 0.586 | 2.102 | 2.046 |
| | Restricted Water | 55.7 | 0.589 | 2.111 | 2.055 |

**Table 3.1:** Average BW and BW Gains were recorded to monitor how the female poults grew throughout the brooding period. These gains were evaluated for each experimental parameter to see which factors significantly effected growth.
[a, b, A, B] Values within a factor & column that do not share a common superscript are significantly different ($P \leq 0.05$).

Once the body weight and body weight gain data was gathered, the average feed conversion was calculated after comparing these measurements to the average feed intake (Table 3.2). The only significant difference that was derived from feed conversion, when compared to the experimental parameters, was the dietary energy from days 21 to 42, $P \leq 0.0407$; however, this did not have a great enough impact on the overall conversion to be considered significant.

**Table 3.2: Average Feed Conversion (kg Feed Intake/kg BW Gain)**

| T2012 PC Study: Average Feed Conversion (Kg Feed Intake/Kg BW Gain) | | | | |
|---|---|---|---|---|
| **Factor** | **Level** | **Days 1-21** | **Days 21-42** | **Overall** |
| Diet | High Energy | 1.389 | 1.526[b] | 1.490 |
| | Low Energy | 1.391 | 1.547[a] | 1.506 |
| Temperature | High Temp. | 1.381 | 1.541 | 1.498 |
| | Low Temp. | 1.400 | 1.532 | 1.498 |
| Water | Control Water | 1.380 | 1.535 | 1.494 |
| | Restricted Water | 1.401 | 1.538 | 1.502 |

**Table 3.2:** Feed conversion was recorded for each factor to see their impact on feed efficiencies. This was calculated by dividing total feed intake (kg) by one pen of birds by the total weight gained (kg) of the birds in that pen.
[a, b] Values within a factor & column that do not share a common superscript are significantly different ($P \leq 0.05$).

**Mortality:**

In evaluating flock mortality, there is no significant evidence that mortality was greatly influenced by any of the experimental factors (Figure 3.3). The ANOVA software indicated that there was a three-way interaction of all three factors, however this was expected since mortality was taken from each environmental combination (Appendix B). The greatest mortality across all of the experimental factors occurred during days 0-21, and the greatest mortality overall for these parameters was found in the Low Energy diet (control).

**Figure 3.3: Percent Flock Mortality**

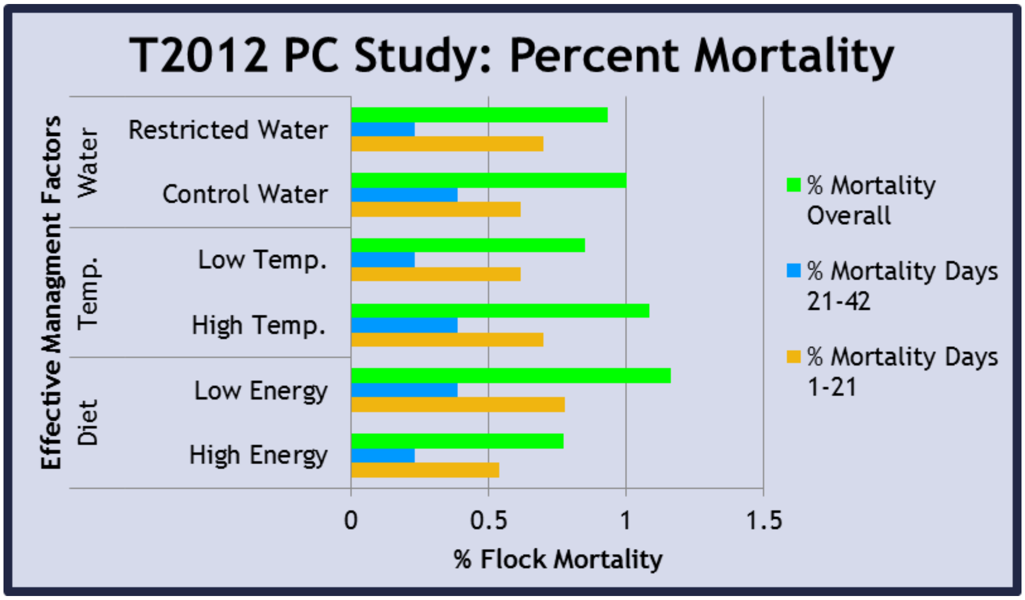



**Figure 3.3:** Total mortality recorded for Trial 1. Birds exhibiting PC did not contribute to any mortality in this particular flock.

**Incidence of Pendulous Crop:**

Upon the completion of this 6 week trial, a total of 22 PCs were recorded, 11 were very pronounced, 5 were pronounced, and the remaining birds with pendulous crop exhibited only slightly pronounced PC. The first PC was recorded on 5/18/2012, on Week 3 of the study. The poult was in a pen receiving the following treatments: low energy feed, high ambient temperature, and restricted water. After three weeks the PC had progressed to be nearly the same size as the poult's body (Figure 2.6).

When comparing the total incidence of PC to all of the experimental factors, temperature was calculated to be the factor with the most significant difference ($P \leq 0.0001$) for inducing pendulous crops; neither of the other factors showed significant differences. This can be seen by a >1% incidence difference between the High

Temperature and Low Temperature environments, where the higher temperature showed the greater number of PCs (Table 3.3). All birds exhibiting PC survived to the end of the trial, and were not culled or removed from the experimental conditions. The purpose of this was to follow the progression of the condition in Converter turkey hens, and to collect the proper evaluations/samples at the end of the study.

**Table 3.3: Pendulous Crop Incidence in Female Converter Turkeys.**

| T2012 PC Study: Pendulous Crop Incidence (%) | | | |
|---|---|---|---|
| Factor | Level | % Birds Housed | % Birds Alive to 42 days |
| Diet | High Energy | 0.926 | 0.932 |
| | Low Energy | 0.932 | 0.944 |
| Temperature | High Temp. | 1.549 | 1.564 |
| | Low Temp. | 0.309 | 0.312 |
| Water | Control Water | 1.003 | 1.018 |
| | Restricted Water | 0.855 | 0.858 |

**Table 3.3:** The incidence of pendulous crop in female converter turkeys during the first 6 weeks of life. Turkeys with pendulous crop were recorded for each factor in the experimental design as compared to the total number of birds housed, as well as to the total adjusted for mortality. The significantly different percentages within the temperature factor are circled.

**Trial 2 Results:**

The following results were compiled after interpreting ANOVA percentage data after an arcsine transformation (Appendix B). Parameters which were evaluated for significance from Trial 2 include average feed intake, body weight/body weight gain, feed conversion, mortality, and the incidence of PC across all of the experimental factors.

**Feed Intake:**

The methods for collecting the results for Feed Intake were identical to those conducted in Trial 1. Once the feed weight measurements were taken, they were analyzed against the experimental parameters.

From these results we can see how each factor influenced feed intake and if there was a significant p-value ($P \leq 0.05$) associated with differences in a particular parameter (Figure 3.4). Significant differences in the starter diet (0-28 days of age) intake were influenced by feed form ($P<0.0001$), incubation temperature ($P \leq 0.0038$), and lighting program (0.0048). During the grower diet phase (28-44 days of age) significant differences of feed intake were found with only feed form ($P<0.0001$), and lighting ($P \leq 0.0259$). Also this set of measurements produced significant differences with interactions between feed form * lighting program ($P \leq 0.0128$), incubation temperature * lighting program ($P \leq 0.0306$), and all three factors combined ($P \leq 0.0203$). After comparing the data from these two sets of feed intake measurements, the only significant difference depended on feed form ($P<0.0001$). However, there were overall interactions between feed form * lighting program ($P \leq 0.0125$), and all three factors combined ($P \leq 0.444$) (Appendix B).

**Figure 3.4: Average Feed Intake of Straight Run Converter Turkeys.**

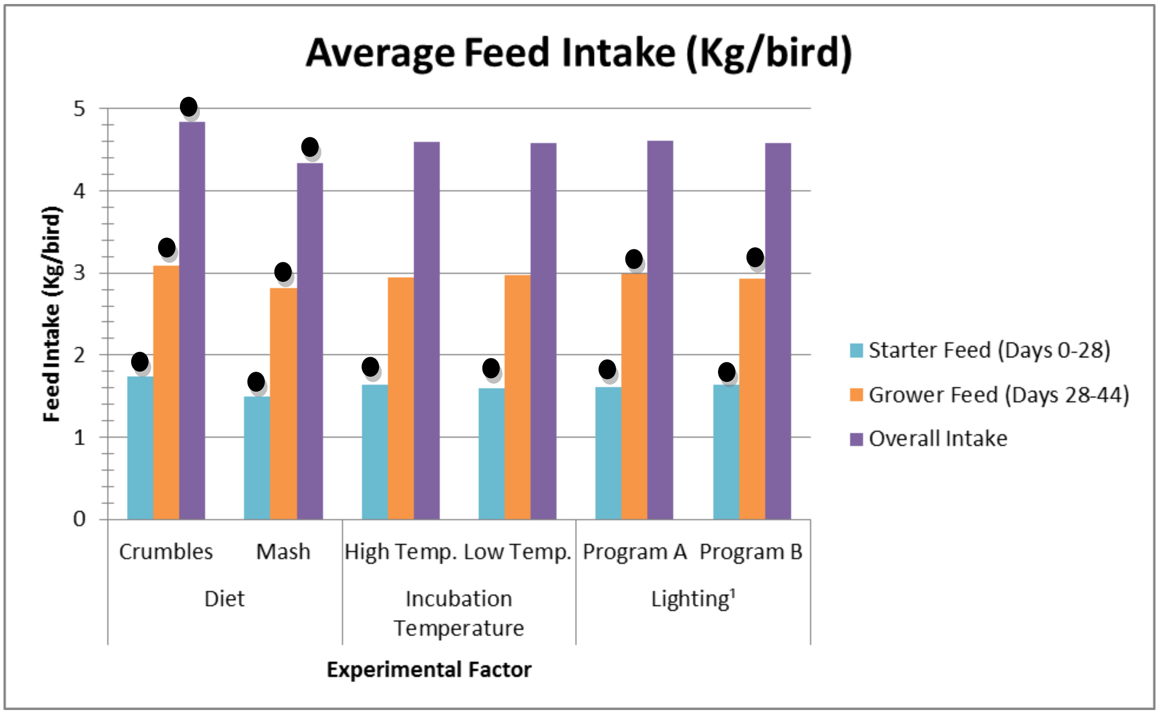



**Figure 3.4:** Average feed intake was significantly influenced by feed form, where intake was much higher for birds fed the crumble/pellet diet when compared to the mash diet.
● Values within a factor & Column are significantly different ($P \leq 0.05$).
[1] Lighting: Program A = Standard 23L:1D on days 1-6, and 16L:8D on days 7-44; Program B = 23L:1D on days 1-6, and an intermittent light schedule on days 7-44 with 4 cycles of 1L:5D.

**Poultry Growth Analysis:**

The methods for collecting the results for poult growth were identical to those conducted in Trial 1. Once the body weight and body weight gain measurements were taken, they were analyzed against the experimental parameters. It is important to note that upon initial weight measurements, the birds within the feed form and lighting experimental parameters had an average weight of 57.20g±0.10g, showing that nearly equal masses of birds were placed in each of the possible environmental combinations. However, the experimental incubation temperature did influence initial body weights where the average initial body weight of the poults from the high temperature was 58.60g, and 55.80g from the low temperature. Equal amounts of poults from each incubation temperature profile were distributed among the other experimental parameters, but were still monitored separately throughout the trail to obtain long term results of incubation temperature.

Once the body weight measurements were taken, they were analyzed against all of the experimental parameters. From these results we can see how each factor influenced poult growth and if there was a significant p-value ($P \leq 0.05$) associated with differences in a particular parameter (Table 3.4). In this second trial, all of the factors appeared to have significant influences in poult body weights (BW) and overall body weight gain (BWG). The results from the mash vs. crumble diet were significantly different at the day 28 BW measurement ($P < 0.0001$), the day 44 BW measurement ($P < 0.0001$), and in the overall BWG ($P < 0.0001$). Incubation temperature results between the high and low temperature profiles were significantly different at the initial poult BW measurement ($P < 0.0001$), the day 28 BW measurement ($P \leq 0.0027$), and the overall BWG ($P \leq 0.05$). Furthermore there was a significant interaction between feed form and incubation temperature on the day 28 BW measurement ($P \leq 0.0064$). Finally, the results from the standard lighting (Program A) vs. intermittent lighting (Program B) were significantly different at the day 28 BW measurement ($P \leq 0.0007$), the day 44 measurement ($P < 0.0001$), and the overall BWG measurement ($P < 0.0001$).

**Table 3.4: Average Body Weight (BW) and BW Gain Per Bird**

| T2013 PC Study: Average Body Weight (BW) and Body Weight Gain Per Bird | | | | | |
|---|---|---|---|---|---|
| Factor | Level | Initial Poult BW (g) | BW (Kg) Day 28 | BW (Kg) Day 44 | BW Gain (Kg) Overall |
| Diet | Crumbles | 57.10 | $1.31^{a}$ | $3.14^{a}$ | $3.08^{a}$ |
| | Mash | 57.30 | $1.03^{b}$ | $2.52^{b}$ | $2.46^{b}$ |
| Incubation Temperature | High Temp. | $55.80^{a}$ | $1.19^{a}$ | $2.86^{a}$ | $2.80^{a}$ |
| | Low Temp. | $58.60^{b}$ | $1.56^{b}$ | $2.81^{b}$ | $2.75^{b}$ |
| Lighting[1] | Program A | 57.10 | $1.19^{a}$ | $2.93^{a}$ | $2.87^{a}$ |
| | Program B | 57.20 | $1.15^{b}$ | $2.75^{b}$ | $2.69^{b}$ |

**Table 3.4:** Average BW and BW Gains were recorded to monitor how the straight-run poults grew throughout the brooding period. These gains were evaluated for each experimental parameter to see which factors significantly effected growth. All factors tested showed overall significant differences within each parameter by the end of the trial.

[a,b] Values within a factor & column that do not share a common superscript are significantly different ($P \leq 0.05$).

[1] Lighting: Program A = Standard 23L:1D on days 1-6, and 16L:8D on days 7-44; Program B = 23L:1D on days 1-6, and an intermittent light schedule on days 7-44 with 4 cycles of 1L:5D.

Once the body weight and body weight gain data was gathered, the average feed conversion was calculated after comparing these measurements to the average feed intake (Table 3.5). Significant differences in feed conversion were present from days 0-28 when comparing feed form ($P<0.0001$), and the lighting programs ($P<0.0001$). During days 28-44 significant differences were recorded across all of the experimental factors: feed form ($P<0.0001$), incubation temperature ($P\leq0.0125$), and lighting ($P<0.0001$). This was also true for the overall feed conversion results where there were significant differences in feed form ($P<0.0001$), incubation temperature ($P\leq0.0065$), and lighting ($P<0.0001$). In addition to the significant differences within each experimental parameter, there was a significant interaction between feed form and lighting for the measurements from days 28-44 (P≤0.0073), and for overall feed conversion (P≤0.0197) (Appendix B).

**Table 3.5: Average Feed Conversion (kg Feed Intake/kg BW Gain)**

| T2013 PC Study: Feed Conversion (Kg Feed Intake/KG BW Gain) | | | | |
|---|---|---|---|---|
| Factor | Level | Days 0-28 | Days 28-44 | Overall |
| Diet | Crumbles | $1.39^{a}$ | $1.70^{a}$ | $1.57^{a}$ |
| | Mash | $1.55^{b}$ | $1.91^{b}$ | $1.77^{b}$ |
| Incubation Temperature | High Temp. | 1.47 | $1.78^{a}$ | $1.65^{a}$ |
| | Low Temp. | 1.48 | $1.82^{b}$ | $1.68^{b}$ |
| Lighting[1] | Program A | $1.43^{a}$ | $1.74^{a}$ | $1.62^{a}$ |
| | Program B | $1.51^{b}$ | $1.86^{b}$ | $1.72^{b}$ |

**Table 3.5:** Feed conversion was recorded for each factor to see their impact on feed efficiencies. This was calculated by dividing total feed intake (kg) by one pen of birds by the total weight gained (kg) of the birds in that pen. All factors showed significant differences within each parameter by the end of the trial.
[a,b] Values within a factor & column that do not share a common superscript are significantly different (P ≤ 0.05).
[1] Lighting: Program A = Standard 23L:1D on days 1-6, and 16L:8D on days 7-44; Program B = 23L:1D on days 1-6, and an intermittent light schedule on days 7-44 with 4 cycles of 1L:5D.

**Mortality:**

In evaluating flock mortality, there is no significant evidence that mortality was greatly influenced by any of the experimental factors (Figure 3.5). The ANOVA software indicated that the closest P-value to being significant was where there was a three-way interaction of all three factors for the percent Mortality overall; this was expected since mortality was taken from each environmental combination (Appendix B). The greatest mortality across all of the experimental factors occurred during days 0-28, and the greatest mortality overall for these parameters was found in Lighting Program B (intermittent lighting).

**Figure 3.5: Percent Flock Mortality**

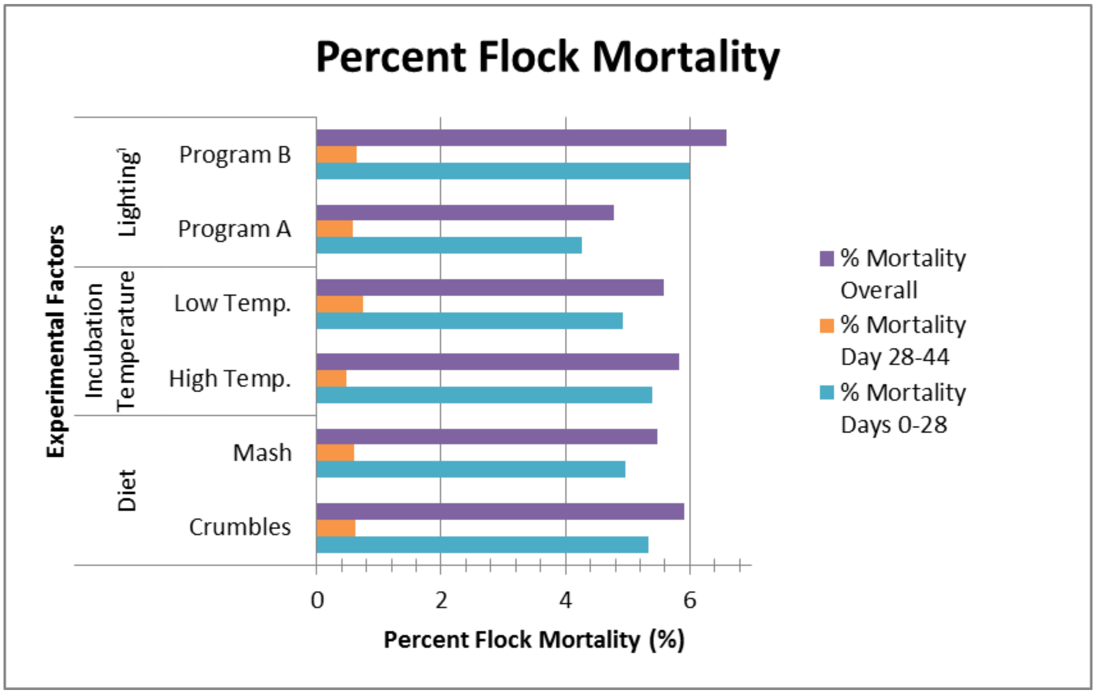



**Figure 3.5:** Total mortality recorded for the trial. Birds exhibiting PC were not purposefully culled out of the flock, ergo all PC poults survived until the end of the study and did not contribute to any mortality in this particular flock.

**Incidence of Pendulous Crop:**

Upon the completion of the 6 week trial, a total of 38 PCs were recorded as pronounced. The first pendulous crop was recorded during the third week of the trial, and all birds were evaluated at the end of the trial for the severity of their pendulous crop. While there was no single, overall effective management factor that showed significant influence over inducing pendulous crop, the interaction between feed form and lighting was calculated to have the greatest overall significance in the percent of birds housed, and the percent of birds alive ($P \leq 0.0109$ and $P \leq 0.0114$, respectively). This significant interaction was first recorded during days 28-44 for the percent of birds housed and the percent ($P \leq 0.0194$ and $P \leq 0.0203$, respectively) (Appendix B).

Of the 38 birds exhibiting PC, 22 poults were on the mash diet and 16 poults were on the crumble/pellet diet. Interactions showed the Mash feed * Program A Lighting had 5 PCs, while the Mash feed * Program B Lighting had 17 PCs; the interaction also showed the Crumble feed * Program A Lighting had 10 PCs, while the Crumble feed * Program B Lighting had 6 PCs. All of these birds with the induced PC survived to the end of the trial, and were not removed from the experimental conditions for the purpose of following the progression of the condition under the prescribed experimental management factors (Table 3.6).

**Table 3.6: Pendulous Crop Incidence in Straight Run Converter Turkeys.**

| T2013 PC Study: Penduous Crop Incidence | | | |
|---|---|---|---|
| Factor | Level | % PC of Birds Housed Days 0-44 | % PC of Birds Alive Days 0-44 |
| Diet | **Crumbles** | **1.33** | **1.41** |
| | **Mash** | **1.91** | **2.03** |
| Incubation Temperature | **High Temp.** | **1.39** | **1.48** |
| | **Low Temp.** | **1.83** | **1.93** |
| Lighting[1] | **Program A** | **1.30** | **1.35** |
| | **Program B** | **1.92** | **2.06** |
| Significant P-values ($P \leq 0.05$) | **Diet* Lighting** | **0.01** | **0.01** |

**Table 3.6:** The incidence of pendulous crop in female converter turkeys during the first 6 weeks of life. Turkeys with pendulous crop were recorded for each factor in the experimental design as compared to the total number of birds housed, as well as to the total adjusted for mortality. While no single factor showed significant p-values, the interaction of the diet (feed form) and lighting program was significant in causing pendulous crop, and was included here.

# Chapter 4

## Discussion

Pendulous crop is a long standing issue in the commercial turkey industry, and has been attributed to many different causes since its discovery. This disease has impacted the commercial turkey industry to the point that thousands of dollars can be being lost in feed efficiencies, and at the processing plants. Hybrid Turkeys selected parameters that they believe to play a role in causing pendulous crop in their commercial flocks (Appendix A).

The following discussion details the conclusions drawn from both Trial 1 and Trial 2 about the effectiveness of the experimental design, the success of the data collection, the progression of PC in modern turkeys, and the final assumptions of PC incidence and other significant factors. It should be noted that the percentage of PCs resulting from both studies did not reach the reported levels as seen by Hybrid in the field. For this reason the blood samples that were collected at the end of each trial were not used for genomic analysis, as it did not appear to be solely a genetic problem (Appendix A). If only genetics are to blame, a higher percentage of birds were expected to express PC in nearly equal amounts across all of the experimental parameters. In general it can be concluded that different management factors do have a significant impact on the incidence of pendulous crop in turkeys.

## Trial 1:

### Experimental Design

#### Dietary Energy

The available dietary energy in the feed did cause expected differences in the data regarding poult growth (Table 3.1 & 3.2); however it did not have significant influence over PC.

A source of human error was present in regards to this experimental management factor. The agars in which the high energy and low energy feeds were placed were mislabeled inside of the barn and went unrealized for 2 weeks. This resulted in all of the poults being fed the high energy pre-starter diet for the first two weeks of life. Once this was realized, the feeds were changed to the correct diets for the designated pen profiles, and the remainder of the pre-starter diet was correctly following Hybrid’s protocol. Prior to feeding the starter diets, the feed agars were checked against the labels inside of the barn to ensure that the proper feeds were being distributed according to the protocol.

This source of human error may have caused different results from what the protocol could have achieved; it was interesting that the first PC did not appear until the third week of growth, after the feeds had been switched. However, this feeding error may have been insignificant since a greater amount of feed intake for both diet formulations occurred after the poults were switched to the starter diets. Also, the poult growth data still showed significant differences between the two feed forms from the pre-starter (0-21 days) diet; thus varying the available energy in the diet still proved to be an effective management factor and still made an impact on the poults.

**Ambient Temperature**

Variations in brooding temperature according to the Hybrid temperature protocols had the greatest influence on PC incidence as well as water intake. From these results it was assumed that there was a direct link between higher brooding temperature and increased water intake, which overextended the crop in PC birds. Furthermore, when compared to past studies, higher environmental temperatures seemed to have a greater association with turkeys exhibiting pendulous crop[1].

For this reason, the results gathered from this trial showing the influences of temperature on PC were expected. By meeting this expectation, it can be inferred that while the domestic turkey has been significantly modified since the initial PC studies[1], some management factors target specific homeostatic responses that have not changed. This includes, but may not be limited to, increased water intake in attempt to cool the body under higher environmental temperatures.

Also in past experiments, humidity variations were also considered along with temperatures[1,9]. This parameter was not a focus of this trial, and the average humidity readings were approximately equal in all of the rooms under both treatments; thus humidity was not considered further here.

**Water Restriction**

Water Restriction had no significant impact on the incidence of pendulous crop, which was initially an unexpected result. It was later realized that each

Plasson® broiler breeder bell drinker is designed to easily accommodate the needs of 100 birds from medium to large poultry species (Appendix A). When the water restriction spacers were placed in these bell drinkers, they reduced the drinking area by half, which presumably limited the drinking space to an area that would still be ideal for approximately 50 medium sized turkeys. Since each pen contained 54 birds that were only grown for 6 weeks, it was assumed that the bell drinkers from both experimental factors allowed ample drinking area throughout the trial.

While the drinking space was reduced by half in the restricted water parameter, it should have been more severely reduced to only 25% of the initial drinking space when only 54 birds are exposed to the treatment. This was stated in Hybrid's protocol for turkey red bell drinkers which are larger than broiler breeding drinkers (Appendix A). Ergo, it would appear that incorrect assumptions were made when restricting water by half in these drinkers for the restricted water birds, while leaving a whole drinker available for the poults with the control water.

It is believed that this particular parameter may have greater influence over inducing pendulous crop in field studies, where the proper drinker area to turkey ratio can be better manipulated for the correct standards and for restricted water environments[9,10].

**Data Collection and Analysis**

After the raw data was collected it was put into the ANOVA program by the Penn State Animal Science's Department- Poultry Science staff (Appendix B). Following the arcsine transformation, the percentage data was given to the primary student researcher to interpret for signs of significant data. Once the primary assumptions were drawn, they were reviewed and acknowledged by the co-authors of this trial.

**Progression of PC**

Visual observations were recorded from the onset of a pendulous crop, until the end of the study. The interpretations from the induced PCs showed that there were no significant differences in how the disease progresses in the modern turkey as compared to the turkeys used in all past trials (Figure 4.1).

**Figure 4.1: Progression of PC in Trial 1**

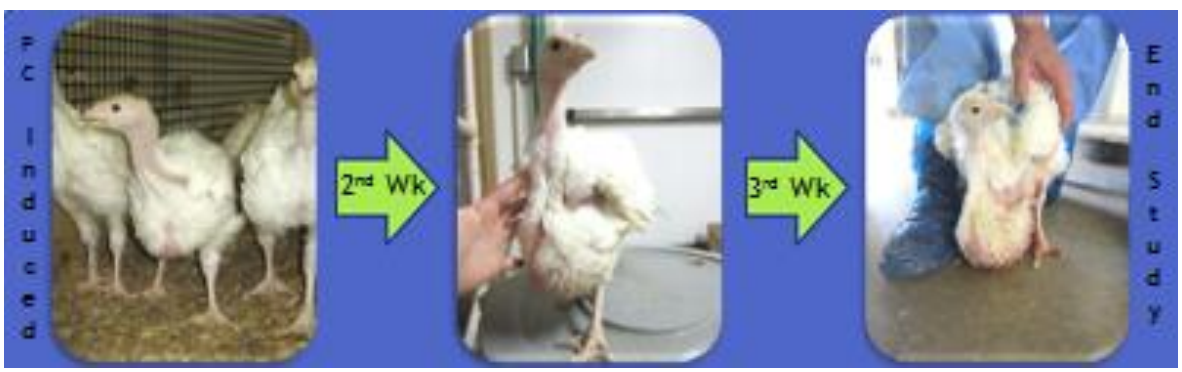



**Figure 4.1:** The first PC was found during the third week of the trial and was observed for the next three weeks until the study ended.

**Concluding Assumptions of Pendulous Crop Incidence & Other Significant Factors**

In conclusion of Trial 1, the results of this study lead us to believe that the ambient temperature during the brooding period of commercial Converter Female poults, and/or increased water consumption due to coping with the higher temperatures increases the incidence of pendulous crops (1.56% vs. 0.31%, $P<0.0001$). This is supported by observing how water intake was very significantly increased ($P<0.01$) in environments where the lower available energy feed was given, as well as in the rooms with a high ambient temperature. In contrast to the significant differences resulting from the temperature variation, there were no significant differences for either the experimental water restriction or available dietary energy.

Although the focus of this study was observing the incidence of PC, other conclusions that were drawn from this study not related to PC. The bulk of these other significant differences arose from the fact that the dietary energy greatly influenced the growth of the poults. The first significant difference was found for the interaction for feed conversion during days 21-42 between the water treatment and the diet ($P\leq0.05$). It was assumed that this was a significant factor because at this stage in life the poults are able to consume more feed than when they were smaller. The poults being fed the lower energy diet were consuming more feed to meet their energy requirements than the birds being fed the higher energy diet, and thus the poults consuming more feed required more water to digest the greater feed volume effectively. This assumption was supported by the significant difference in feed conversion during days 21-42 where the birds being fed the high energy diet converted feed more effectively into body mass than the birds being fed the lower energy diet.

A final significant difference resulting from dietary energy differences was body weight. This was demonstrated where the body weight results were significantly greater for the birds fed the lower energy diets throughout the entire trail when compared to the body weights of those fed the higher energy feed. This was to be expected, as birds which eat more feed will typically weigh less than those who do not.

## Trial 2:

Trial 2 was pursued by Hybrid Turkeys due to the fact that the Trial 1 results did not meet their expectations in the flock percentage of PC incidence; 10-15% as reported by a number of farms they supply. The new parameters were chosen using three other management factors that have been associated with pendulous crop syndrome (Appendix A).

### Experimental Design

#### Incubation Temperature

Incubation temperature had no significant long term impact on the incidence of PC on the live poults that were randomly selected to continue on in the study for the brooding phase. This being said, hatchery mortality data was collected for the general flock records but was not included in the results of this trial regarding PC. The birds under the high temperature treatment showed higher mortality when compared to the standard treatment. Once the birds were chosen from each hatch group and placed in the brooding environment, mortality remained below expectations.

Furthermore, it was anticipated that higher incubation temperature would adversely affect poult growth, which was demonstrated by the body weight and body weight gain measurements. Other than these measurements incubation temperature did not produce significant data, or increases or decreases in the incidence of PC. For this reason, it was assumed that the mortality loss from the incubation period did not affect the outcomes of this study.

**Lighting Program**

The lighting protocols provided the most defined and consistent experimental parameter, as definite on/off times were designated to the exact minute for both lighting profiles. While there can be slight temperature variations in commercial incubation settings and feed can vary both in its form and nutritional profile, there was very little room for error when following Hybrid's protocol for the lighting parameters (Appendix A).

Lighting proved to have the most influence over triggering the poult's water and feed consumption and thus produced significant results for all of the measurements compiled from the collected data. Since lighting influenced the time periods where the poults consumed feed, it is believed the significant interactions stemming from the feed form and lighting originated here.

Interestingly enough the interactions showed the Mash feed * Program A Lighting had 5 PCs, while the Mash feed * Program B Lighting had 17 PCs; the interaction also showed the Crumble feed * Program A Lighting had 10 PCs, while the Crumble feed * Program B Lighting had 6 PCs. From these results, it can be stated that the intermittent lighting program induced more pendulous crops. This program is typically enforced to increase feed efficiency, but this was not exemplified in this trial; moreover, with a higher rate of PCs, feed is also going to be poorly converted by a greater number of birds.

**Feed Form**

In this study feed form was varied to mimic two common particle sizes of poult feed. As learned from the source of error in the dietary aspect of Trial 1, care was take in making sure the appropriate pens were given their designated feed throughout the duration of the trial. The two different treatments, as previously mentioned, played a significant role under different lighting programs in the incidence of pendulous crop. Since rapidly growing birds are often in search of feed, they could readily identify both feed forms as their diet source.

It is assumed that the increased number of PCs associated with Program B lighting, and the decreased number of PCs associated with Program A lighting both can be traced to the palatability of the feed. A drier, powdery feed demands a higher fluid intake during consumption times. Additionally, via observations, when the birds are hungrier between feeding times they will put more energy towards gorging during feedings, and will focus more on the quantity of feed and crop filling rather than the quality and mouth-feel of the feed.

From the interacting lighting and feed results, treatment of PC by management may be feasible. One such scenario could include a management setting where there is intermittent lighting and mash feed with increased PC incidence. The occurrence of PC may be reduced by either switching the lighting program to a standard 16L:8D growing program, or the diet can be fed as a crumble/pellet feed. This may reduce the incidence of more PCs in the flock.

## Data Collection and Analysis

Similarly to Trial 1, after the raw data was collected it was put into the ANOVA program by the Penn State Animal Science's Department- Poultry Science staff (Appendix B). Following the arcsine transformation, the percentage data was given to the primary student researcher to interpret for signs of significant data. Once the primary assumptions were drawn, they were reviewed and acknowledged by the co-authors of this trial.

## Progression of PC

Visual observations were recorded from the onset of a pendulous crop, until the end of the study. The interpretations from the induced PCs showed that there were no significant differences in how the disease progresses in the modern turkey as compared to the turkeys used in all past trials. While this methodology is identical to the Trial 1 practice, these observations were recorded to standardize the interpretation of PC severity in the commercial Converter turkeys (Figure 4.2).

An interesting observation that came from this practice was that in both Trials 1 and 2, the first pendulous crop occurred during week 3 of the 6-week trial. Furthermore, when the crops were induced this early in the trial, by the end of the study the crops were often the same size or larger than the poult's body. In a commercial setting, these birds should be culled from the flock as soon as they are found with a permanent PC so that they do not become emaciated or physically hindered in their movement.

**Figure 4.2: Progression of PC in Trial 2**


**Figure 4.2:** The first PC was found during the third week of the trial and was observed for the next three weeks until the study ended.

**Concluding Assumptions of Pendulous Crop Incidence & Other Significant Factors**

Considering all of the findings from Trial 2, the results of this study lead us to believe that an interaction between feed form and lighting program significantly influence the feeding and drinking habits of poults. This leads to the onset of pendulous crop syndrome during the brooding period of straight-run, commercial Converter poults ($P \leq 0.0114$). By observing this interaction and the resulting PCs, it can be concluded that poults fed a mash died under intermittent lighting are more at risk for developing this anatomical abnormality than those fed a crumble/pellet diet under the same lighting program. Furthermore, it can be concluded that poults fed a crumble diet under the standard lighting are more at risk for developing pendulous crop than those fed a mash diet with the same lighting program.

From these conclusions it can be assumed that the mash diet is less palatable to the turkey poults, as its more powdery texture is not conducive to swallowing. Although water intake was not measured for this trial, it can be assumed that birds fed the mash diet needed to consume more water after eating in order to clear the mash feed from the beak. This being said, it would appear as though birds on the mash diet were not consuming enough feed to remain satiated between light periods in the intermittent lighting program, causing gorging on the mash diet and consequently large volumes of water. Regular gorging may have led to frequent, excessive expansions of the crop, thus weakening the supportive tissues around the crop which then led to PC.

When the birds on the mash diet had more time to consume feed under the standard lighting program, they were not triggered to gorge on the feed or water; thus their crops were not subject to periodic drastic expansions that may have led to PC.

On the other hand, the crumble/pellet diet is typically the preferred feed form of turkeys, as it is more palatable when considering the ease of swallowing. Also, this feed form is denser and has a more uniform nutrient density than the powdery mash, and may have allowed for greater volumes of nutrient-dense feed to be consumed during one feeding. When the poults had a longer period of light for continuous feeding, they were able to eat more feed during this time since it was easier to consume. When greater volumes of feed were consumed, it was assumed that there was also greater water intake. Having a crop full of dense feed and other contents for an extended period of time, under the standard lighting program, may have caused a gradual weakening of the supportive tissues around the crop, or a weakening of the crop itself.

When the birds on the crumble diet were under an intermittent lighting program, it was assumed that they were able to reach and maintain their satiety levels between lighting periods. This conclusion was drawn since the feed was denser, more uniform in nutrient consistency, and was easier to consume. Moreover, large amounts of water were not required to digest this feed easily, thus allowing the birds to meet their energy requirements in a more concentrated volume. When taking these factors into account, the crop should not have been overextended for any great period of time, so the integrity of the crop tissues and surrounding supportive structures was better maintained.

While Trial 2's focus was primarily on inducing pendulous crop, other conclusions that were drawn from this study not related to PC. Similarly to Trial 1, the bulk of these other significant differences arose from variations in the diet, but in this trial the amount consumed was dictated by the feed form and not by the nutrient composition. Feed intake, body weight gain, and feed conversion were all significantly influenced by feed form ($P \leq 0.05$ for diet P-values in each result set). The poults which were on the mash diet were 0.51kg lighter on average.

# Chapter 5

## Further Studies

With the notion that management practices are the main factors in causing PC, there is potential for further studies beyond the research parameters used in this experiment. These include: growing the turkeys past the brooder phase, the incidence of PC in tom turkeys, restricting water in a more severe fashion, collecting crop tissues and surrounding tissues for localized histology, etc.

Prior to this study, and other current studies on PC, the most extensive research on turkey PCs was carried out over 60 years ago. From this research it was concluded that there were genetic factors predisposing the turkeys to PC, wherein management factors would facilitate the expression of PC. This area of research may also have potential if PC experiments would be carried out with modern commercial turkeys, where the DNA of birds with PC would be analyzed.

### DNA and Genetic Influences of Pendulous Crop

Many of the previous studies focusing on pendulous crop were focused on the possibility of this disease being a genetic trait[1,7,8,10,13,14,15,16,17]. Since this is not a gender-specific trait, PC has been attributed to a homozygous pair(s) of autosomal recessive gene(s) in the past[1,15]. With modern genotyping technologies, there is potential to identify if there is a common gene sequence in turkeys exhibiting PC. Once this anomaly is identified, it can be included in SNP chips in the future to analyze DNA of turkey breeder flocks to reduce breedings that would result in progeny that are susceptible to the disease.

This method of gene analysis is currently being explored with both broiler chickens and laying hens[12]. Ergo, it would be logical for a turkey SNP genotyping array to be created in order to further improve the poultry industry.

## Pendulous Crop Observations in Older Birds

This study focused on turkey poults during the first six weeks of life, which only allowed us to analyze the birds while in the brooding environment. After these six weeks, the turkeys are still being managed for another 8 to 12 weeks to grow the birds to market weight, depending on the gender of the bird. While it is true that the possibility that PC can be a much more severe problem for the flock if observed earlier in life, the rest of the growing period will expose the birds to more management situations that could trigger the onset of the abnormality.

While most early PC studies focused on birds older than 12 weeks of age, the research was also conducted to find a genetic origin of the disease, rather than solely management factors as we did for our trials[1,5,6,17].

## Feeding Different Nutrient Concentrations

The crop of the bird is a very unique and important structure in the digestive tract, and all matter that is swallowed by the bird will come into contact with the crop tissues. At this point in digestion no specific nutrients have been broken-down or absorbed for metabolism. Therefore, the environment within the crop has the most diverse content which may influence further feed and/or water intake, or any factor that causes expansion of the crop past its normal limits. This could be due to either the feed’s direct effects on the bird's tissues, or the effects on the microbial populations within the digestive system[10].

In Trial 1, the diet was manipulated for higher energy density through the inclusion of more fat, which influenced the amount of feed consumed. Also, previous studies done with carbohydrate sources of glucose vs. starch showed promotion of microorganism growth and gas production which expanded the crop, especially with yeast species[11,16,17]. However, other diet components such as increased sodium or protein may also potentially affect the health of the crop.

**Increased Sodium**

When presenting the data from Trial 1 at the 36th Annual Turkey Days, and the data from Trial 2 at the 2014 International Poultry Scientific Forum it was brought to our attention that increased sodium levels in the diet are believed to contribute to the incidence of PC in turkeys (Appendix C). This may be due to increased water intake, or gorging water in large quantities after feeding, to remain hydrated. The large volumes of water would cause expansion of the crop to the point where it falls in in front of the supportive ligaments.

Specific sodium concentrations were not discussed, but could be determined if in fact sodium is responsible for inducing PC, through further studies. Turkeys in a 1962 trial showed incidence of PC at 4.0% dietary sodium, yet the diets of the modern bird must be formulated for a faster growing animal[4].

### Increased Protein

In early PC studies, protein was attributed to be one of the factors in inducing pendulous crop; however it was not heavily analyzed, as the main objectives were to find a genetic link to the disease[11,17]. Depending on which proteins or essential amino acids are manipulated, this feed component could lead to a more complex mechanism of influencing PC.

## Modern Approaches to Histological and Pathological Analysis of Pendulous Crop

The most recent analysis of crop histology and pathology is from Rigdon *et al.*, from 1960[16]. In the past 50 years, there have been significant changes in the commercialization of the domestic turkey. For this reason, the more rapid growth and increased finishing weight may influence how the muscular and connective tissues develop around the crop in the earlier stages of life when growth is fastest, which requires increased intake of feed and water. If the muscles are not as well developed in the crop region during these times of increased consumption, this may lead to PC early in life.

In regards to pathology, after the onset of PC the Rigdon *et al.* study indicated that certain degenerative bodies accompanied ulcers that would form on the interior of the crop, and would further weaken the muscles around the crop[16]. Also, it was suggested that infectious agents took advantage of this situation and further damaged the tissues[2,16]. It would be worth researching if these microorganisms are still present, or if there are new microbes, in modern commercial turkeys which are grown in more biosecure facilities than they were 50 years ago. In our studies, the only observed infections related to PC were due to puncture wounds by the toes or beaks of the birds.

**Field Trials**

It is important to realize that studies like this, carried out in research facilities, will often create the desired results, but maybe not to the most accurate extent of doing research at the commercial scale with the normal activity of commercial turkey production. Both of the trials completed for this research were successful in causing PC, but not to the extent of the 10-15% incidence as reported from the Hybrid flocks in question.

Furthermore, commercial flocks of turkeys are typically comprised of a single gender majority, where toms are grown to heavier body weights. If studies are done in the field, variations in how the different genders are managed could be observed for inducing PC.

**Final Statement:**

To conclude, Pendulous Crop has been an issue in the turkey industry for many years and is still a problem today. It has been concluded from these studies that PC incidence can be manipulated through different management schemes. Modern management practices and technologies allow for many more opportunities to study the turkeys we are using in the industry, and may even lead to reducing this problem in the field in the future.

# Appendix A

## Detailed Protocols

**PSU IACUC Protocol:**

Students are required to complete IACUC training prior to working with animal specimens in a research setting. My IACUC training was completed and approved in the spring of 2011.

The IACUC protocol numbers for these studies were #39574 for Trial 1, and # 41906 for Trial 2.

# The Pennsylvania State University

## Animal Worker Questionnaire and Self-Assessment Tool

**Certain medical conditions can increase the level of risk an individual may encounter when working with animals. These medical conditions include, but are not limited to, allergies to animals and/or animal dander, asthma, heart valve disease, immunosuppression, and chronic back injury. The Animal Worker Questionnaire (AWQ) and Self-Assessment Tool will serve to enroll you in Penn State's Occupational Health and Safety Program for Animal Care Personnel (all employees, students, volunteers and/or visitors who work with or will be exposed to vertebrate animals), and will help you determine if you have personal risks that should be evaluated by medical professionals.**

**<u>PERSONNEL INFORMATION (this section requires your responses)</u>:**

Date: 2/17/13 Name: (Last) Steimling _______________________ (First) Corissa____________(MI) A. __
Mailing Address (campus if available): 213 Henning Building , University Park, PA 16802_________________
Telephone Number: 570-765-0015 __________________
E-mail Address (@psu.edu is preferred): cas5792@psu.edu ________________
Department: Animal Sciences _____________College: College of Agriculture______________
Principal Investigator/Supervisor Name: Dr. R. M. Hulet ____________ Email: rmh4@psu.edu ____________
Status – Mark all that apply:

- ☐ Faculty
- ☐ Staff
- ☐ Tech. Service
- **X** Undergraduate Student
- ☐ Graduate Student
- ☐ Post-Doc
- ☐ Volunteer
- ☐ Other– please describe:

**<u>DESCRIBE YOUR ANIMAL CONTACT (check all that apply)</u>:**

☐ I will **<u>not</u>** have contact with animals or facilities supporting the program. **<u>No further action is needed</u>**.

**X** I **<u>will</u>** have contact with animals or facilities supporting the program: **Please utilize the self-assessment tool below to determine if you should be evaluated by medical professionals and participate in an Occupational Medicine surveillance program.**

☐ I **<u>will</u>** be working with non-human primates. **Please utilize the self-assessment tool below to determine if you should be evaluated by medical professionals and participate in an Occupational Medicine surveillance program. <u>NOTE</u>: If you will be working with non-**

**human primates, a current TB test is <u>required</u> prior to contact with the animals. Please make an appointment with Occupational Medicine (814-863-8492).**

# <u>SELF-ASSESSMENT TOOL</u>

**<u>In collaboration with the Occupational Medicine Physician and Environmental Health and Safety at Penn State, this two-page assessment tool was developed to assist you with determining whether your personal health status will elevate the level of risk you may encounter while working with animals.</u>**

1. Consider all animal species you may have contact with. Based on the information provided in the web training (http://www.research.psu.edu/orp/animals/trainings), consider the risks that you may potentially be exposed to while working with animals.

   - Laboratory Animals - rodents, rabbits, non-human primates, cats, dogs, and others
   - Agricultural Animals - poultry, swine, sheep, goats, cattle, horses and others
   - Wildlife - fish, reptiles, amphibians and others

2. Consider other potential situations in which you may be exposed to the hazards listed below. Consider any associated risks.

   - Chemicals
   - Radioactivity
   - Biological Agents
   - Physical hazards

3. **<u>Tetanus</u>**

   The CDC recommends that all adults maintain a current tetanus immunization by receiving a booster at a minimum of every ten years. In addition, certain kinds of work increase the risk of exposure to this organism because of increased exposure to dirty environments and/or increased incidents of skin wounds. This immunization is strongly recommended for those at increased risk of exposure. Not maintaining current tetanus immunity places you at increased of contracting tetanus.

   ***<u>If you have not had a tetanus booster within 10 years, especially if working outside (e.g., in barns or with wildlife), please call Occupational Medicine (814-863-8492).</u>**

4. If any of the following statements apply to you, you are strongly encouraged to schedule an appointment with the Occupational Medicine Physician to evaluate potential risks and discuss necessary precautions.

   - You've experienced shortness of breath; coughing; wheezing; skin problems; eye burning, scratching or irritation when around animals. Note: These are examples of animal allergies. Animal allergy is one of the most common conditions that affect animal workers, and those who are continually exposed to animal allergens tend to have progressively more frequent and severe symptoms.

   - You are pregnant or could become pregnant. There is the potential that working around animals could pose specific risks to your health (for example, toxoplasmosis from cat feces).

   - You have one or more of the following conditions: diabetes; kidney disease; spleen problems; hepatitis or liver disease; immune system deficiencies; heart valve problems;

treatment with high dose steroids; radiation or cancer therapy. There is the potential that working around animals could pose specific risks to your health.

- You will be working with wildlife that could be infected with rabies and you have not completed a series of three rabies immunizations.
- You have experienced a change in your health status that might be related to your work with animals or your work in the laboratory.

If you have any other health questions or issues related to your work with animals that you would like to discuss with the Occupational Medicine Physician, please call Occupational Medicine (814-863-8492).

## Once you have reviewed the Self-Assessment Tool, check the appropriate box below:

**PLEASE SELECT/CHECK ONE STATEMENT BELOW:**

☐ I have reviewed the information provided in the Self-Assessment Tool and, based on what I've learned,

**I PLAN** to visit Occupational Medicine (814-863-8492). Note: The cost of this visit will be covered by the institution via the Principal Investigator/Supervisor of your activities.

X I have reviewed the information provided in the Self-Assessment Tool and, based on what I've learned,

**I DO NOT PLAN** to visit Occupational Medicine.

**By submitting this form, you agree to the following**:

I have read and understood the above Animal Worker Questionnaire and Self-Assessment Tool and I understand that this is an initial step in Penn State's Occupational Medicine Program to determine if there are potential health hazards that I may encounter through my exposure to vertebrate animals while at Penn State.

If, after I have completed this Self-Assessment Tool, I have additional concerns about my personal risk, further assessment by the Occupational Medicine Physician (814-863-8462) can determine to what degree my own personal risks are elevated by my exposure to animals.

Regardless of my response to the above statements, I understand that I may now, or at any time during my animal use activities at or under the auspices of Penn State, contact Occupational Medicine (814-863-8492) to schedule an appointment and participate in the medical surveillance portion of the program. I understand that participation in the medical surveillance portion of the Occupational Medicine Program is very important to ensure that the risks associated with the care and use of animals are minimized and that I am **strongly encouraged to participate in the program**.

**Individuals who will be working on IACUC protocol(s):**
Individuals who will be working on a new IACUC Application must be listed on an IACUC application that is submitted to the Office for Research Protections. Individuals who will be added to an already-approved protocol must be added via a modification to the protocol. Instructions for submitting IACUC applications and modifications are online at http://www.research.psu.edu/orp/animals/applications.

**Hybrid Turkeys Trial 1 Protocol:**

# Research Protocol 2012-1

| | | | |
|---|---|---|---|
| **Location:** | **Pennsylvania State University** | **Type:** | **Commercial Converter Female Trial** |
| **Barn:** | | **Start:** | **April 2012 (week 17)** |
| **Flock #:** | | **Completion:** | **June 2012 (week 24)** |
| | | | |

## Objective

Investigate the effect of different management factors on the incidence of pendulous crops (PC) in commercial female turkeys.

## Housing and Protocol Design

| | Room | Target # To Place | Treatment | Sq ft/bird from 0-6 weeks | Sq ft/bird at 6 weeks | Estimated # birds at 16 wks | Target Sq ft/bird at 16 wks | Target Sq ft/bird at 21 wks |
|---|---|---|---|---|---|---|---|---|
| Converter females | 1 | 648 | T1 | 1.0 | | | | |
| Converter females | 2 | 648 | T2 | 1.0 | | | | |
| Converter females | 3 | 648 | T1 | 1.0 | | | | |
| Converter females | 4 | 648 | T2 | 1.0 | | | | |
| **Total** | | **2592** | | | | | | |

Poults are sourced from Cargill – Virginia, John Menges will coordinate poult delivery with Mike Hulet.

**Assumptions**

- Each room (4) is divided in 12 equal pens of 54 $ft^2$
- Each room has separate controllers for temperature and light

**Treatment by Room:**

- In each room a standard conventional lighting program will be used:

| Age | Hours of light |
|---|---|
| Day 1 | 24 |
| Day 2 | 23 |

| | |
|---|---|
| Day 3 – 5 | 20 |
| Day 6 – 9 | 18 |
| Day 10 – 42 | 16 |

- Different temperature profiles will be tested by room with 2 replications per profile.
- Temperature profiles will simulate moderate climate conditions (**T1**) versus hot summer conditions (**T2**):

  - Room temperature during brooding from 0 – 6 weeks:

| Age | Room temp. – T1 | Room temp. – T2 |
|---|---|---|
| Week 1 | 88 down to 83 | 95 down to 89 |
| Week 2 | 82 | 89 |
| Week 3 | 80 | 89 |
| Week 4 | 78 | 89 |
| Week 5 | 73 | 89 |
| Week 6 | 70 | 89 |

**Within each room, treatment by Pen:**

- Within each room, 2 possible treatments (water availability and energy content in the diet) will be applied to 6 pens each

  - Water availability:
    - Red dome drinkers will be used as water source for poults
      - Manufacturers recommendation of 100 poults per drinker – **W1☞ 0.5 drinkers per pen**
    - Double the number of poults per drinker (200) compared to manufacturers recommendation – **W2**
      **☞ 0.25 drinkers per pen**
    - Water consumption by pen will be measured on day 6

  - Energy Content in the diet:
    - Low energy in starter diets – **E1**, regular Hybrid recommendations available on Hybrid Turkeys website
    - High energy in starter diets – **E2**, Cargill-Virginia's feed formulations
    - Mike will organize the control feed through a local feed supplier, John will coordinate trucking in of bagged feed from Cargill - Virginia.
    - Pre-starter and starter diets will both be fed for a period of 3 weeks. All pens will be weighed at the time that feed is changed and left-over feed will be weighed back.

**Actions**

- Feed samples of each diet will be analyzed for crude protein, fat, fibre, Ca, P and Na.
- Poult order for the week of April 23rd needs to be confirmed
- All Treatments will be grown as commercials until 7 weeks of age.
- All regular hatch services will be applied, as well as vaccinations during grow-out

- Record mortality and reason (if possible) daily by pen
- Incidence of pendulous crops should be recorded daily by pen
- Water consumption will be measured by treatment within each room on day 6.
- All poults with obvious pendulous crops will be removed from the experimental pens (be careful not to draw this conclusion too early, though). From these birds a blood sample will be taken into a vaccutainer (3ml) containing EDTA as anti-coagulant and stored in the freezer (-20 $^{o}$C).
- Based on the incidence at the end of the experiment, additional blood samples from affected and unaffected birds will be taken for genomic analysis.

**Costs**

Costs involved are cost of production + $2,500 per room; Hybrid Turkeys will be billed at the end of the experiment.

| **Responsibilities** | | |
|---|---|---|
| | Brooding and growing | PSU |
| | Supervision and data collection | PSU / John Menges / Jeff Mohr |
| | Data analysis | PSU / Ben Wood |

Contact person for Penn State University will be **Dr. Michael Hulet** and for Hybrid Turkeys **John Menges.**

**Final report**

- Report test results and analysis

| **Copies to:** | | | | | |
|---|---|---|---|---|---|
| | John Menges | | Peter Gruhl | | Dr. Michael Hulet |
| | Nico Buddiger | | Jeff Mohr | | |
| | Ben Wood | | Bill Hodge | | |

**Hybrid Turkeys Trial 2 Protocol:**

# Research Protocol 2013-1

| | | | |
|---|---|---|---|
| **Location:** | **Pennsylvania State University** | **Type:** | **Commercial Converter Female and Male Trial** |
| **Barn:** | | **Start:** | **Jan 2013 (week 4)** |
| **Flock #:** | | **Completion:** | **Mar 2013 (week 11)** |
| | | | |

## Objective

Investigate the effect of different management factors on the incidence of pendulous crops (PC) in commercial female turkeys. Incubation temperature (2), Feed Form (2), and Intermittent Lighting (2 meal feeding/drinking ) factors will be evaluated for incidence of pendulous crop and growth performance.

## Housing and Protocol Design

| | Room | Target # To Place | Treatment | Sq ft/bird from 0-6 weeks | Sq ft/bird at 6 weeks | Estimated # birds at 16 wks | Target Sq ft/bird at 16 wks | Target Sq ft/bird at 21 wks |
|---|---|---|---|---|---|---|---|---|
| Converter poults | 1 | 600 | T1 | 1.0 | 1.0 | | | |
| Converter poults | 2 | 600 | T2 | 1.0 | 1.0 | | | |
| Converter poults | 3 | 600 | T1 | 1.0 | 1.0 | | | |
| Converter poults | 4 | 600 | T2 | 1.0 | 1.0 | | | |
| **Total** | | **2400** | | | | | | |

Eggs are sourced from Coopers Farms Hatchery, John Bentley will coordinate egg delivery with Mike Hulet.

**Assumptions**

- Each room (4) is divided in 12 equal pens of 50 $ft^2$
- Each room has separate controllers for temperature and light

**Treatment by Incubator**

- Half of the eggs will be incubated consistent with Hybrid's design (HYB) and the other half will decrease according to an industry standard (Proposed) and similar to industry practices for single stage incubation.

### Hybrid Turkeys Incubation Trial Profiles:

| Date | Day | HYB Profile | Treatment Profile |
|---|---|---|---|
| December 17 | 1 | **100.4** | **100.4** |
| 18 | 2 | **100.2** | **100.2** |
| 19 | 3 | **100.0** | **100.0** |

| | | | |
|---|---|---|---|
| 20 | 4 | **100.0** | **100.0** |
| 21 | 5 | **100.0** | **100.0** |
| 22 | 6 | **100.0** | **100.0** |
| 23 | 7 | **99.8** | **100.0** |
| 24 | 8 | **99.5** | **100.0** |
| 25 | 9 | **99.5** | **100.0** |
| 26 | 10 | **99.5** | **100.0** |
| 27 | 11 | **99.2** | **99.7** |
| 28 | 12 | **99.2** | **99.7** |
| 29 | 13 | **99.2** | **99.7** |
| 30 | 14 | **99.2** | **99.7** |
| 31 | 15 | **99.2** | **99.7** |
| January 1 | 16 | **99.2** | **99.7** |
| 2 | 17 | **98.8** | **99.3** |
| 3 | 18 | **98.8** | **99.3** |
| 4 | 19 | **98.8** | **99.3** |
| 5 | 20 | **98.5** | **99.0** |
| 6 | 21 | **98.5** | **99.0** |
| 7 | 22 | **98.5** | **99.0** |
| 8 | 23 | **98.5** | **99.0** |
| 9 | 24 | **98.5** | **99.0** |
| 10 | 25 | **98.0** | **98.5** |
| 11 | 26 | **97.8** | **98.3** |
| 12 | 27 | **97.6** | **98.1** |
| 13 | 28 | **97.5** | **98.0** |

**January 14 - Hatch**

**<u>Treatment by Room:</u>**

- In half the rooms a standard conventional lighting program will be used and in half of the rooms an intermittent lighting pattern will be used from 7 – 42 days:

| Age | Standard: Hours of light | Intermittent: Hours of light |
|---|---|---|
| Day 1 - 6 | 23 | 23 |
| Day 7 – 42 | 16 | 4 (1 L: 5 D) |

- Standard temperature profiles will simulate moderate climate conditions
    - Room temperature during brooding from 0 – 6 weeks:

| Age | Room temp. |
|---|---|
| Week 1 | 88 down to 83 |
| Week 2 | 82 to 78 |
| Week 3 | 78 to 73 |
| Week 4 | 73 to 68 |
| Week 5 | 68 |
| Week 6 | 68 |

**<u>Within each room, treatment by Pen:</u>**

- Water availability:
  - Red dome drinkers will be used as water source for poults
  - Manufacturers recommendation of 100 poults per drinker
    - ☞ **1.0 drinkers per pen**

- **Feed form in the diet**:
  - Pre-starter diets –, regular Hybrid recommendations available on Hybrid Turkeys website with either crumbles **E1** or mash **E2**,for 0 – 4 weeks
  - Starter diets –regular Hybrid recommendations with either pellets **E1** or mash **E2** for 4 – 6 weeks.
  - Hulet will organize the control feed through a local feed supplier, All pens will be weighed at the time that feed is changed and left-over feed will be weighed back.

## Actions

- Feed samples of each diet will be analyzed for crude protein, fat, fibre, Ca, P and Na.
- All Treatments will be grown as commercials until 6 weeks of age.
- Poults will be straight run
- Record mortality and reason (if possible) daily by pen
- Incidence of pendulous crops should be recorded daily by pen
- All poults with obvious pendulous crops will be removed from the experimental pens (be careful not to draw this conclusion too early, though).
- Based on the incidence at the end of the experiment, blood samples from affected and unaffected birds will be taken for genomic analysis.

## Costs

Costs involved are cost of production + $2,500 per room; Hybrid Turkeys will be billed at the end of the experiment.

| **Responsibilities** | | |
|---|---|---|
| 1 | Incubation, Brooding and Growing | PSU |
| 2 | Supervision and data collection | PSU |
| 3 | Data analysis | PSU / Ben Wood |

Contact person for Penn State University will be **Dr. Michael Hulet** and for Hybrid Turkeys **Ben Wood.**

## Final report

- Report test results and analysis

| | Copies to: | | | | |
|---|---|---|---|---|---|
| | | X | Peter Gruhl | X | Dr. Michael Hulet |
| X | Nico Buddiger | X | Jeff Mohr | | |
| X | Ben Wood | X | Bill Hodge | | |

**Table 1. T2012 PC Study: Chemical[1] Analysis of Feed[2] (Percentage) for Crumbles/Pellets and Mash Diets**

| Phase | Proposed Diet | % Chemical Analysis of Feed Actually Fed | | | | |
|---|---|---|---|---|---|---|
| | | CP | Crude Fat | Crude Fiber | Ash | Moist |
| 1 - 28 d | Pre-Starter | 27.28 | 3.87 | 3.3 | 6.01 | 12.43 |
| 28 - 42 d | Starter | 23.91 | 4.95 | 2.6 | 5.68 | 10.91 |

[1] Chemical analysis performed by Barrow-Agee Laboratories (Memphis, TN).
[2] Feeds mixed and delivered by Empire Kosher (Selinsgrove, PA).

# Appendix B

# Data Compilation Using ANOVA

**Trial 1 ANOVA Analysis:**

**Table A1. T2012 PC Study: Chemical Analysis of Feed[1,2]**

| Phase | Proposed Diet (Actual) | Chemical Analysis of Feed (%) | | | | |
|---|---|---|---|---|---|---|
| | | CP | Crude Fat | Crude Fiber | Ash | Moisture |
| Early: 1-21 d | Low Energy Pre-Starter (Pre White) | 27.28 | 3.87 | 3.3 | 6.01 | 12.43 |
| | High Energy Pre-Starter (Starter White) | 25.08 | 4.30 | 2.9 | 6.37 | 11.80 |
| Early: 21-26 d | Low Energy Starter (Pre-red) | 26.27 | 5.58 | 2.7 | 6.43 | 10.72 |
| | High Energy Starter (Starter Red) | 23.91 | 4.95 | 2.6 | 5.68 | 10.91 |
| Starter: 26-39 d | Low Energy Starter (Starter White) | 25.08 | 4.30 | 2.9 | 6.37 | 11.80 |
| | High Energy Starter (Starter Red) | 23.91 | 4.95 | 2.6 | 5.68 | 10.91 |
| Starter: 39-42 d | Low Energy Starter (Starter White) | 23.91 | 4.95 | 2.6 | 5.68 | 10.91 |
| | High Energy Starter (Starter Red) | 23.91 | 4.95 | 2.6 | 5.68 | 10.91 |

[1] Chemical analysis performed by Barrow-Agee Laboratories (Memphis, TN).
[2] Feeds mixed and delivered by Wengers Feed (Rheems, PA).

**Figure A1: T2012 PC Study – Daily High Temperature**

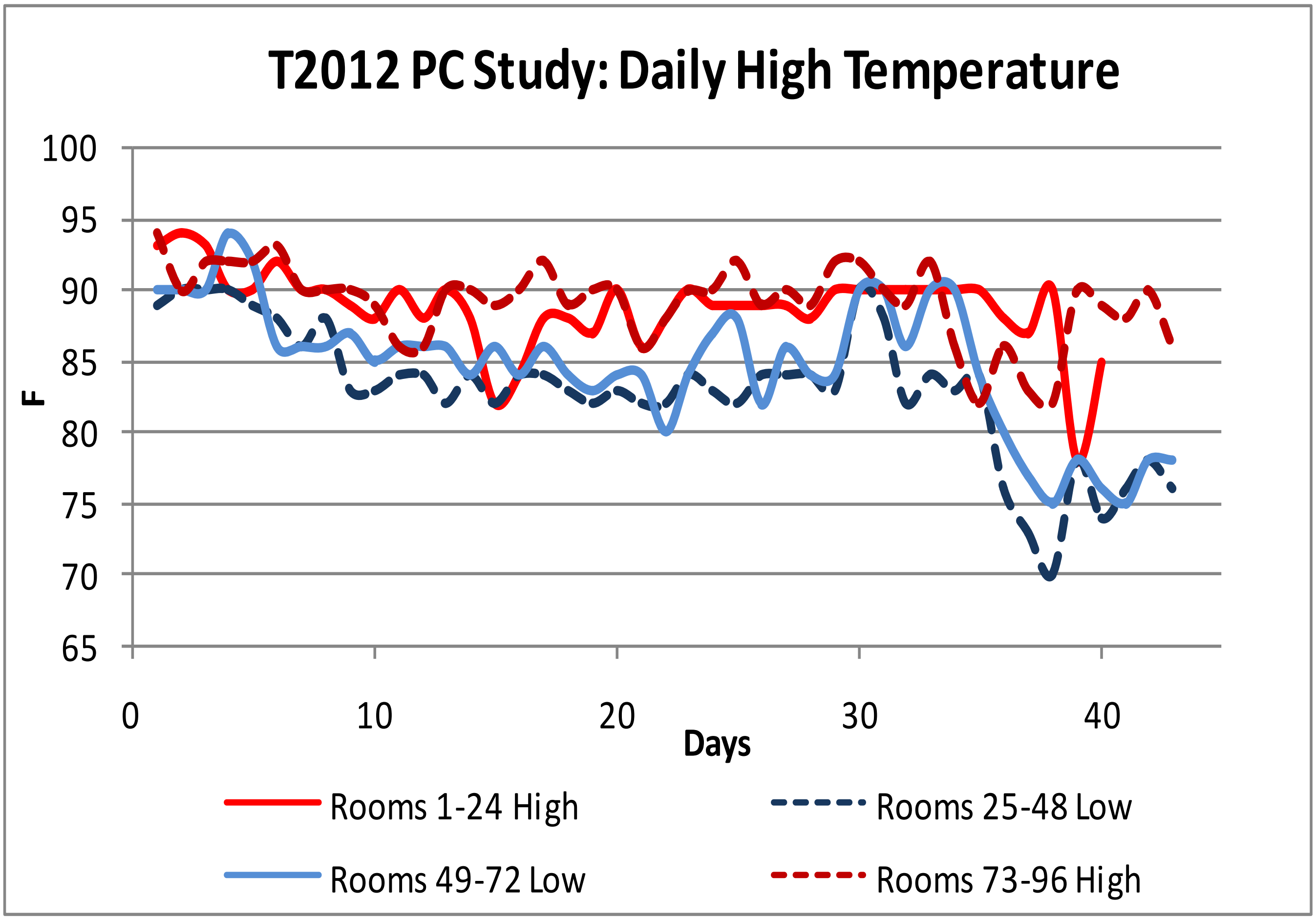



**Figure 1:** Average daily high temperature data as recorded by temperature/humidity gauges in each experimental room.

**Table A2. T2012 PC Study: Water Intake (kg/bird/hr)**

| Factor | Level | Day 11 | Day 18 | Day 25 | Day 33 | Day 39 |
|---|---|---|---|---|---|---|
| Diet | High Energy | 0.0065[b] | 0.0106[b] | 0.0142[b] | 0.0198[b] | 0.0274[b] |
| | Low Energy | 0.0074[a] | 0.0121[a] | 0.0163[a] | 0.0213[a] | 0.0286[a] |
| Temp | High Temp | 0.0074[a] | 0.0124[a] | 0.0174[a] | 0.0243[a] | 0.0314[a] |
| | Low Temp | 0.0065[b] | 0.0102[b] | 0.0131[b] | 0.0172[b] | 0.0246[b] |
| Water | Control Water | 0.0071 | 0.0113 | 0.0149 | 0.0206 | 0.0281 |
| | Restricted Water | 0.0068 | 0.0113 | 0.0156 | 0.0206 | 0.0279 |
| *P* – value | Diet | 0.0002 | <0.0001 | 0.0003 | 0.0167 | 0.0388 |
| | Temp | 0.0006 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| | Water | 0.0910 | 0.8536 | 0.1949 | 0.6077 | 0.6706 |
| | Diet*Temp | 0.4875 | 0.7582 | 0.0762 | 0.5901 | 0.8645 |
| | Diet*Water | 0.4755 | 0.8994 | 0.8886 | 0.0374 | 0.9093 |
| | Temp*Water | 0.1174 | 0.5871 | 0.4445 | 0.6308 | 0.5887 |
| | Diet*Temp*Water | 0.6139 | 0.7871 | 0.2302 | 0.2911 | 0.9208 |

[a-c] Means within a factor that do not share a common superscript are considered significantly different ($P \leq 0.05$).

The effect of water restriction on water intake at d 33 was different depending on whether low or high energy diets were fed.

**Table A3. T2012 PC Study: Body Weight (BW) and Body Weight Gain (BWG) Per Bird**

| Factor | Level | Initial Chick BW (g) | BW (Kg) Day 21 | BWG (Kg) Day 0-21 | BW (Kg) Day 42 | BWG (Kg) Day 21-42 | BWG (Kg) Overall |
|---|---|---|---|---|---|---|---|
| Diet | High Energy | 55.5 | 0.559[b] | 0.503[b] | 1.979[b] | 1.419[b] | 1.923[b] |
| | Low Energy | 55.7 | 0.617[a] | 0.561[a] | 2.234[a] | 1.615[a] | 2.178[a] |
| Temp | High Temp | 55.5 | 0.591 | 0.535 | 2.090[b] | 1.497[b] | 2.034[b] |
| | Low Temp | 55.8 | 0.585 | 0.529 | 2.124[a] | 1.538[a] | 2.067[a] |
| Water | Control Water | 55.6 | 0.586 | 0.530 | 2.102 | 1.514 | 2.046 |
| | Restricted Water | 55.7 | 0.589 | 0.533 | 2.111 | 1.520 | 2.055 |
| *P* - value | Diet | 0.4776 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| | Temp | 0.2388 | 0.2905 | 0.2768 | 0.0383 | 0.0022 | 0.0384 |
| | Water | 0.5054 | 0.5595 | 0.5886 | 0.5946 | 0.6160 | 0.5990 |
| | Diet*Temp | 0.9999 | 0.6494 | 0.6107 | 0.6159 | 0.5563 | 0.5930 |
| | Diet*Water | 0.9452 | 0.9267 | 0.9333 | 0.5959 | 0.3870 | 0.5853 |
| | Temp*Water | 0.5021 | 0.7360 | 0.7096 | 0.5262 | 0.6166 | 0.5236 |
| | Diet*Temp*Water | 0.8995 | 0.1284 | 0.1095 | 0.7209 | 0.6499 | 0.7075 |

[1] Average Daily High Temperature was 89.0 F for the High rooms (Rooms 1-24 = 88.8, Rooms 73-96 = 89.3). Average Daily High temperature for the Low rooms was 85.3 F (Rooms 25-48 = 83.5, Rooms 49-72 = 85.3).

**Table A4. T2012 PC Study: Feed Intake (kg/Bird)**

| Factor | Level | Starter Feed 0-21 d | Grower Feed 21-42 d | Overall |
|---|---|---|---|---|
| Diet | High Energy | 0.694[b] | 2.160[b] | 2.858[b] |
| | Low Energy | 0.772[a] | 2.488[a] | 3.266[a] |
| Temp | High Temp | 0.732 | 2.297[b] | 3.034[b] |
| | Low Temp | 0.734 | 2.351[a] | 3.090[a] |
| Water | Control Water | 0.726 | 2.316 | 3.047 |
| | Restricted Water | 0.740 | 2.332 | 3.078 |
| *P* – value | Diet | <0.0001 | <0.0001 | <0.0001 |
| | Temp | 0.7869 | 0.0032 | 0.0201 |
| | Water | 0.1433 | 0.3668 | 0.1788 |
| | Diet*Temp | 0.4183 | 0.5001 | 0.9709 |
| | Diet*Water | 0.1433 | 0.7107 | 0.7346 |
| | Temp*Water | 0.2007 | 0.5504 | 0.8765 |
| | Diet*Temp*Water | 0.9357 | 0.4294 | 0.3506 |

[1]Average Daily High Temperature was 89.0 F for the High rooms (Rooms 1-24=88.8, Rooms 73-96=89.3). Average Daily High temperature for the Low rooms was 85.3 F (Rooms 25-48=83.5, Rooms 49-72 =85.3).

**Table A5. T2012 PC Study: Feed Conversion (kg Feed Intake/kg BWG)**

| Factor | Level | Days 1-21 | Days 21-42 | Overall |
|---|---|---|---|---|
| Diet | High Energy | 1.389 | 1.526[b] | 1.490 |
| | Low Energy | 1.391 | 1.547[a] | 1.506 |
| Temp | High Temp | 1.381 | 1.541 | 1.498 |
| | Low Temp | 1.400 | 1.532 | 1.498 |
| Water | Control Water | 1.380 | 1.535 | 1.494 |
| | Restricted Water | 1.401 | 1.538 | 1.502 |
| *P* – value | Diet | 0.9365 | 0.0407 | 0.0593 |
| | Temp | 0.4700 | 0.3952 | 0.9482 |
| | Water | 0.4232 | 0.7781 | 0.3895 |
| | Diet*Temp | 0.2069 | 0.6470 | 0.1663 |
| | Diet*Water | 0.2804 | 0.0344 | 0.3439 |
| | Temp*Water | 0.2352 | 0.5441 | 0.6684 |
| | Diet*Temp*Water | 0.1652 | 0.6462 | 0.3944 |

[1] Average Daily High Temperature was 89.0 F for the High rooms (Rooms 1-24=88.8, Rooms 73-96=89.3). Average Daily High temperature for the Low rooms was 85.3 F (Rooms 25-48=83.5, Rooms 49-72 =85.3).

The effect of water restriction on feed conversion at 21-42 d was different depending on whether low or high energy diets were fed.

**Table A6. T2012 PC Study: Percent[1] Mortality**

| Factor | Level | % Mortality Days 1-21 | % Mortality Days 21-42 | % Mortality Overall |
|---|---|---|---|---|
| Diet | High Energy | 0.540 | 0.233 | 0.772 |
| | Low Energy | 0.776 | 0.387 | 1.161 |
| Temp | High Temp | 0.698 | 0.387 | 1.084 |
| | Low Temp | 0.617 | 0.233 | 0.849 |
| Water | Control Water | 0.617 | 0.387 | 1.003 |
| | Restricted Water | 0.698 | 0.233 | 0.930 |
| *P* – value | Diet | 0.5493 | 0.5812 | 0.3910 |
| | Temp | 0.7914 | 0.5812 | 0.9144 |
| | Water | 0.7914 | 0.5812 | 0.5701 |
| | Diet*Temp | 0.1738 | 0.1854 | 0.0880 |
| | Diet*Water | 0.4190 | 0.1854 | 0.2173 |
| | Temp*Water | 0.9575 | 0.1854 | 0.6236 |
| | Diet*Temp*Water | 0.0364 | 0.0399 | 0.5597 |

[1] Percentage data analyzed with an arcsine transformation.
[2] Average Daily High Temperature was 89.0 F for the High rooms (Rooms 1-24=88.8, Rooms 73-96=89.3). Average Daily High temperature for the Low rooms was 85.3 F (Rooms 25-48=83.5, Rooms 49-72 =85.3)

Percent mortality from 1-21 d and 21-42 d was influenced by the combined effects of the altering diet, temperature, and water availability.

**Table A7. T2012 PC Study: Pendulous Crop Incidence (%)[1]**

| Factor | Level | % Birds Housed | % Birds Alive to 42 d |
|---|---|---|---|
| Diet | High Energy | 0.926 | 0.932 |
| | Low Energy | 0.932 | 0.944 |
| Temp | High Temp | 1.549 [a] | 1.564[a] |
| | Low Temp | 0.309[b] | 0.312[b] |
| Water | Control Water | 1.003 | 1.018 |
| | Restricted Water | 0.855 | 0.858 |
| *P* – value | Diet | 0.8651 | 0.8699 |
| | Temp | 0.0014 | 0.0014 |
| | Water | 0.5201 | 0.5120 |
| | Diet*Temp | 0.5668 | 0.5601 |
| | Diet*Water | 0.4376 | 0.4324 |
| | Temp*Water | 0.7340 | 0.7183 |
| | Diet*Temp*Water | 0.9719 | 0.9677 |

Percentage data analyzed with an arcsine transformation.

[2] Average Daily High Temperature was 89.0 F for the High rooms (Rooms 1-24 = 88.8, Rooms 73-96=89.3). Average Daily High temperature for the Low rooms was 85.3 F (Rooms 25-48=83.5, Rooms 49-72 =85.3).

**Trial 2 ANOVA Analysis:**

**Table A8. T2013 PC Study: Chemical Analysis of Feed[1]**

| Phase | Diet | Chemical Analysis of Feed (%) | | | | |
|---|---|---|---|---|---|---|
| | | CP | Crude Fat | Crude Fiber | Ash | Moist |
| Starter: 0-28 d | Crumbles | 27.69 | 4.47 | 2.67 | 6.68 | 12.54 |
| | Mash | 26.63 | 3.20 | 2.80 | 6.32 | 11.81 |
| Grower: 28-44 d | Crumbles | 25.39 | 5.11 | 2.73 | 6.47 | 11.71 |
| | Mash | 27.35 | 3.65 | 3.00 | 6.70 | 11.05 |

[1] Chemical analysis performed by Barrow-Agee Laboratories (Memphis, TN); 3 replicates per diet.

**Table A9. T2013 PC Study: Body Weight (BW) and Body Weight Gain (BWG) Per Bird**

| Factor | Level | Initial Chick BW (g) | BW (Kg) Day 28 | BWG (Kg) Day 0-28 | BW (Kg) Day 44 | BWG (Kg) Day 28-44 | BWG (Kg) Overall |
|---|---|---|---|---|---|---|---|
| Diet | Mash | 57.3 | 1.026[b] | 0.966[b] | 2.518[b] | 1.486[b] | 2.458[b] |
| | Crumbles | 57.1 | 1.310[a] | 1.249[a] | 3.140[a] | 1.822[a] | 3.079[a] |
| Incubation | High Temp | 55.8[b] | 1.187[a] | 1.128[a] | 2.862[a] | 1.669 | 2.803[a] |
| | Low Temp | 58.6[a] | 1.155[b] | 1.094[b] | 2.810[b] | 1.646 | 2.748[b] |
| Lighting[1] | Program A | 57.1 | 1.189[a] | 1.130[a] | 2.928[a] | 1.732[a] | 2.868[a] |
| | Program B | 57.2 | 1.153[b] | 1.092[b] | 2.747[b] | 1.586[b] | 2.685[b] |
| *P* - value | Diet | 0.3185 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| | Incubation | <0.0001 | 0.0027 | 0.0014 | 0.0668 | 0.2712 | 0.0538 |
| | Lighting | 0.4714 | 0.0007 | 0.0006 | <0.0001 | <0.0001 | <0.0001 |
| | Diet*Incubation | 0.0874 | 0.5282 | 0.6642 | 0.5724 | 0.2788 | 0.5306 |
| | Diet*Lighting | 0.1695 | 0.0064 | 0.0059 | 0.0680 | 0.3689 | 0.0664 |
| | Incubation*Lighting | 0.2871 | 0.3523 | 0.4220 | 0.2061 | 0.2492 | 0.2267 |
| | Diet* Incubation*Lighting | 0.9887 | 0.0195 | 0.0171 | 0.0050 | 0.0061 | 0.0048 |

[a,b] Values within a factor and column that do not share a common superscript are significantly different ($P \leq 0.05$).

[1] Lighting Program A = 23 hr light from day 1-6 and 16 hr light from day 7-44 and Lighting Program B = 23 hr light from day 1-6 and an intermittent light schedule from day 7-44 - 4 cycles of 1 hr light and 5 hr dark.

**Table A10. T2013 PC Study: Feed Intake (kg/Bird)**

| Factor | Level | Starter Feed 0-28 d | Grower Feed 28-44 d | Overall |
|---|---|---|---|---|
| Diet | Mash | 1.500[b] | 2.824[b] | 4.333[b] |
| | Crumbles | 1.740[a] | 3.091[a] | 4.841[a] |
| Incubation | High Temp | 1.643[a] | 2.952 | 4.603 |
| | Low Temp | 1.602[b] | 2.969 | 4.582 |
| Lighting[1] | Program A | 1.607[b] | 2.992[a] | 4.609 |
| | Program B | 1.637[a] | 2.930[b] | 4.577 |
| *P* - value | Diet | <0.0001 | <0.0001 | <0.0001 |
| | Incubation | 0.0038 | 0.3646 | 0.7867 |
| | Lighting | 0.0048 | 0.0269 | 0.5542 |
| | Diet*Incubation | 0.9407 | 0.3488 | 0.5474 |
| | Diet*Lighting | 0.0825 | 0.0128 | 0.0125 |
| | Incubation*Lighting | 0.3056 | 0.0306 | 0.0509 |
| | Diet* Incubation*Lighting | 0.1836 | 0.0203 | 0.0444 |

[a,b] Values within a factor and column that do not share a common superscript are significantly different ($P \leq 0.05$).

[1] Lighting Program A = 23 hr light from day 1-6 and 16 hr light from day 7-44 and Lighting Program B = 23 hr light from day 1-6 and an intermittent light schedule from day 7-44 - 4 cycles of 1 hr light and 5 hr dark.

**Table A11. T2013 PC Study: Feed Conversion (kg Feed Intake/kg BWG)**

| Factor | Level | Days 0-28 | Days 28-44 | Overall |
|---|---|---|---|---|
| Diet | Mash | 1.553[a] | 1.905[a] | 1.765[a] |
| | Crumbles | 1.394[b] | 1.699[b] | 1.574[b] |
| Incubation | High Temp | 1.468 | 1.781[b] | 1.654[b] |
| | Low Temp | 1.475 | 1.818[a] | 1.680[a] |
| Lighting[1] | Program A | 1.434[b] | 1.737[b] | 1.617[b] |
| | Program B | 1.508[a] | 1.860[a] | 1.716[a] |
| *P* - value | Diet | <0.0001 | <0.0001 | <0.0001 |
| | Incubation | 0.2874 | 0.0125 | 0.0065 |
| | Lighting | <0.0001 | <0.0001 | <0.0001 |
| | Diet*Incubation | 0.7271 | 0.4880 | 0.6238 |
| | Diet*Lighting | 0.5870 | 0.0073 | 0.0197 |
| | Incubation*Lighting | 0.5069 | 0.3528 | 0.2636 |
| | Diet* Incubation*Lighting | 0.0186 | 0.1872 | 0.0748 |

[a,b] Values within a factor and column that do not share a common superscript are significantly different ($P \leq 0.05$).

[1] Lighting Program A = 23 hr light from day 1-6 and 16 hr light from day 7-44 and Lighting Program B = 23 hr light from day 1-6 and an intermittent light schedule from day 7-44 - 4 cycles of 1 hr light and 5 hr dark.

**Table A12. T2013 PC Study: Percent Mortality[1]**

| Factor | Level | % Mortality Days 0-28 | % Mortality Days 28-44 | % Mortality Overall |
|---|---|---|---|---|
| Diet | Mash | 4.957 | 0.597 | 5.478 |
| | Crumbles | 5.333 | 0.626 | 5.917 |
| Incubation | High Temp | 5.391 | 0.478 | 5.826 |
| | Low Temp | 4.917 | 0.740 | 5.583 |
| Lighting[2] | Program A | 4.261 | 0.583 | 4.783 |
| | Program B | 6.000 | 0.639 | 6.583 |
| *P* - value | Diet | 0.7755 | 0.8110 | 0.4615 |
| | Incubation | 0.8622 | 0.5959 | 0.9351 |
| | Lighting | 0.1729 | 0.5465 | 0.1768 |
| | Diet*Incubation | 0.4862 | 0.7416 | 0.5567 |
| | Diet*Lighting | 0.7111 | 0.4073 | 0.9351 |
| | Incubation*Lighting | 0.3186 | 0.9797 | 0.3289 |
| | Diet* Incubation*Lighting | 0.2143 | 0.3849 | 0.1374 |

[1] Percentage data analyzed with an arcsine transformation.

[2] Lighting Program A = 23 hr light from day 1-6 and 16 hr light from day 7-44 and Lighting Program B = 23 hr light from day 1-6 and an intermittent light schedule from day 7-44 - 4 cycles of 1 hr light and 5 hr dark.

**Table A13. T2013 PC Study: Pendulous Crop Incidence (%)[1]**

| Factor | Level | % PC 0-28d of birds housed | % PC of birds alive 0-28d | % PC 28-44d of birds housed | % PC of birds alive 28-44d | % PC 0-44d of birds housed | % PC of birds alive 0-44d |
|---|---|---|---|---|---|---|---|
| Diet | Mash | 0.435 | 0.466 | 1.478 | 1.555 | 1.913 | 2.025 |
| | Crumbles | 0.417 | 0.449 | 0.917 | 0.960 | 1.333 | 1.409 |
| Incubation | High Temp | 0.348 | 0.370 | 1.044 | 1.109 | 1.391 | 1.482 |
| | Low Temp | 0.500 | 0.541 | 1.333 | 1.387 | 1.833 | 1.930 |
| Lighting[1] | Program A | 0.174[b] | 0.183[b] | 1.130 | 1.165 | 1.304 | 1.348 |
| | Program B | 0.667[a] | 0.720[a] | 1.250 | 1.334 | 1.917 | 2.058 |
| *P* - value | Diet | 1.0000 | 0.9944 | 0.1317 | 0.1325 | 0.1479 | 0.1486 |
| | Incubation | 0.4589 | 0.4507 | 0.2371 | 0.2482 | 0.1621 | 0.1669 |
| | Lighting | 0.0306 | 0.0295 | 0.7401 | 0.7002 | 0.3138 | 0.2851 |
| | Diet*Incubation | 1.0000 | 0.9813 | 0.3720 | 0.3511 | 0.5301 | 0.5100 |
| | Diet*Lighting | 0.1427 | 0.1484 | 0.0194 | 0.0203 | 0.0109 | 0.0114 |
| | Incubation*Lighting | 0.0306 | 0.0306 | 0.4323 | 0.4391 | 0.9437 | 0.9236 |
| | Diet* Incubation*Lighting | 0.1427 | 0.1404 | 0.0550 | 0.0496 | 0.0539 | 0.0503 |

[a,b] Values within a factor and column that do not share a common superscript are significantly different ($P \leq 0.05$).

[1] Percentage data analyzed with an arcsine transformation.

[2] Lighting Program A = 23 hr light from day 1-6 and 16 hr light from day 7-44 and Lighting Program B = 23 hr light from day 1-6 and an intermittent light schedule from day 7-44 - 4 cycles of 1 hr light and 5 hr dark.

## Appendix C

## Professional Presentations on Pendulous Crop

**Presentations 1 & 2:** International Poultry Scientific Forum, January 28-29, 2013. Poster presentation on *The Effect of Different Management Factors on the Incidence of Pendulous Crop (PC) in Commercial Female Turkeys.*

**Presentation 3:** 36th Annual North Carolina Turkey Days. Speaker presentation* on *Management Effects on the Incidence of Pendulous Crop in Turkeys.*

*A PowerPoint presentation was also created to provide visual aids for this research presentation, but was not included in this thesis to avoid redundancy.

**Presentation 4:** International Poultry Scientific Forum, January 27-28, 2014. Poster presentation on the *Influence of Incubation Temperature, Lighting, and Feed Form on Incidence of Pendulous Crop (PC) in Commercial Straight Run Turkeys.*

# The Effect of Different Management Factors on the Incidence of Pendulous Crop (PC) in Commercial Female Turkeys

Corissa A. Steimling[1]*, R. M. Hulet[1], T. L. Cravener[1], B. Wood[2], and N. Buddiger[2], [1]*Department of Animal Science, Penn State University, University Park, PA 16801*, [2]*A Hendrix Genetics Company, 650 Riverbend Drive, Suite C, Kitchener, ON*


## Abstract:

The incidence of Pendulous Crop (PC) in domesticated turkeys is a long standing issue in turkey production. A study was conducted to evaluate the incidence of PC under different management practices. The experiment used 2592 female Converter poults (Hybrid Turkeys), and was carried out over a period of 6 weeks. The poults were randomized into 4 separate rooms each with 12 equal pens (5 m²) containing 54 birds. The factors evaluated for their ability to induce PC lesions were ambient temperature, water space per bird, and dietary energy. The room temperature was varied with two rooms following the typical temperature profile that decreased from 31˚ to 20˚C (decrease of 2.8 ˚C /week) for the control group. The other two rooms were held at a higher ambient temperature that was 31 to 29˚C for the six weeks. Water was supplied with half of the pens containing a red dome drinker; the other half of the pens used the same drinker with half of the drinking area blocked from poult access (424 versus 212 cm²/bird, respectively). Finally, the energy contained in the diets was considered. Pre-starter and starter feeds were each fed for 3 weeks; the pre-starter and starter feed contained two different levels of energy (2895 versus 3073 kcal/kg).

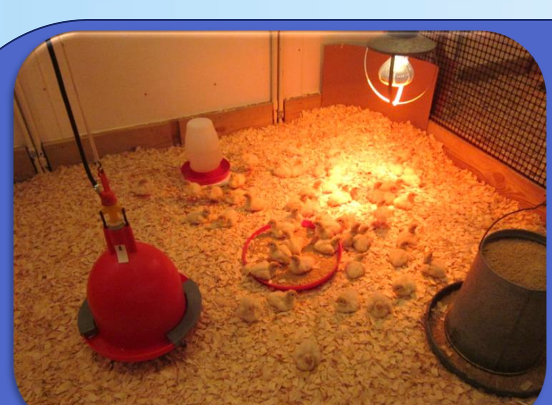
The birds were weighed upon arrival, and then in three-week intervals following placement. Each bird showing symptoms of PC was tagged, and examined for severity of the lesion at the end of the experiment. No significant differences were found for water intake, body weight, feed intake, feed conversion, percent mortality, or incidence of pendulous crop. However, water intake (at all days measured) and incidence of pendulous crop (% of hen housed and % of remaining birds) were significantly greater (P < 0.01) for the birds reared on the higher temperature profile when compared to those on the control temperature profile.

From these results, we can conclude that ambient temperature during brooding and/or increased water consumption increases the incidence of pendulous crops in female poults (1.56 % vs 0.31 %, P < 0.001).

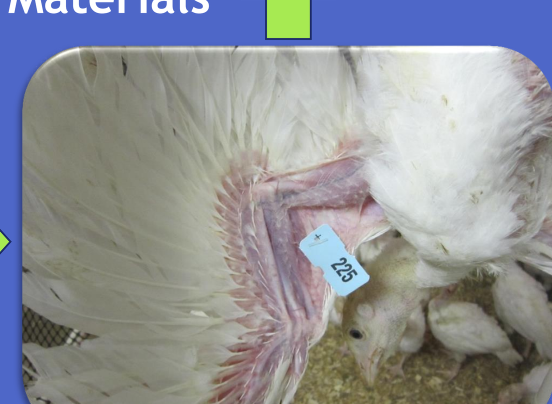

## What is Pendulous Crop (PC)?

Pendulous Crop is an abnormal condition where the crop becomes distended from its normal position and fills with ingested fluid and feed. In this state, the materials inside the PC stagnate and have the potential to ferment; however, the contents have not been proven to be directly toxic to the birds. The adverse effects are typically due to the physical limitations the PC causes the bird. Since nutrients are not being absorbed by the crop, the turkey becomes stunted and emaciated. Furthermore, there is a higher risk of the crop and associated tissues to become necrotic or infected, if punctured. In some cases, 15% of flocks have experienced mortality via PC. The line of birds being used in this study have shown flock mortalities of 5-8% due to PC.

Traditionally, PC is believed to be caused by a genetic predisposition which is enhanced by environmental factors. However, with the development of the commercial turkeys in today's industry, it is suspected that flock management is having an increasing influence over the incidence of PC.



Methods and Materials

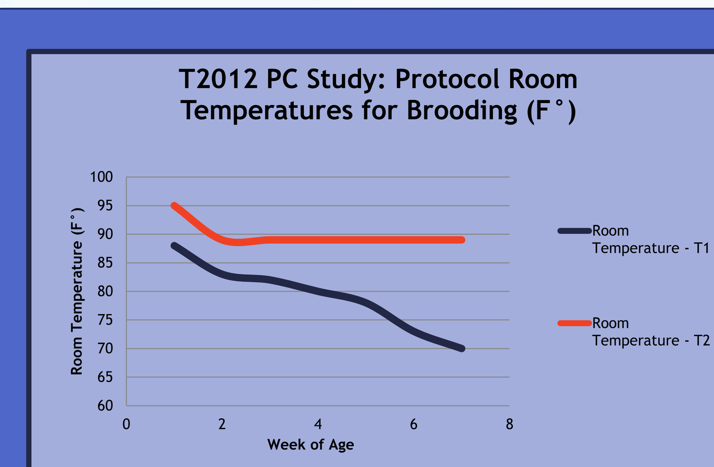


## Experimental Design

Diet

| T2012 PC Study: Diet Composition | | | | |
|---|---|---|---|---|
| Diet<br>Age in Wks<br>Feed/Hen (lbs) | Control<br>(wks 0-3)<br>2.27 | Control<br>(wks 3-6)<br>6.29 | High Energy<br>(wks 0-3)<br>2.27 | High Energy<br>(wks 3-6)<br>6.29 |
| Protein, % | 27.490 | 26.010 | 26.890 | 23.890 |
| Fat, % | 3.510 | 4.180 | 5.280 | 5.050 |
| Calcium, % | 1.390 | 1.400 | 1.460 | 1.310 |
| Available Phosphorus, % | 0.750 | 0.750 | 0.780 | 0.660 |
| Methionine, % | 0.730 | 0.650 | 0.670 | 0.630 |
| Met. + Cys,. % | 1.170 | 1.070 | 1.110 | 1.020 |
| Available Lysine, % | 1.630 | 1.480 | 1.510 | 1.400 |
| Avg ME Poultry, kcal/lb | | 1316 | | 1394 |

Temperature




*Trial Average Daily High Temperature: T1 = 85.3˚F and T2 = 88.8˚F.

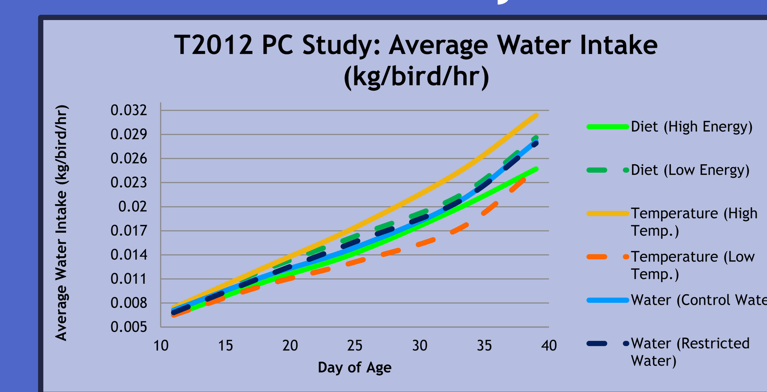
Water

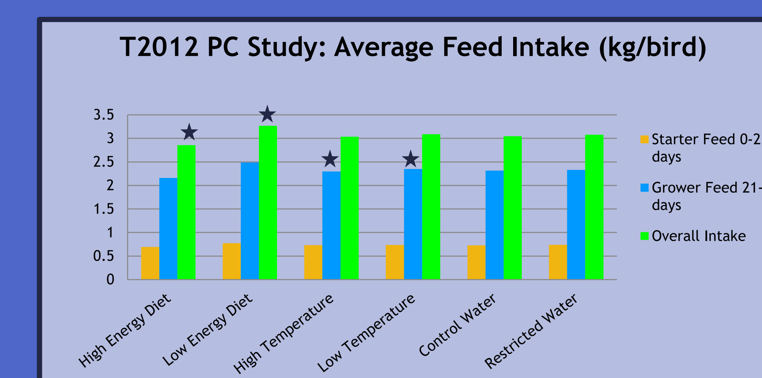

Control Water    Restricted Water

## Inducing the Occurrence of PC:
### *Methods & Materials*

- Collected 2592 female converter poults from Hybrid Turkeys at 1 day of age.
- Birds were divided equally into 4 separate rooms, 12 pens in each.
- Experimental Design: 2 X 2 X 2 Factorial - Diet, Temperature, and Water.
- Each room: ½ low (control) energy feed, ½ high energy feed. 3 weeks pre-starter, 3 weeks starter feed. Feed available ad libitum.
- 2 rooms at high temp, 2 rooms following standard temperature decrease.
- Each Room: ½ control water, ½ restricted water. Water available ad libitum.
- Monitored for incidence of PC; Birds were tagged, and pens were marked if signs of PC were present. After 6 weeks, the study was completed; blood samples were drawn from all tagged PC birds, and 10 control hens.
- Data was collected and interpreted based on the experimental factors by ANOVA. Percentage data was analyzed after arcsine transformation.

## Result Analysis




★ Means are considered significantly different($P \le 0.05$) for factors. When above Overall Intake, factor significantly impacted feed intake throughout entire study.

| T2012 PC Study: Average Body Weight (BW) and Body Weight Gain Per Bird | | | | | |
|---|---|---|---|---|---|
| Factor | Level | Initial Chick BW (g) | BW (Kg) Day 21 | BW (Kg) Day 42 | BW Gain (Kg) Overall |
| Diet | High Energy | 55.5 | $0.559^{b}$ | $1.979^{b}$ | $1.923^{b}$ |
| | Low Energy | 55.7 | $0.617^{a}$ | $2.234^{a}$ | $2.178^{a}$ |
| Temperature | High Temp. | 55.5 | 0.591 | $2.09^{B}$ | $2.034^{B}$ |
| | Low Temp. | 55.8 | 0.585 | $2.124^{A}$ | $2.067^{A}$ |
| Water | Control Water | 55.6 | 0.586 | 2.102 | 2.046 |
| | Restricted Water | 55.7 | 0.589 | 2.111 | 2.055 |

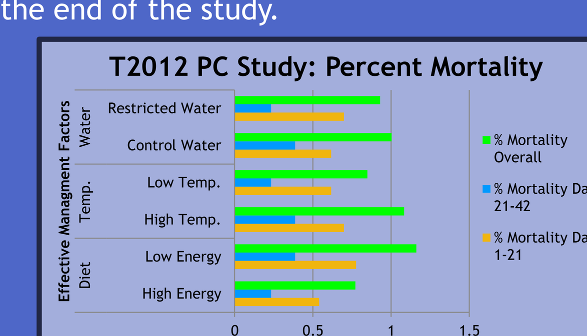
| T2012 PC Study: Average Feed Conversion (Kg Feed Intake/Kg BW Gain) | | | | |
|---|---|---|---|---|
| Factor | Level | Days 1-21 | Days 21-42 | Overall |
| Diet | High Energy | 1.389 | $1.526^{b}$ | 1.490 |
| | Low Energy | 1.391 | $1.547^{a}$ | 1.506 |
| Temperature | High Temp. | 1.381 | 1.541 | 1.498 |
| | Low Temp. | 1.400 | 1.532 | 1.498 |
| Water | Control Water | 1.380 | 1.535 | 1.494 |
| | Restricted Water | 1.401 | 1.538 | 1.502 |

$^{a, b, A, B}$ Means within the same factor that do not share a common superscript are considered significantly different ($P \le 0.05$) for both average BW/ BW Gain and average feed conversion.

## Resulting Pendulous Crops

| T2012 PC Study: Pendulous Crop Incidence (%) | | | |
|---|---|---|---|
| Factor | Level | % Birds Housed | % Birds Alive to 42 days |
| Diet | High Energy | 0.926 | 0.932 |
| | Low Energy | 0.932 | 0.944 |
| Temperature | High Temp. | 1.549 | 1.564 |
| | Low Temp. | 0.309 | 0.312 |
| Water | Control Water | 1.003 | 1.018 |
| | Restricted Water | 0.855 | 0.858 |

- Upon the completion of the 6 wk trial, temperature was calculated to be the factor with the most significant factor ($P \le 0.001$) for inducing Pendulous Crop.
- The 1st PC was recorded on 5/18, on Week 3 of the study. The poult was in a pen receiving the following treatments: low energy feed, high temperature, and restricted water.
- A total of 22 PCs were recorded, 11 of which were very pronounced by the end of the study.
- All birds exhibiting PC survived to the end of the trial, and were not culled or removed from the experimental conditions , for the purpose of following the progression of the condition and to collect the proper samples at the end of the study.





## Conclusions:

- The ambient temperature during the brooding period of commercial female poults, and/or increased water consumption increases the incidence of pendulous crops (1.56 % vs. 0.31%, P < 0.001).
- The influence of diet did not show any significant impact on the occurrence of PC, when examined as a independent or multi-factorial aspect.
- The intake of water was very significantly influenced (P < 0.01) by the low energy feed, as well as the higher temperature brooding condition.
- It was found a significant interaction on feed conversion during days 21-42 for water treatment and diet (P< 0.05).
- Body Weight was significantly greater when fed the lower energy diets throughout the entire trial when compared to the higher energy feed treatment. After day 21, temperature had a significant impact on BW (P<0.05) and also for feed intake.

## Further Studies on the Incidence of PC in Turkeys:

- Grow out turkeys past 6 weeks
- Restrict water in a more severe fashion
- Carry out feed separation by energy profile.
- Collect samples of crop and surrounding tissue for localized histology of damaged tissue.
- Collect samples for DNA analysis from birds on trial.
- **Currently (as of 12/16/12):**
  - Incubation at High vs. Standard Temperatures
  - Mash vs. Crumble feed form
    - Crumble feed switched to Pelleted feed at 4 wks
  - 5 weeks of 1L:5D vs. 23L:1D Lighting (Wk 1= 23:1)


## References:

Asmundson, V.S., and W.R. Hinshaw. On the Inheritance of Pendulous Crop in Turkeys (Meleagris Gallopavo). Tech. Davis, California: University of California, November 22, 1937. Print.

Charlton, B. R. Avian Disease Manual. Kennett Square, Pa. (382 W. Street Rd., Kennett Square 19348): Order from American Association of Avian Pathologists, Poultry Pathology Laboratory, University of Pennsylvania, 2000. Print.

Hinshaw, W. R. "Chapter 41: Diseases of the Turkey: Pendulous Crop." Diseases of Poultry. Ed. H. E. Biester and L. H. Schwartz. 4th ed. Ames, Iowa, USA: Iowa State UP, 1959. 1068-1070. Print.

Hinshaw, W.R, and V.S. Asmundson. "Observations on Pendulous Crop in Turkeys." J. Am. Vet. Med. Assoc. (1936). 88 (m.s. 41): 154-165. Print.

Hungerford, T. G. "Pendulous Crop of Turkeys." Agr. Gaz. . N S Wales, 50 (1939): 231-232, 282-284. Print.

Hutt, F. B. "Matings Showing That Pendulous Crop Is Hereditary." Genetics of the Fowl. New York: McGraw-Hill Book, 1949. 240-141. Print.

Hutt, F. B. "Pendulous Crop Is Water and High Temperature Induced." Genetics of the Fowl. New York: McGraw-Hill Book, 1949. 432. Print.

Hybrid Turkeys. Info: Pendulous or Drop Crop (PC). Kitchener, Ontario: Hybrid Turkeys, 2012. Print.

Odberg, Espen. "Pendulous Crops in Budgies." Journal of the Association of Avian Veterinarians 7.4 (1993): 219. Print.

Prier, James E. "Pendulous Crop." Turkey Diseases. Danville, IL: Interstate Printers and, 1953. 78-80. Print.

Quinton, C.D., B.J. Wood, and S.P. Miller. "Genetic Analysis of Survival and Fitness in Turkeys with Multiple-Trait Animal Models." Hybrid Turkeys. Kitchener, ON (n.d.): n. pag. Rpt. in Centre for Genetic Improvement of Livestock, Department of Animal and Poultry Science. Guelph, ON: University of Guelph and, 2011. 1-8. Print.

Reed, Kent M., Dr. "Chapter 6: Turkey (Food and Fiber Animals)." Genome Mapping and Genomics in Animals. Ed. N.E. Cockett and C. Kole. Vol. 3. Berlin Heidelberg: Springer-Verlag, 2009. 143-63. Print. Genome Mapping in Animals.

Rigdon, R.H., T.M. Ferguson, and J.R. Couch. "Pendulous Crops in Turkeys Ananatomic and Pathologic Study." American Journal of Veterinary Research Vol. 21. (1960): 979-86. Print.

# Management Effects on the Incidence of Pendulous Crop in Turkeys

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**Introduction:**

Pendulous Crop (PC) is an abnormal condition where the crop becomes distended from its normal position and fills with ingested fluid and feed (Hinshaw, 1959) . In this state, the materials inside the PC stagnate and have the potential to ferment; however, the contents have not been proven to be directly toxic to the birds. The adverse effects are typically due to the physical limitations the PC causes the bird. Since nutrients are not being absorbed by the crop, the turkey becomes stunted and emaciated. Furthermore, there is a higher risk of the crop and associated tissues to become necrotic or infected, if punctured. Processing of birds often results in contaminated carcasses and chill tanks.  In some cases, producers have reported flock mortalities of 5-8% due to PC (Hybrid Turkeys, 2012).

Traditionally, PC is believed to be caused by a genetic predisposition which is enhanced by environmental factors (Asmundson, 1937; Hutt, 1949; Reed, 2009). However, with the development of the commercial turkeys in today's industry, it is suspected that flock management is having an increasing influence on the incidence of PC (Hybrid Turkeys, 2012).

Any management practice that would cause excessive extension of the crop is thought to exacerbate the incidence of pendulous crops. Extension of the crop is usually associated with practices when distension of the crop is found.  Environmental conditions or management practices where increased water or feed or a combination would be consumed are often blamed for causing PC (Hinshaw, 1936; Hungerford, 1939; Hutt, 1949; Prier, 1953). These different practices include those which were tested throughout the duration of this experiment.

**Methods and Materials:**

The incidence of Pendulous Crop (PC) in domesticated turkeys is a long standing issue in turkey production. Two experiments were conducted to evaluate the incidence of PC under different management practices. The first experiment used 2592 female Converter poults (Hybrid Turkeys), and was carried out over a period of 6 weeks where temperature, water accessibility and available energy in the feed were manipulated. The second experiment used 2400 straight run Converter poults (Hybrid Turkeys), and was carried out over an 11 week time period, where incubation temperature, feed form, and lighting were manipulated.

In the first trial, the poults were randomized into 4 separate rooms each with 12 equal pens (5 $m^2$) containing 54 birds. The factors evaluated for their ability to induce PC lesions were ambient temperature, water space per bird, and dietary energy. The room temperature was varied with two rooms following the typical temperature profile that decreased from 31° (88˚F) to 20°C (68˚F) (decrease of 2.8 °C /week; 5˚F/week) for the control group. The other two rooms were held at a higher ambient temperature that was 31 to 29°C (84˚F) for the six weeks. Water was supplied with half of the pens containing a red dome drinker; the other half of the pens used the same drinker with half of the drinking area blocked from poult access (424 versus 212 $cm^2$/bird, respectively). Finally, the energy contained in the diets was considered. Pre-starter and starter feeds were each fed for 3 weeks; the pre-starter and starter feed contained two different levels of energy (2895 versus 3073 kcal/kg).

The birds were weighed upon arrival, and then in three-week intervals following placement. Each bird showing symptoms of PC was tagged, and examined for severity of the lesion at the end of the experiment.

**Results:**

No significant differences were found for water intake, body weight, feed intake, feed conversion, percent mortality, or incidence of pendulous crop. However, water intake (at all days measured) and incidence of pendulous crop (% of hen housed and % of remaining birds) were significantly greater ($P < 0.01$) for the birds reared on the higher temperature profile when compared to those on the control temperature profile.

From these results, we can conclude that ambient temperature during brooding and/or increased water consumption increases the incidence of pendulous crops in female poults (1.56 % vs 0.31 %, $P < 0.001$).

The results from this first study were not at the reported levels as seen in the field, and it was concluded to continue with another trial with 3 different management factors. For the second trial of this study, the poults were randomized in the same manner; however, each pen contained 50 birds. The factors evaluated for their ability to induce PC lesions were incubation temperature (High vs. Control), feed form (Mash vs. Crumble/Pellet), and lighting (Intermittent vs. Continuous); all other factors were held to industry standards. The data from the second trial is currently being analyzed, and the official results are still unknown at this time.

**Chart 1: Average Water Intake of Female Converter Turkeys.**

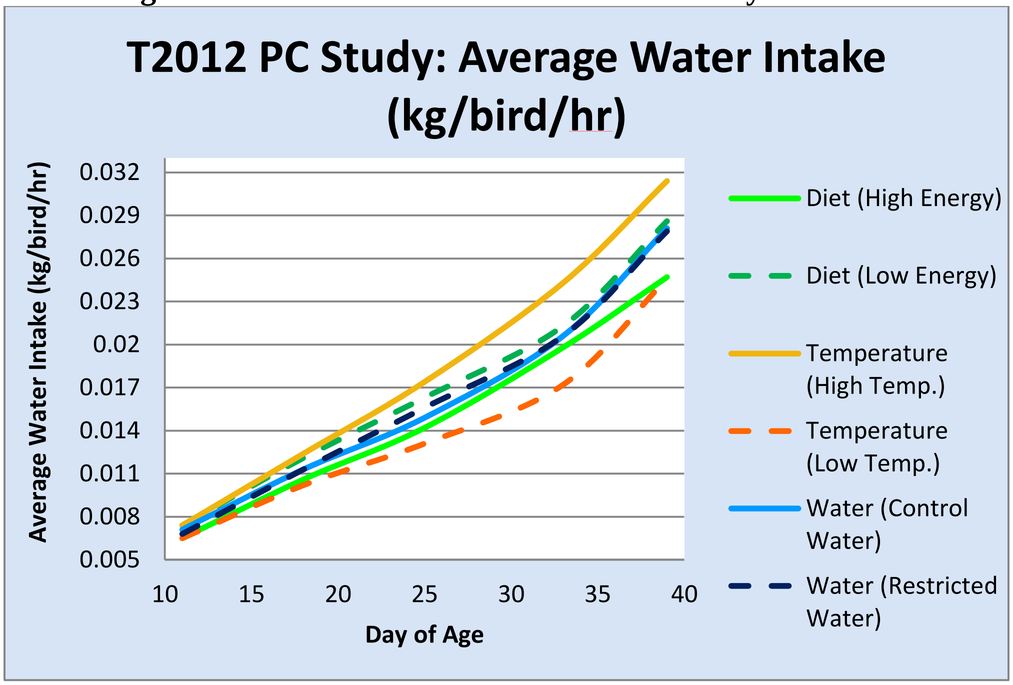


Chart 1: The average water intake of female Converter turkeys in kg/bird/hour during the first 6 weeks of life. Variations in temperature had the greatest influence over the amount of water consumed.

**Chart 2: Average Feed Intake of Female Converter Turkeys.**

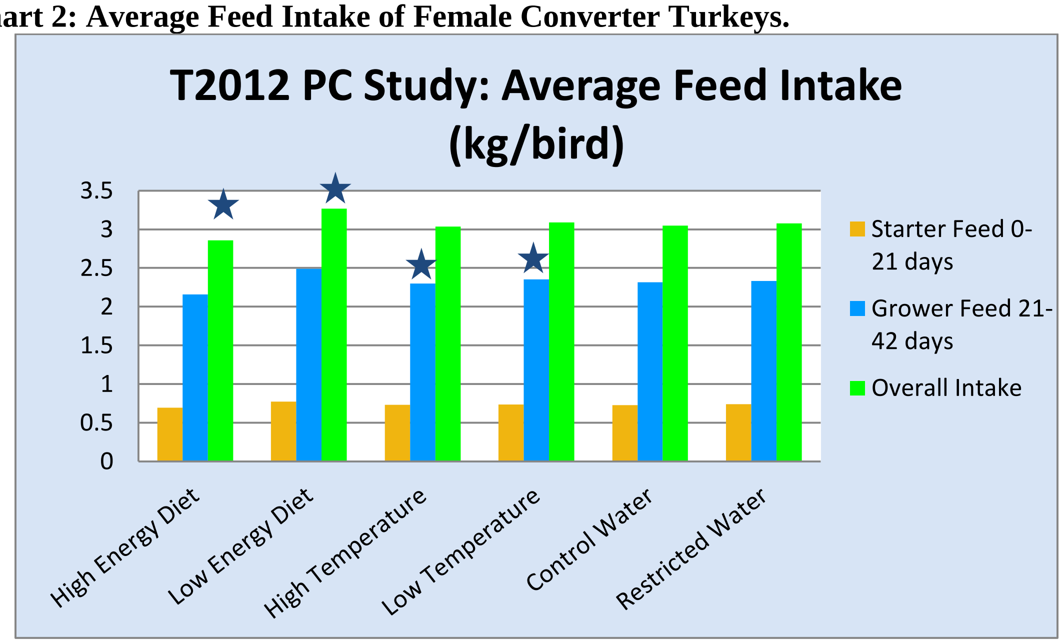


Chart 2: The average feed intake of female Converter turkeys in kg/bird, evaluated by weighing total feed consumed compared to average bird weights for each pen, during the first 6 weeks of life.

★ Means are considered significantly different ($P \leq 0.05$) for factors. When above Overall Intake, factor significantly impacted feed intake throughout the entire study.

**Table 1: Pendulous Crop Incidence in Female Converter Turkeys.**

| T2012 PC Study: Pendulous Crop Incidence (%) | | | |
|---|---|---|---|
| Factor | Level | % Birds Housed | % Birds Alive to 42 days |
| Diet | High Energy | 0.926 | 0.932 |
| | Low Energy | 0.932 | 0.944 |
| Temperature | High Temp. | 1.549 | 1.564 |
| | Low Temp. | 0.309 | 0.312 |
| Water | Control Water | 1.003 | 1.018 |
| | Restricted Water | 0.855 | 0.858 |

Table 1: The incidence of pendulous crop in female converter turkeys during the first 6 weeks of life. Turkeys with pendulous crop were recorded for each factor in the experimental design as compared to the total number of birds housed, as well as to the total adjusted for mortality.

**Conclusions:**

- ¤ The ambient temperature during the brooding period of commercial female poults, and/or increased water consumption increases the incidence of pendulous crops (1.56 % vs. 0.31%, $P < 0.001$).
- ¤ The influence of diet did not show any significant impact on the occurrence of PC, when examined as a independent or multi-factorial aspect.
- ¤ The intake of water was very significantly influenced ($P < 0.01$) by the low energy feed, as well as the higher temperature brooding condition.
- ¤ A significant difference was found for the interaction for feed conversion during days 21-42 between water treatment and diet ($P< 0.05$).
- ¤ Body Weight was significantly greater when fed the lower energy diets throughout the entire trial when compared to the higher energy feed treatment. After day 21, temperature had a significant impact on BW ($P<0.05$) and also for feed intake.

**Follow-up Research:**

After the conclusion of this first phase of the experiment, it was determined that temperature had a key role in the causation of pendulous crop in the three factorial design. However, the only 1.549% of the birds initially housed exhibited the signs of Pendulous Crop; which is significantly lower than the 5-8% incidence reported using the same strain of birds in the field (Hybrid Turkeys, 2012). Due to this difference, it was decided that the follow up trial should use different factors to attempt to find other management practices which could cause a higher incidence of PC.

The follow up trial was completed and there were instances of pendulous crop throughout the flock. Data from this study is still being analyzed to see if the updated conditions were more effective in the causation of PC.

With the notion that management practices are the main factors in causing PC, there is potential for further studies beyond the studies carried out in this experiment. These include: growing the turkeys out past the brooding phase, the incidence of PC in tom turkeys,  restricting the water in a more sever fashion, carry out feed separation by energy profile, collecting samples of crop and surrounding tissue for localized histology from damaged tissue, and many others. Prior to this study, and other current PC studies,  the most extensive research on PC in turkeys was carried out over 60 years ago (Asmundson, 1937; Hutt, 1949). From this research it was concluded that there were also genetic factors predisposing the turkeys to PC, wherein management factors would facilitate the expression of PC. This area of study may also have potential if PC experiments would be carried out with modern turkeys, and the DNA of the birds exhibiting PC would be analyzed.

To conclude, Pendulous Crop has been an issue in the turkey industry for many years and it is still a problem today. Modern management practices and technologies allow for many more opportunities to study the turkeys we are using in the industry, and may even lead to reducing this problem in the field in the future.

**References:**


Asmundson, V.S., and W.R. Hinshaw. On the  Inheritance of Pendulous Crop in Turkeys (Meleagris Gallopavo). Tech. Davis, California: University of California, November 22, 1937. Print.

Charlton, B. R. Avian Disease Manual. Kennett Square, Pa. (382 W. Street Rd., Kennett Square 19348): Order from American Association of Avian Pathologists, Poultry Pathology Laboratory, University of Pennsylvania, 2000. Print.

Hinshaw, W. R. "Chapter 41: Diseases of the Turkey: Pendulous Crop." Diseases of Poultry. Ed. H. E. Biester and L. H. Schwartz. 4th ed. Ames, Iowa, USA: Iowa State UP, 1959. 1068-1070. Print.

Hinshaw, W.R, and V.S. Asmundson. "Observations on Pendulous Crop in Turkeys." J. Am. Vet. Med. Assoc. (1936). 88 (m.s. 41): 154-165. Print.

Hungerford, T. G. "Pendulous Crop of Turkeys." Agr. Gaz. . N S Wales, 50 (1939): 231-232, 282-284. Print.

Hutt, F. B. "Matings Showing That Pendulous Crop Is Hereditary." Genetics of the Fowl. New York: McGraw-Hill Book, 1949. 240-141. Print.

Hutt, F. B. "Pendulous Crop Is Water and High Temperature Induced." Genetics of the Fowl. New York: McGraw-Hill Book, 1949. 432. Print.

Hybrid Turkeys. Info: Pendulous or Drop Crop (PC). Kitchener, Ontario: Hybrid Turkeys, 2012. Print.

Odberg, Espen. "Pendulous Crops in Budgies." Journal of the Association of Avian Veterinarians 7.4 (1993): 219. Print.

Prier, James E. "Pendulous Crop." Turkey Diseases. Danville, IL: Interstate Printers and, 1953. 78-80. Print.

Quinton, C.D., B.J. Wood, and S.P. Miller. "Genetic Analysis of Survival and Fitness in Turkeys with Multiple-Trait Animal Models." Hybrid Turkeys. Kitchener, ON (n.d.): n. pag. Rpt. In Centre for Genetic Improvement of Livestock, Department of Animal and Poultry Science. Guelph, ON: University of Guelph and, 2011. 1-8. Print.

Reed, Kent M., Dr. "Chapter 6: Turkey (Food and Fiber Animals)." Genome Mapping and Genomics in Animals. Ed. N.E. Cockett and C. Kole. Vol. 3. Berlin Heidelberg: Springer-Verlag, 2009. 143-63. Print. Genome Mapping in Animals.

Rigdon, R.H., T.M. Ferguson, and J.R. Couch.(200) "Pendulous Crops in Turkeys Anatomic and Pathologic Study." American Journal of Veterinary Research Vol. 21

# Influence of Incubation Temperature, Lighting, and Feed Form on Incidence of Pendulous Crop (PC) in Commercial Straight Run Turkeys

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## Abstract:

The incidence of Pendulous Crop (PC) in domesticated turkeys is a long standing issue in turkey production. A study was conducted to evaluate the incidence of PC under different management practices. The experiment used 2400 straight-run Converter poults (Hybrid Turkeys), and was carried out over a period of 10 weeks. Turkey eggs (3600) were incubated for 28 days, wherein 2400 of the poults were collected and equally distributed into 4 separate rooms each with 12 equal pens (5 $m^2$) containing 50 birds.

The factors evaluated for their ability to induce PC lesions were incubation temperature, light exposure, and feed form. Incubation temperature for the control group was varied with two incubators following the Hybrid temperature profile which decreased from 100.4° to 97.5°F. The other two incubators were held at the higher temperature, and were lowered from 100.4 to 98.0°F for the experimental treatment. Lighting was varied so that all four rooms initially received standard lighting (23L:1D) for the first week of life; then for the following 5 weeks, two rooms received intermittent light (4 periods of 1L:5D), while the remaining two rooms received standard brooding light (16L:8D) . The same feed composition was given in both a mash and crumble form for the first 4 weeks of life to the respective groups of poults. After 4 weeks, the birds receiving the crumble starter diet were switched to a pelleted grower diet for the remainder of the trial, while the birds consuming the mash starter diet received a mash grower diet. There were 6 replicates of each experimental combination of conditions.

The birds were weighed after hatching, and then in three-week intervals following placement. Each bird showing symptoms of PC was tagged, and examined for severity of the lesion at the end of the experiment.

Incubation and lighting (for all days measured before 28 days of age) and diet and lighting (for all days measured after 28 days of age) appeared to have the most significant effects on the incidence of PC. However, there were no significant differences for main effects within the factor during the study.

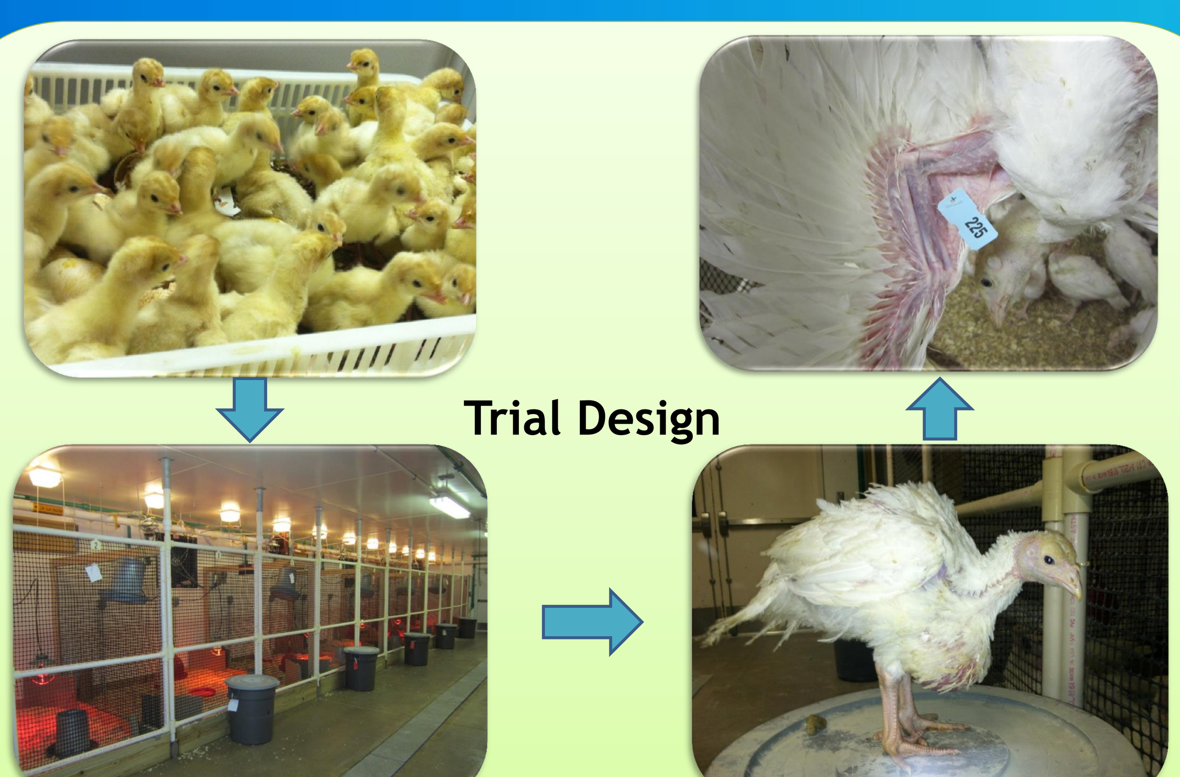
From these results, we can conclude that there is a significant interaction between feed form during brooding, and the particular lighting program which can influence the incidence of pendulous crops in poults ($P \leq 0.0114$).


## What is Pendulous Crop (PC)?

Pendulous Crop is an abnormal condition where the crop becomes distended from its normal position and fills with ingested fluid and feed. In this state, the materials inside the PC stagnate and have the potential to ferment; however, the contents have not been proven to be directly toxic to the birds. The adverse effects are typically due to the physical limitations the PC causes the bird.

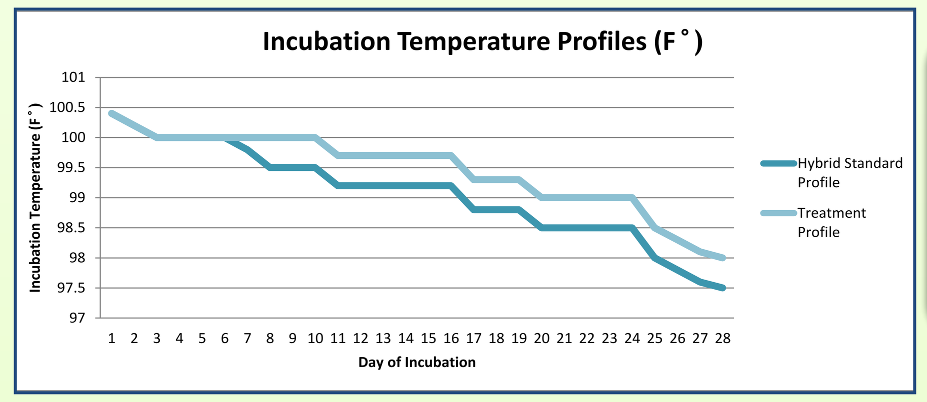
Since nutrients are not being absorbed by the crop, the turkey becomes stunted and emaciated. Furthermore, there is a higher risk of the crop and associated tissues to become necrotic or infected, if punctured. In some cases, 15% of flocks have experienced mortality via PC. The line of birds being used in this study have shown flock mortalities of 5-8% due to PC.

Traditionally, PC is believed to be caused by a genetic predisposition which is enhanced by environmental factors. However, with the development of the commercial turkeys in today's industry, it is suspected that flock management is having an increasing influence over the incidence of PC.

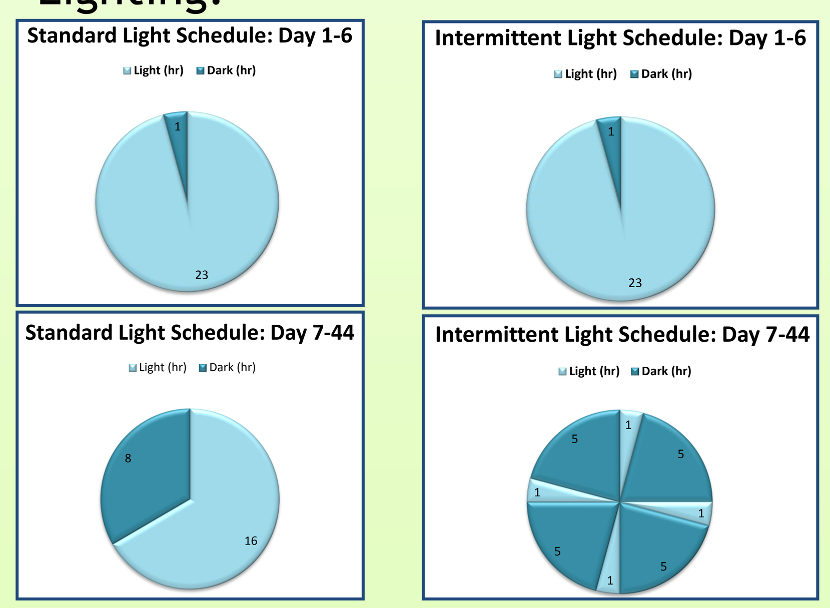



## Experimental Design:

### Incubation Temperature:




### Lighting:




### Feed Form:


T2013 PC Study Feed Composition: Chemical Analysis of Feed (%)

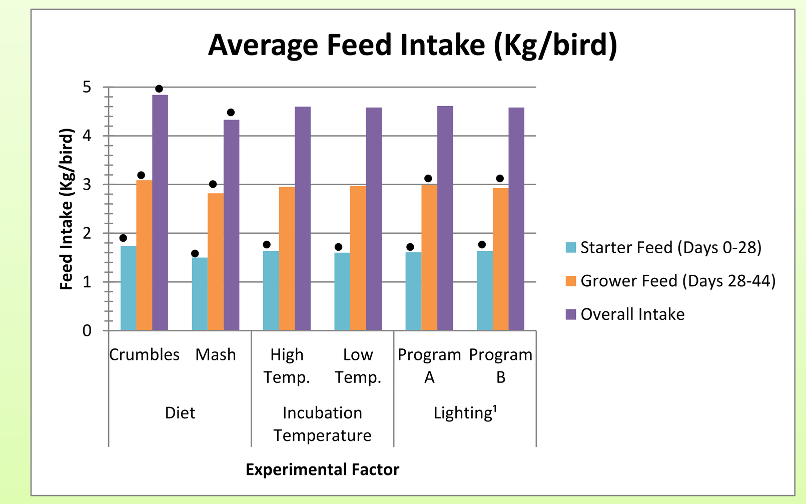
| Phase | Diet | Crude Protein | Crude Fat | Crude Fiber | Ash | Moisture |
|---|---|---|---|---|---|---|
| Starter: 0-28 d | Crumbles | 27.69 | 4.47 | 2.67 | 6.68 | 12.54 |
| | Mash | 26.63 | 3.20 | 2.80 | 6.32 | 11.81 |
| Grower: 28-44 d | Pellets | 25.39 | 5.11 | 2.73 | 6.47 | 11.71 |
| | Mash | 27.35 | 3.65 | 3.00 | 6.70 | 11.05 |

## Methods and Materials:

To induce PC, the following methods and materials were applied:

- Experimental design: 2 x 2 x 2 Factorial - Incubation Temperature, Light Exposure, and Feed Form. There were 6 replicates of each possible environment.
- Collected 3600 commercial turkey eggs from a Hybrid Turkeys breeder flock.
- 1800 eggs were placed in 2 incubators set for the Hybrid Standard Temperature profile (Low Temp.), and 1800 eggs were placed in 2 incubators set for the Experimental Temperature Profile (High Temp.).
- After hatching, 1200 poults were selected from both incubation groups and were separated into respective groups of 50 birds.
- Poults were divided equally into 4 separate rooms, each containing 12 pens.
- Each Room: ½ Crumble Feed Form, ½ Mash Feed Form; 3 weeks pre-starter, 3 weeks starter feed; feed available ad libitum. ½ Low Temp. (control) incubation poults, ½ High Temp. (experimental) incubation poults.
- 2 rooms used intermittent lighting (1L:5D), 2 rooms used standard lighting (16L:8D).
- Monitored birds for incidence of PC; birds were tagged, and pens were marked if signs of PC were evident. After 6 weeks, the study was completed.
- Data was collected and interpreted based on the experimental factors by ANOVA. Percentage data was analyzed after arcsine transformation.

## Feed Intake:




• Values within a factor & Column are significantly different ($P \leq 0.05$).
[1] Lighting: Program A = Standard 23L:1D on days 1-6, and 16L:8D on days 7-44; Program B = 23L:1D on days 1-6, and an intermittent light schedule on days 7-44 with 4 cycles of 1L:5D.

## Poult Growth Analysis:

### Average Weight Gain:

T2013 PC Study: Average Body Weight (BW) and Body Weight Gain Per Bird

| Factor | Level | Initial Poult BW (g) | BW (Kg) Day 28 | BW (Kg) Day 44 | BW Gain (Kg) Overall |
|---|---|---|---|---|---|
| Diet | Crumbles | 57.10 | $1.31^a$ | $3.14^a$ | $3.08^a$ |
| | Mash | 57.30 | $1.03^b$ | $2.52^b$ | $2.46^b$ |
| Incubation Temperature | High Temp. | $55.80^a$ | $1.19^a$ | $2.86^a$ | $2.80^a$ |
| | Low Temp. | $58.60^b$ | $1.56^b$ | $2.81^b$ | $2.75^b$ |
| Lighting[1] | Program A | 57.10 | $1.19^a$ | $2.93^a$ | $2.87^a$ |
| | Program B | 57.20 | $1.15^b$ | $2.75^b$ | $2.69^b$ |

### Average Feed Conversion:

T2013 PC Study: Feed Conversion (Kg Feed Intake/KG BW Gain)

| Factor | Level | Days 0-28 | Days 28-44 | Overall |
|---|---|---|---|---|
| Diet | Crumbles | $1.39^a$ | $1.70^a$ | $1.57^a$ |
| | Mash | $1.55^b$ | $1.91^b$ | $1.77^b$ |
| Incubation Temperature | High Temp. | 1.47 | $1.78^a$ | $1.65^a$ |
| | Low Temp. | 1.48 | $1.82^b$ | $1.68^b$ |
| Lighting[1] | Program A | $1.43^a$ | $1.74^a$ | $1.62^a$ |
| | Program B | $1.51^b$ | $1.86^b$ | $1.72^b$ |

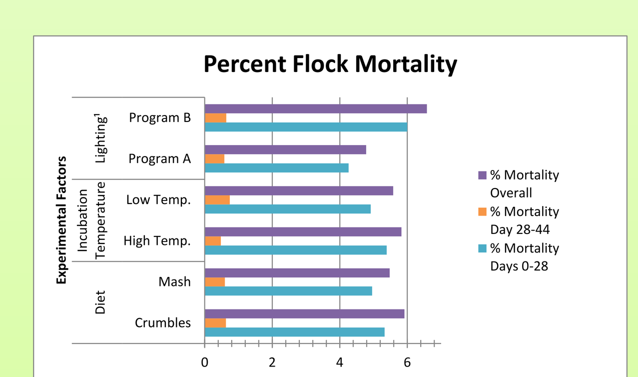
[a,b] Values within a factor & Column that do not share a common superscript are significantly different ($P \leq 0.05$).
[1] Lighting: Program A = Standard 23L:1D on days 1-6, and 16L:8D on days 7-44; Program B = 23L:1D on days 1-6, and an intermittent light schedule on days 7-44 with 4 cycles of 1L:5D.

## Resulting Pendulous Crops:

T2013 PC Study: Penduous Crop Incidence

| Factor | Level | % PC of Birds Housed Days 0-44 | % PC of Birds Alive Days 0-44 |
|---|---|---|---|
| Diet | Crumbles | 1.33 | 1.41 |
| | Mash | 1.91 | 2.03 |
| Incubation Temperature | High Temp. | 1.39 | 1.48 |
| | Low Temp. | 1.83 | 1.93 |
| Lighting[1] | Program A | 1.30 | 1.35 |
| | Program B | 1.92 | 2.06 |
| Significant P-values ($P \leq 0.05$) | Diet* Lighting | 0.01 | 0.01 |

- Upon the completion of the 6 week trial, the interaction between feed form and lighting was calculated to be the factor with the greatest significance ($P \leq 0.05$) for inducing Pendulous Crop.
- A total of 38 PCs were recorded as "pronounced" by the end of the trial.
- Of the 38 birds, 22 poults on the mash diet and 16 poults on the crumble diet exhibited PC. Interactions showed Mash*Program A = 5 PCs, Mash*Program B = 17 PCs, Crumble*Program A = 10 PCs, Crumble*Program B = 6 PCs.
- All birds with PC survived to the end of the trial, and were not removed from the experimental conditions for the purpose of following the progression of the condition.




## Conclusions:


- The feed form and light exposure during the brooding period of commercial straight run poults, influences feeding and drinking habits which lead to the onset of pendulous crop syndrome ($P \leq 0.0114$).
- It can be concluded from PC observation that when considering this interaction, poults fed a mash diet under intermittent lighting are more at risk than those fed a crumble diet, and poults fed a crumble diet under standard lighting are more at risk than those fed a mash diet.
- Incubation temperature did not show any significant impact in the overall occurrence of PC, when examined independently or multi-factorially.
- Feed intake, body weight gain, and feed conversion were also significantly effected by feed form ($P \leq 0.05$) where poults fed mash were 0.51kg lighter on average.

## Previous Research:

- Factors:
  - Diet Energy Profile (control/high energy)
  - Brooding Temperature (control/high temperature)
  - Water Availability (control/ ½ restricted drinking area)
- Birds Studied: 2600 Female Hybrid Commercial Converter poults.
- Resulting PCs: A total of 22 PCs were recorded, 11 of which were very pronounced.
- Most significant cause: Temperature was calculated to be the factor with the most significant factor ($P \leq 0.001$) for inducing PC.
- Conclusions:
  - Brooding temperature and/or water consumption increases the incidence of PC in commercial female poults (1.56% vs. 0.31%, $P \leq 0.001$). Water intake was greatly influenced by higher temperature and low energy feed consumption. Diet did not have a significant effect on PC when viewed independently.

## Further Studies on the Incidence of PC in Turkeys:

- Grow out turkeys past 6 weeks of age.
- Collect samples for DNA analysis from birds on trial.
- Compare PC incidence between different genetic strains of commercial turkeys.
- Carry out field trials in barns with commercial dimensions.
- Feed with higher sodium concentrations.

## References:


Asmundson, V.S., and W.R. Hinshaw. On the Inheritance of Pendulous Crop in Turkeys (Meleagris Gallopavo). Tech. Davis, California: University of California, November 22, 1937. Print.

Charlton, B. R. Avian Disease Manual. Kennett Square, Pa. (382 W. Street Rd., Kennett Square 19348): Order from American Association of Avian Pathologists, Poultry Pathology Laboratory, University of Pennsylvania, 2000. Print.

Hinshaw, W. R. "Chapter 41: Diseases of the Turkey: Pendulous Crop." Diseases of Poultry. Ed. H. E. Biester and L. H. Schwartz. 4th ed. Ames, Iowa, USA: Iowa State UP, 1959. 1068-1070. Print.

Hinshaw, W.R, and V.S. Asmundson. "Observations on Pendulous Crop in Turkeys." J. Am. Vet. Med. Assoc. (1936). 88 (m.s. 41): 154-165. Print.

Hungerford, T. G. "Pendulous Crop of Turkeys." Agr. Gaz. . N S Wales, 50 (1939): 231-232, 282-284. Print.

Hutt, F. B. "Matings Showing That Pendulous Crop Is Hereditary." Genetics of the Fowl. New York: McGraw-Hill Book, 1949. 240-141. Print.

Hutt, F. B. "Pendulous Crop Is Water and High Temperature Induced." Genetics of the Fowl. New York: McGraw-Hill Book, 1949. 432. Print.

Hybrid Turkeys. Info: Pendulous or Drop Crop (PC). Kitchener, Ontario: Hybrid Turkeys, 2012. Print.

Odberg, Espen. "Pendulous Crops in Budgies." Journal of the Association of Avian Veterinarians 7.4 (1993): 219. Print.

Prier, James E. "Pendulous Crop." Turkey Diseases. Danville, IL: Interstate Printers and, 1953. 78-80. Print.

Quinton, C.D., B.J. Wood, and S.P. Miller. "Genetic Analysis of Survival and Fitness in Turkeys with Multiple-Trait Animal Models." Hybrid Turkeys. Kitchener, ON (n.d.): n. pag. Rpt. in Centre for Genetic Improvement of Livestock, Department of Animal and Poultry Science. Guelph, ON: University of Guelph and, 2011. 1-8. Print.

Reed, Kent M., Dr. "Chapter 6: Turkey (Food and Fiber Animals)." Genome Mapping and Genomics in Animals. Ed. N.E. Cockett and C. Kole. Vol. 3. Berlin Heidelberg: Springer-Verlag, 2009. 143-63. Print. Genome Mapping in Animals.

Rigdon, R.H., T.M. Ferguson, and J.R. Couch. "Pendulous Crops in Turkeys Ananatomic and Pathologic Study." American Journal of Veterinary Research Vol. 21. (1960): 979-86. Print.

## BIBLIOGRAPHY

[1] Asmundson, V.S., and W.R. Hinshaw. 1937. “On the Inheritance of Pendulous Crop in Turkeys (Meleagris Gallopavo).” Tech. Davis, California: University of California. Print.

[2] Boulianne, M. 2013. “Avian Disease Manual.” Jacksonville, Fl.: American Association of Avian Pathologists. 7th Edition. 199, 243, 247, 269, 289. Print.

[3] Charlton, B. R. 2000. “Avian Disease Manual.” Kennett Square, Pa.: American Association of Avian Pathologists, Poultry Pathology Laboratory, University of Pennsylvania. 5th Edition.67-129. Print.

[4] Harper, J.A. and G.H. Arscott. 1962. “Salt as Stress Factor in Relation to Pendulous Crop and Aortic Rupture in Turkeys.” Poultry Science. 41: 497-499. Print.

[5] Hinshaw, W. R. 1959. "Chapter 41: Diseases of the Turkey: Pendulous Crop." Diseases of Poultry. Ed. H. E. Biester and L. H. Schwartz. 4th ed. Ames, Iowa, USA: Iowa State UP. 1068-1070. Print.

[6] Hinshaw, W.R, and V.S. Asmundson. 1936. "Observations on Pendulous Crop in Turkeys." Journal of the American Veterinary Medical Association. 88: 154-165. Print.

[7] Hungerford, T. G. 1939. "Pendulous Crop of Turkeys." Agr. Gaz. N S Wales, 50: 231-232, 282-284. Print.

[8] Hutt, F. B. 1949. "Matings Showing That Pendulous Crop Is Hereditary." Genetics of the Fowl. New York: McGraw-Hill Book. 240-141. Print.

[9] Hutt, F. B. 1949. "Pendulous Crop Is Water and High Temperature Induced." Genetics of the Fowl. New York: McGraw-Hill Book. 432. Print.

[10] Hybrid Turkeys. 2012. “Info: Pendulous or Drop Crop (PC).” Kitchener, Ontario: Hybrid Turkeys. Print.

[11] Jones, J.E., W.V. Chalupa, and J.C. Ellers. 1973. "Volatile Fatty Acids in Contents of Pendulous Crops and Normal Crops of Turkey Hens." Poultry Science. 52: 510-512. Print.

[12] Kranis A, Gheyas AA, Boschiero C, Turner F, Yu L, Smith S, Talbot R, Pirani A, Brew F, Kaiser P, Hocking PM, Fife M, Salmon N, Fulton J, Strom TM, Haberer G, Weigend S, Preisinger R, Gholami M, Qanbari S, Simianer H, Watson KA, Woolliams JA, Burt DW. 2013. "Development of a high density 600 K SNP genotyping array for chicken." BMC Genomics. **14:**59

[13] Prier, James E. 1953. "Pendulous Crop." Turkey Diseases. Danville, IL: Interstate Printers. 78-80. Print.

[14] Quinton, C.D., B.J. Wood, and S.P. Miller. 2011. "Genetic Analysis of Survival and Fitness in Turkeys with Multiple-Trait Animal Models." Poultry Science. 90: 2479-2486. Print.

[15] Reed, Kent M. 2009. "Chapter 6: Turkey (Food and Fiber Animals)." Genome Mapping and Genomics in Animals. Ed. N.E. Cockett and C. Kole. Vol. 3. Berlin Heidelberg: Springer-Verlag. 143-63. Print.

[16] Rigdon, R.H., T.M. Ferguson, and J.R. Couch. 1960. "Pendulous Crops in Turkeys Anatomic and Pathologic Study." American Journal of Veterinary Research. 21: 979-986. Print.

[17] Wheeler, H.O., B.L. Reid, T.M. Ferguson, J.R. Couch, and R.H. Rigdon. 1960. "Differences in Susceptibility of Broad Breasted Bronze and Beltsville Small White Turkeys to Dietary-Induced Pendulous Crop." Poultry Science. 39: 263-267. Print.

# ACADEMIC VITA

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**Education**

- Bachelor of Science, Animal Sciences – Science Option, May 2014. The Pennsylvania State University, University Park, Pa
- Minors: Poultry and Avian Sciences; Equine Science.

**Honors and Awards**

- Don R. Sloan Undergraduate Research Award, January 28-29, 2013. International Poultry Scientific Forum and Southern Conference of Avian Disease, hosted by the Southern Poultry Science Society and the U.S. Poultry and Egg Association.
- American Society of Animal Science Scholastic Achievement Award, April 2013.
- Don R. Sloan Undergraduate Research Honorable Mention, January 27-28, 2014. International Poultry Scientific Forum and Southern Conference of Avian Disease, hosted by the Southern Poultry Science Society and the U.S. Poultry and Egg Association.
- 2014 Student of the Year, Second Place, January 28, 2013. College Student Career Program, hosted by the U.S. Poultry and Egg Association, and the U.S. Poultry Foundation.
- American Association of Avian Pathologists Foundation Poultry Scholarship, March 2014.
- American Society of Animal Science Scholastic Achievement Award, April 2014.

**Association Memberships/Activities**

- Poultry Science Association, 2013-2014
- American Society of Animal Science, 2013-2014
- Gamma Sigma Delta, 2013-2014
- Phi Kappa Phi, 2013-2014
- National Society of Collegiate Scholars, 2013-2014
- Coaly Society, 2012-2014. Vice President.
- Poultry Science Club, 2011-2014. Vice President.
- Girl Scouts of America. Lifetime member 2010-2014

**Professional Experience**

- Externships in flock diagnostics with Dr. Robert Owen, Huvepharma Senior Technical Services Veterinarian, 2013.
- Internship with BJE Farm Contracts as a Flock Supervisor, Summer 2013.

**Professional Presentations**

- International Poultry Scientific Forum, January 28-29, 2013. Poster presentation on *The Effect of Different Management Factors on the Incidence of Pendulous Crop (PC) in Commercial Female Turkeys.*
- College of Agricultural Sciences, Gamma Sigma Delta Undergraduate and Graduate Annual Research Expo, March 13-14, 2013. Poster presentation on *The Effect of Different Management Factors on the Incidence of Pendulous Crop (PC) in Commercial Female Turkeys.*

- 36th Annual North Carolina Turkey Days. Speaker presentation on *Management Effects on the Incidence of Pendulous Crop in Turkeys.*
- International Poultry Scientific Forum, January 27-28, 2014. Poster presentation on the *Influence of Incubation Temperature, Lighting, and Feed Form on Incidence of Pendulous Crop (PC) in Commercial Straight Run Turkeys*.

**Publications and Papers**

- Hybrid Turkeys: A Hendrix Genetics Company is looking to further review this research on Pendulous Crop, and publish a literature review and the findings.

**Research Interests**

Following graduation I will be attending veterinary school at the Ohio State University, with an influence in poultry and agricultural animal medicine. I hope to aid in continuing the progression of animal agriculture to provide our society with a safe, reliable and sustainable source of animal products. There are great opportunities for future development in this industry both through management practices and medicine.